Allyl Isothiocyanate

Petition for Inclusion on the National List for Use in Organic Crop Production

Submission
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National Organic Program

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Table of Contents

Overview

Isagro USA, Inc. (Isagro), is requesting the USDA's National Organic Program (NOP) to include Allyl Isothiocyanate (AITC) as a Synthetic Substance for use as a soil applied nematicide, as a soil applied fungicide and as an organic option supporting the certification of organic nursery seed and nursery stock plants in organic crop production. The following petition to the National Organic Standards Board (NOSB) supports the proposed addition of AITC as an allowed synthetic substance for use in organic crop production (listing under 7 Code of Federal Regulations Part 205.601).

Isagro's AITC and the corresponding federally registered use patterns offer organic growers the only effective management tool for soil-borne diseases and pathogenic nematodes at levels that are commercially relevant and supports the phytosanitary certification process for organic fruit and vegetable nursery stock production. Future organic growth depends on tools that are: commercially available for certified organic farm land, support crop rotation practice standards (Part 205.205) with minimal interruptions to cropping cycles due to unmanageable pest populations, commercially obtainable organic nursery stock for a holistic organic crop and a proven, effective management tool which reduces the risk of financial loss incurred from soil-borne disease and nematodes. The addition of Isagro's innovative and economically viable source of oil of mustard (AITC) to the list of allowed substances under the NOP will enable AITC to be available to organic production agriculture, benefiting the long-term interest of organic farming operations with a long term benefit as a biologically based disease and nematode control option.

AITC is a naturally occurring compound found in plants such as broccoli, brussel sprouts, mustard, wasabi, and horseradish (Family Brassicaceae). AITC, commonly referred to as Oil of Mustard, is the active ingredient in two Isagro biopesticide products registered by the US Environmental Protection Agency (EPA), Biopesticides and Pollution Prevention Division (BPPD).

Listed as "Generally Regarded as Safe" (GRAS), AITC is commonly used as a food ingredient and additive under US Food and Drug Administration (FDA) jurisdiction. Additionally, AITC is exempt from the requirement of a tolerance under the Title 40 Code Federal of Regulations (40CFR) Part 180.1167.

I. Item A.

1. Petition for Inclusion of Allyl Isothiocyanate (AITC) on the National List as a Synthetic Substance Allowed for Use as a Nematicide and as a Fungicide in Organic Crop Product, Part 205.601.

Isagro USA, Inc. (Isagro), is requesting the USDA's National Organic Program (NOP) to include Allyl Isothiocyanate (AITC) for use as a Synthetic Substance for use as a soil applied nematicide and as a soil applied fungicide in organic crop production. This petition will provide the guidance to the National Organic Standards Board (NOSB) to support the proposed addition of AITC as an allowed synthetic substance for use in organic crop production (listing under Title 7 Code of Federal Regulations Part 205.601).

Fungicide Justification Statement

The importance of crop rotation practices in organic production systems is essential for disease management in grower fields, imperative within the leafy vegetable and berry commodity industries. Future organic growth is limited by a shortage of certified organic farm land to support proper crop rotations and the risk of financial loss incurred from soil-borne disease. Subsequent, crop rotations of strawberry/lettuce have led to epidemics of *Verticillium* and *Fusarium* wilt diseases. *Verticillium* and *Fusarium* wilt, are caused by the plant pathogenic fungi *Verticillium spp.*, and *Fusarium spp.* affects both strawberries and leafy greens as well as a number of other crops (e.g. potato, eggplant, pepper, tomato, etc…). Once established, these diseases are difficult to manage without pre-plant applications of soil fungicides. The organisms remain viable in the soil for up to 14 years making crop rotation ineffective and problematic given the wide host range for both these soil pathogens. A single infected lettuce plant produces over 2 million resting spores (microsclerotia) with survivability capable of infecting organic crops and at high enough populations to reduce and/or render the soil incapable of commercial production. Disease resistant lettuce or strawberry varieties are currently not commercially available. The process of developing disease resistance traits in plants is lengthy and time consuming as evidenced with only one variety of potato to date having demonstrated resistance to *Verticillium* wilt according to the Cornell Organic Production Guide. Green manuring cannot overcome the presence of high populations of these plant wilt diseases in soil. *AITC provides the only organic control measure to facilitate such rotation for the critical management of soil-borne pathogens such as Verticillium and Fusarium wilt diseases. AITC is essential to the success of a systems-based approach and the ability to reduce pest pathogen populations to levels that are biologically manageable and for a well-balanced soil environment.* Cropping site selection and soil health are indispensable to organic farming. "Sites should not have recently been cropped to plants susceptible to *Verticillium* Wilt" (Cornell University 2015; Organic Production and IPM Guide for Strawberries). Additionally, the Cornell University Organic Production and IPM Guide for Strawberries guide recommends planting cover crops for disease *suppression* then recommends, "Rotating a field out of strawberries for at least 2 - 3 years is strongly recommended" when diseases such as Black root rot (*Pythium* spp. & *Rhizoctonia* spp. disease complex) pressures are not suppressed. The Cornell University 2015; Organic Production and IPM Guide for Potatoes states, "The pathogen [*Verticillium* wilt] survives for several years without a host crop and will infect and reproduce on many weeds." The guide then recommends the grower, "Plan a minimum of 3-4 years without tomato, eggplant or pepper and maintain good weed control in rotational crops."

AITC is highly efficacious against a number of soil-borne pathogens, AITC is the only organic alternative for organic growers to manage high infestations of soil-borne pathogens like *Verticillium* wilt. As a Level C Part 205.206(e), the fungicidal properties of AITC supports the mandated NOP Crop Rotation Practice Standards as defined under 7CFR Part 205.205 while avoiding the 3 year prohibition as defined under 7CFR Part 205.202- Land Requirements.

Nematicide Justification Statement- Crop Termination

AITC provides a beneficial methodology for organic nematicidal control as a post-harvest (crop-termination) application. Parasitic nematodes are prevalent in many soil types and geographies that attack the roots of susceptible host plants causing mechanical damage associated with feeding and host invasion followed by dysfunctional plant physiological effects, as well as, creating wound sites for potential disease infection. Population dynamics increase as nematodes multiply within their endoparasitic habitat. High populations of nematodes can cause significant yield losses and even low nematode infestations can interact with diseases (e.g. lesion nematode and *Verticillium* wilt in potatoes) exacerbating crop and yield losses. Crops have significantly different tolerances for levels of nematodes and pathogen colony forming units (CFU's). The characterization of nematode-host interactions has a myriad of dependencies, however post-harvest applications of AITC has demonstrated a significant reduction in plant parasitic nematodes.

While the practice of rotating crops is instrumental in many integrated pest management programs, crop rotation can be detrimental as high levels of nematode populations from the previous crops can remain in the infested soils infecting a more susceptible host crop at a future date. Standard control measures for nematodes consist of pre-plant treatments and the use of resistant varieties. However, a number of nematode species (e.g. lesion nematode) have hundreds of potential host plants making crop rotation and crop selection in infested soils unmanageable under current organic programs. Additionally, the list of available resistant organic seed nursery stock as well as the list of effective organically approved nematicides are extremely limited. These surviving high levels of plant parasitic nematodes significantly diminish the efficacy of pre-plant practices limiting their effect in protecting the next crop. By controlling parasitic nematode populations in soil and in the host plant, the novel post-harvest application methodology used to terminate the nematode infested (& pathogen infected) host crop (post-harvest) is unique to AITC as registered and labeled by the US EPA. *AITC provides organic producers an enhanced benefit of crop rotation and no-till cultural practices optimal growing conditions for organically produced commodities.* This novel AITC use pattern gives growers a tool for nematode management. The crop termination application of AITC supports the mandated NOP Crop Rotation Practice Standards as defined under 7CFR Part 205.205 and avoids the 3- year prohibition as defined under 7CFR Part 205.202-Land Requirements.

Fungicide and Nematicide Justification Statement- Nursery Plants

The phytosanitary certification process facilitates the intra- and interstate movement of plant materials (e.g. seeds and nursery stock) through an inspection and certification program. The USDA Guide for Organic Crop Producers states, "Although the seeds, annual seedlings, and planting stock used in organic production must not be treated with prohibited substances, there is one exception. Treatment with prohibited substances is allowed when the application of those substances is a requirement of Federal or State phytosanitary regulations." The "California Department of Food and Agriculture (CDFA) established a plant registration and certification (R & C) program. These programs are implemented by the California Code of Regulations and enforced by the Secretary of CDFA. These phytosanitary restrictions require the plant materials to meet standards based on specific state and local requirements. These programs are the result of close-working relationships between the University of California, USDA and CDFA, with the added support of the agricultural industry. Specific soil-borne pathogens and nematodes are the targeted pests of the nursery stock registration and certification programs. The criteria for establishing these programs are: 1) an established need; 2) sufficient by available technical information; 3) an established source of "clean" propagating stock; and 4) developed to assure the continued pest cleanliness of the stock. Specific to this petition are the "Strawberry Nursery Stock Certification" and the "Nematode Certification". The primary tools developed for maintaining pest cleanliness of the stock in these programs are: 1) biological indexing (use of indicator plants which exhibit symptoms of virus or virus-like diseases) and enzyme-linked immunosorbent assay (ELISA); 2) laboratory techniques for the detection of nematodes; 3) eradication treatments (thermotherapy, fumigation (methyl bromide or Telone II™) and hot water treatments); and 4) visual field inspections targeted to specific life cycles of the pests and plants."

The use of organic seed is a NOP requirement when organic seeds are commercially available. Organic seed and nursery stock is difficult to obtain under the strict qualifications of the certification programs. For example, organic strawberry production has been included under a NOP exception, as organic control options are not commercially available in strawberry nursery stock or seed operations. “Growers must also consider where they obtain their planting stock. According to language in the USDA-NOP regulation §205.202, ‘the producer must use organically grown seeds, annual seedlings, and planting stock. The producer may use untreated nonorganic seeds and planting stock when equivalent organic varieties are not commercially available. Seed and planting stock treated with substances that appear on the National List may be used when an organically produced or untreated variety is not commercially available. Planting stock used to produce a perennial crop may be sold as organically produced planting stock after it has been maintained under a system of organic management for at least 1 year. Seeds, annual seedlings, and planting stock treated with prohibited substances may be used to produce an organic crop when the application of the substance is a requirement of Federal or State phytosanitary regulations.’ With the limited availability of organically certified strawberry stock, growers will likely be able to justify the use of nonorganic stock to their certifying agency” (Cornell University 2015; Organic Production and IPM Guide for Strawberries).

The NOP regulations allow for the use of nonorganic materials when there are no comparable organic pesticide options, in accordance with The California Code of Regulations Sections 3055 -3056.6 and Section 3640 these pesticide options are methyl bromide and Telone II (1,3-dichloropropene). *AITC provides the only organic option to allow for the certification of organic nursery seed and nursery stock plants (e.g. strawberries) in commercial organic operations.* AITC can be used to treat substrates for nematodes and pathogens supporting the production of organic nursery stock and seed stock while complying with Federal and state certification initiatives including the California Code of Regulations, Article 9, “Regulations for California Certified Strawberry Plants” and the “Nursery Stock Nematode Certification” program.

AITC organic crop production benefits:

- Exemption from a required tolerance under 40 CFR; no crop residue profile.
- Registered as a biopesticide by the US EPA Biopesticides and Pollution Prevention Division.
- Improves soil profile; food source for soil microbes.
- An integrated management tool eliminating the 3 year re-cropping prohibition; supporting crop rotation with no re-crop restrictions.
- Provides an organic management tool for soil-borne pathogens and pests where no alternatives exist.

- Provides a proactive management practice as an approved management tool for production of organic seed and nursery stock where no commercial alternatives exist (i.e. organic strawberry nursery stock).
- Supports and enhances the objectives of an Integrated Pest Management program.
- Environmentally sound production under the manufacturing facility's Standard Operating Procedure considered all environmental, health, and safety aspects of the process and took these into account in the plant design.
- The formulation of AITC is a simple batch mixing process, and no excessive heat or materials are generated. There are no impurities formed during the processing and therefore no impurities of toxicological significance associated with the manufacturing of AITC.

2. Organic Foods Production Act (OFPA) Category- Crop and Livestock Materials

The chemical name and molecular formula (C_4H_5NS), allyl isothiocyanate (AITC) contains a single sulfur atom; therefore, AITC may be considered a sulfur compound. Sulfur compounds are identified under 7 CFR Part 6517 (c)(1)(B)(i) as eligible substances to be included on the USDA's NOP Synthetic Substance for use in organic crop production.

II. Item B: Product Overview

1. Chemical Common Name

Substance name: Allyl Isothiocyanate, AITC

Allyl Isothiocyanate (AITC) has a long history of use having been first registered by the U.S. EPA in 1962 for use in pesticides and rodent control products. Oil of Mustard is a common food ingredient and has been listed on the U.S. Food and Drug Administration's Generally Regarded As Safe (GRAS) list since 1975.

AITC is an isothiocyanate containing a single sulfur atom. AITC is part of a linear triad of double-bonded nitrogen, carbon, and sulfur atoms, with nitrogen tethered to the isopropyl group and the sulfur atom at the terminus of this triad. The triad, isothiocyanate, is the dominant chemical identity and is considered as a singular group for classification.

2. Petitioner and Manufacturer Information

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3. The Intended or Current Use

The current use of the substance, AITC, is pre-plant and post-harvest soil treatments with broad-spectrum efficacy to control soil-borne pests such as fungi, nematodes, insects, and weeds. The product is applied into the soil via drip injection or using tractor-mounted shank injection (both shallow and deep) to bare ground with or without plastic tarp. The proposed products may be used to treat soils to be planted with any crop. Additionally, the product is labeled for end of season crop termination treatment (post-harvest). The post-harvest use pattern is applied after crop harvest for crop destruction. The targeted soil-borne pathogens and nematodes are controlled as the infected / infested crop is terminated by the post-harvest application. The product and uses of AITC have been classified by the US Environmental Protection Agency (EPA) as non-food use biopesticides. AITC is under review for participation in the certified seed program under California Law. For further details of the approved uses, please refer to the EPA stamped labels.

4. Intended Activities and Application Rate

Application rates and crops currently registered for use. Please refer to the US EPA stamped labels for further details on the approved uses.

Table 1. Pre-plant soil application rates

Treatment site	Broadcast equivalent rates (Gal/A)	Broadcast equivalent rates (Lb/A)
Field soils to be planted to: Crop Groups 1 (root and tuber vegetables), 3 (bulb vegetables), 4 (leafy vegetables), 5 (brassica leafy vegetables), 6 (legume vegetables), 15 (cereal grains) and (herbs and spices)	10 - 40	85 – 340
Field soils to be planted to: Crop groups 8 (fruiting vegetables), 9 (cucurbit vegetables) and13 (Berry and small fruit)	10 - 40	85 – 340
Field soils to be planted to: Crop groups 11 (pome fruit), 12 (stone fruit), 13-F (berry and small fruit – vine including grapes) and 14 (tree nuts)	10 - 40	85 – 340
Nursery, Turf, and Ornamental Soils to be planted to: turf, lawns, parks, golf greens, athletic fields, recreational turf area, ornamentals, floral crops, forest tree seedlings	10 - 40	85 – 340
Seed or Transplant beds to be planted to: Food crops and non-food crops	10 - 40	85 – 340

Table 2. End of season crop termination treatment rates

Treatment site	Broadcast equivalent rates (Gal/A)	Broadcast equivalent rates (Lb/A)
Soils that were planted with the following crops: Asparagus, brassica vegetables (broccoli, cauliflower), cereal grains, cucurbit crops (cucumber, squash, melons), fruiting vegetables (e.g. eggplant, peppers, tomatoes), herbs and spices, leek, leafy vegetables (e.g. lettuce), legume vegetables, root and tuber vegetables (carrot, garlic, onion, potato, sweet potato), strawberries, berries (cane fruit).	3-20	26-170

Please refer to the US EPA stamped labels for further details on the approved uses.

5. Manufacturing Process

The petition requests that this source of AITC be an allowed synthetic substance in organic crop production. Various techniques can be used by organic growers for *suppression* of soil-borne pests. However, not all organic farmers can utilize the same approaches and not all organic farms have the same level of soil-borne pest pressure to achieve *acceptable management* levels. Additionally, disease thresholds vary significantly by crop which further impacts rotation decisions if a more sensitive crop is planted directly following a less sensitive crop. For example lettuce tolerance against *Verticillium* is 150 microsclerotia per gram of soil where strawberry is only 3 microsclerotia / gram of soil.

AITC, when extracted from natural sources such as mustard, is over an order of magnitude more costly than the petitioned substance. Furthermore, extraction of AITC from natural source material uses significant amounts of these natural sources (such as wasabi or mustard) in the production process, straining these resources.

AITC, as delivered via cover crops, mustard meal, or other green manuering techniques is impractical and costly (in 2015 a 9 ton per acre rate of mustard meal cost the grower $1,800 per acre). The quantity of material needed to be partially efficacious would result in a significant commitment beyond that of the world's current supply of these plant materials and the applications into fields of large quantities of plant material that would be required for efficacy would have significant impacts on the ecosystems of these fields. Thus, concluding the plant based approach is not sustainable for either technical or economic viability under the current raw material sourcing. "Certain cover crops, when tilled into the soil as green manures and degraded by microbes, release volatile chemicals that have been shown to *inhibit* weeds, pathogens, and nematodes. These biofumigant cover crops include Sudangrass, sorghum-sudangrass, and many in the brassica family. …..

Wait at least two weeks before planting a subsequent crop to reduce the potential for the breakdown product to harm the crop (phytotoxicity). *This biofumigant effect is not predictable or consistent. The levels of the active compounds and ability to suppress disease can vary by season, cover crop variety, maturity at incorporation, soil microbial diversity, and microbe population density"* (Cornell Organic Potato Guide 2015).

The petitioned substance, AITC as an allowed synthetic substance, enables the growers to have a consistent supply and truly effective tool to control soil-born pests at a cost that is 50% less compared to applied mustard meal per acre. Adding this economically viable source of oil of mustard (AITC) to the list of allowed substances under the NOP will enable AITC to be available to all production agriculture - both organic and conventional. This will benefit the public's long-term interest in moving production agriculture further away from the use of traditional, non-plant based soil treatments, whose impacts are problematic to the environment and public health compared to the beneficial characteristics of AITC.

The manufacturing facility had been studying the AITC process in the laboratory, in pilot batches and at commercialization. A team comprising of process and analytical chemists studied the individual process steps in detail. The manufacturing facility considered all environmental, health, and safety aspects of the process and took these into account in the plant design and in developing a Standard Operating Procedure.

The manufacturing process does not involve any step that is not associated with the formation of AITC, therefore, the presence of impurities of toxicological concern is not considered possible. There are no impurities of toxicological significance associated with the manufacturing of the active ingredient.

All equipment is cleaned, sanitized and inspected for cleanliness immediately before use. The equipment used to transfer product is cleaned and flushed before use. Weights and lot numbers of ingredients are recorded during formulation. All mixtures are visually inspected for uniformity and homogeneity. Representative samples are tested for active ingredient content in each production batch and provided with export (Certificate of Analysis).

AITC is manufactured in the facility with rigorous clean out procedures will be implemented between campaigns to minimize the potential for cross-contamination.

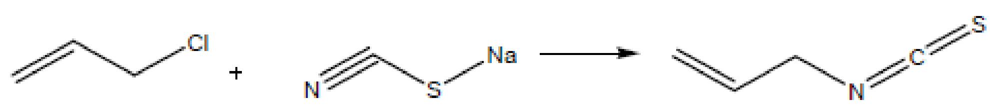
No impurities are expected in the product as a result of carry-over of impurities present in the intentionally added inert ingredients.

Manufacturing processes are carried out in vessels that are easily cleaned between batches and between different products.

Table 3. Composition

CAS Chemical Name	CAS No.	Nominal (% w/w)	Purpose in Product
Allyl isothiocyanate	57-06-7	99.8	Active Ingredient
Impurities formed in situ	NA	0.2	Impurity
		100.00	

Manufacturing Process Steps- Route of Synthesis



AITC is produced in a batch process through a reaction and isomerization process.

Allyl chloride (CAS No. 107-05-1) is added to sodium thiocyanate (CAS No. 540-72-7) in water with tetrabutylammonium bromide (CAS No. 1643-19-2). The mixture is then heated and agitated for 3 hours. After allyl chloride has disappeared and a cooling and reheating process ensues, the resulting liquid is allyl isothiocyanate (CAS No. 57-06-7).

The finished product is packaged in Department of Transportation approved containers, i.e. poly ethylene jugs, bulk containers or mild steel cylinders. A representative sample is retained from each batch in accordance with Quality Controlled requirements for this product and analyzed for active ingredient concentration. Scales used for weighing finished product in the packaging step are calibrated every 6 months for accuracy.

Chemical synthesis of oil of mustard (AITC) is the only economically feasible method of production, particularly for commercial scale use. The production of AITC and production facility are registered by the US EPA.

6. Ancillary Substances

Not applicable to this application.

7. Previous Reviews

The use of AITC as a biopesticide for soil treatment is a novel application of this naturally occurring chemical resulting in the need for evaluation by the National Organic Standard Board (NOSB).

The Isagro end use product, Dominus®, containing AITC was registered unconditionally by the EPA, Biopesticides Pollution Prevention Division (BPPD) as a biopesticide on September 26, 2013. BPPD is responsible for regulating biologically-based pesticides derived from materials such as animals, plants, bacteria, and certain minerals. These biologically based substances are: naturally occurring or are synthetically derived equivalent; historically demonstrate minimal toxicity to humans and the environment; and have a nontoxic mode of action to the target pest(s). The product use was intended as broad spectrum soil-treatment, biopesticide. On December 20, 2013 Isagro USA, Inc. submitted a petition to the USDA NOP. The NOP petition was based on the chemical equivalence of synthetic AITC to naturally occurring AITC (oil of mustard) but did not accurately define the specific use patterns AITC would provide the organic grower community. During the first seasonal use of Dominus (AITC), Isagro continued to learn about the product and the potential adoption of novel use patterns supporting organic grower and government certification programs. While Isagro believes the initial petition was founded on supporting evidence, on March 12, 2015 the petition was withdrawn to included specific use patterns providing control solutions for organic growers for situation where no organic control measures exist.

AITC has been used in crop production and as a pesticide active ingredient since the early 1960's, and is allowed for use in organic production when derived from natural plant sources (e.g. Mustgrow 5-1-1 Fertilizer; Pescadero Gold Mustard Meal Fertilizer). Natural sources of AITC are derived from essential oil of mustard (black mustard seed) and are in agricultural production at low concentrations (Dazitol and Bugitol). However, the concentration of AITC in those products (≤3.7% AITC) is not high enough to effectively terminate the crop and reduce pathogen and pest populations before the crop residue is redistributed in the field. Additionally, these products are not approved under the phytosanitary certification program supporting organic seed and nursery stock production.

With adoption into the USDA's NOP, AITC would provide the agricultural community an organic control solution for current organic growers and be a useful incentive to those interested in converting conventional acres to organic.

8. Regulatory Authority

AITC (IR9804; EPA Reg. No. 89285-1) is the active ingredient in the end use product marketed under the EPA alternate band name, Dominus (Primary Brand name: IRF135; EPA Reg. No. 89285-2).

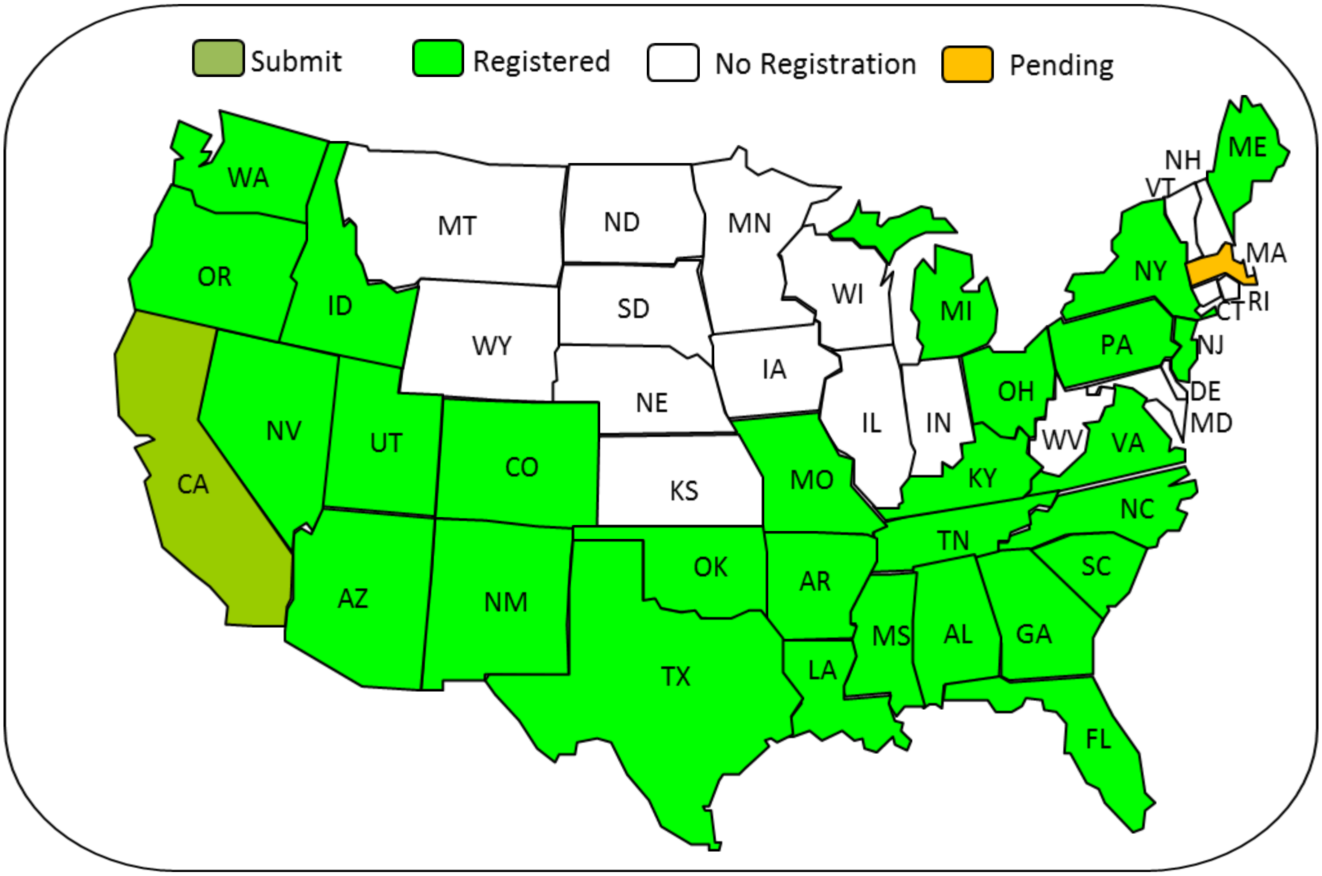
The NOP is the first jurisdiction globally where synthetically produced AITC has ever been proposed for organic inclusion by a certifying entity. International regulatory authorities have not considered or rejected synthetically-produced AITC for inclusion as an approved substance for use in organic production, since these international organizations have never been petitioned for such consideration. The first biopesticide registration of AITC was conducted by the US EPA. Isagro is in the process of apply and obtaining global registrations for AITC (Dominus).

Previous uses of AITC for organic production have all been limited in their scope and quantity, and, therefore, production of AITC by synthetic means has never before been an issue for consideration. Recently, however, the new use of AITC as a soil-incorporated biofumigant has triggered the need for synthetic production methods as a means of making the delivery of oil of mustard a commercially feasible option for growers. As a consequence, the NOSB is the first regulatory authority to consider these new beneficial use patterns of a long-used naturally-occurring biochemical.

AITC is exempt from the requirement of a tolerance under 40CFR Part 180.1167 and GRAS listed by the US FDA.

The end use product containing AITC is registered in number of states.

State registrations are identified in the chart below (see State Regulatory Agencies for the most current registration status).



9. The Chemical Abstract Service (CAS) number or other product numbers of the substance and labels of products that contains the petitioned substance. If the substance does not have an assigned product number, the petitioner should state so in the petition.

Chemical Abstracts Service (CAS): CAS No. 57-06-7; EINECS No. 200-309-2

10. The substance's physical properties and chemical mode of action including (a) Chemical interactions with other substances, especially substances used in organic production; (b) toxicity and environmental persistence; (c) environmental impacts from its use and/or manufacture; (d) effects on human health; and, (e) effects on soil organisms, crops, or livestock.

a. Chemical interactions with other substances

The physical attributes and chemical characteristics of Isagro's AITC and naturally occurring AITC (oil of mustard) are indistinguishable (Table 4).

Table 4. Oil of Mustard Properties.

	Isagro AITC	Oil of Mustard
Gas chromatograph purity analysis	100% w/w	98.93% w/w
Boiling Point	420 K	422 K
Density	1.017 g/mol	1.016 g/mol

b. Toxicity and environmental persistence

The behavior of AITC following applications as a biopesticide has been recently summarized by the US EPA as part of their evaluation of this proposed new use for oil of mustard (AITC) in their Biopesticide Registration Action Document, BRAD (US EPA 2013). US EPA found that the scientific data on AITC indicate the compound will have limited mobility within the soil, resulting in little or no concern regarding propensity to enter into groundwater or surface water. The characteristics indicate that the limited solubility, rapid breakdown in soils, and organic carbon/water and octanol/water partition coefficients all lead to the conclusion that there is limited concern as to the fate of AITC into environmental waters.

a. Environmental impacts from its use and/or manufacture;

In nature, AITC is produced naturally as a plant defense found in the plant Family, Brassicaceae. "Residues from Brassica crops have been shown to have biotoxic activity against many soil-borne pathogens and pests. Isothiocyanates (ITCs), mainly allyl isothiocyanate, contribute to the majority of toxic effects observed in decomposing Brassica tissues (Chew, 1988)(Price, 2005)".

The limited volatility of AITC, coupled with its relatively rapid rate of breakdown within soils indicates that emissions into the air will be limited, particularly when compared to any of the ingredients used for fumigation in conventional agriculture. The limited emission of AITC following use as a soil treatment has been specifically verified in field-based volatility studies.

None of the metabolites anticipated to result from AITC use in soils are persistent and none are expected to accumulate or result in emissions from application sites at any appreciable level. For example, Carbon disulfide (CDS) is a transient metabolite of AITC. However, it does not accumulate, breaks down further into less reactive metabolites, and is not of significant concern. CDS, to the extent that it is generated, is produced in the sub-surface soils following application and, due to its own instability, degrades further within the sub-surface environment. Ingestion of AITC in foods results in a similar transient profile.

The environmental fate characteristics:

- *Vapor Pressure* (mm Hg) of 3.5 is lower than all other commercial fumigants and lower still when compared with many classified "non-fumigant" conventional pesticides. Accordingly, AITC does not "fume" within the soils and readily moves to the proximity of pests that are relatively far away from the point of product introduction into the soils. The relatively low vapor pressure also indicates that AITC has a low potential to move to the soil surfaces and result in air emissions. This low potential has been verified through the production of field based studies of AITC flux rates into the air following applications as a biopesticide.

- *Octanol/Water Partition Coefficient* (Log P) of 2.11 indicates that AITC has a limited attraction to the aqueous environment and, consequently, has a limited potential for leaching into ground-waters or otherwise moving into the aqueous phase of soils.
- *Hydrolysis* (half-life in hours) of 744 at pH 7 and 642 at pH 9. While some metabolites can be observed within 80 minutes, these rates indicate that AITC breakdown via hydrolysis over time is slow and a minor pathway.

The physical characteristics of AITC and the structurally-related Methyl isothiocyanate (MITC) are *NOT* similar, and their comparative behavior in field and laboratory studies bares these differences (e.g. AITC vapor pressure 3.7 mm Hg at 25 °C vs. MITC vapor pressure 16mm Hg at 25 °C). AITC, compared to MITC, has numerous characteristics that set it apart in a manner that would predict lower levels of volatility, exposure, and even propensity to result in adverse effects in studies with animals (e.g. AITC Acute Oral Toxicity 425 mg/kg vs. MITC Acute Oral Toxicity 55 mg/kg). These parameters include vapor pressure, flash point, boiling point, octanol/water and organic/water partitions, water solubility, soil adsorption, and soil degradation. All of these differences support why AITC behaves differently as a biopesticide than the structurally similar, but characteristically different MITC (Table 5).

Table 5. Environmental Fate of AITC & MITC

Environmental Factors	AITC	MITC
Molecular Weight	99.15	73.3
Boiling Point	151 °C	119 °C
Odor	Pungent	Pungent
Stability (metals, etc)	Stable	Unstable/Reactive
Flash Point	47 °C	23-30 °C
Octanol/H_2O Partition Coeff.(Log P)	2.11	1.1
Vapor Pressure	3.5 mm Hg	16 mm Hg
Soil Degradation Rates ($t_{½}$)	20-60 hrs	192-336 hrs
Hydrolysis (pH 7 / pH 9)	744/624 hrs	490 /110 hrs

Environmental Factors	AITC	MITC
Water Solubility	2.0 g/L	8.94 g/L
Photolysis in Air ($t_{½}$)	~ 30 hours	30 hours
Application rate	Up To 326 Lbs/A	320 Lbs/A (metam sodium)
Green cells indicate AITC's more favorable environmental footprint.		

(d) Effects on human health;

As a long-approved and commonly used food additive and food ingredient, AITC has been characterized with a broad range of toxicological studies, from acute toxicity studies to full sub-chronic toxicity, chronic toxicity studies, and oncogenicity studies in multiple species. These studies have largely been produced and coordinated directly by the FDA's authority (i.e., National Toxicology Program (NTP) studies). The exposures to AITC (oil of mustard) occurring broadly on a daily basis due to the presence of the substance in foods, both naturally and as a food additive, all approved by the FDA, are significantly higher than those that could occur to workers and bystanders from the use of AITC as a biopesticide.

AITC is a strong eye and skin irritant as illustrated in acute toxicity studies (eye irritation and skin irritation), and indicated within the broad array of studies performed on AITC. For example, sub-chronic and chronic feeding with AITC, at high enough levels in rats, causes increased thickness in the mucosal surface of the stomach, an effect which is anticipated for a strong irritant. Essentially all observations from the toxicological database can be associated with the irritation potential of AITC. Observations of subcutaneous fibrosarcomas and bladder transitional cell papillomas in rats are consistent with the findings expected of a strong irritant upon long-term feeding at high rates. Foods in which AITC is present at relatively high levels, such as wasabi and Dijon mustard result in analogous traits of irritation to mucosal tissues.

When AITC is used as a biopesticide, using the EPA-required protective equipment, application techniques, and post-application procedures, poses no significant risks of adverse effects on workers, bystanders, and the general public. The potential for exposure to workers has been evaluated extensively by the US EPA, which has concluded that adequate mammalian toxicology data are available to support safe use of AITC. The irritation potential of the product is known and can be satisfactorily addressed through worker protection mitigation measures (Personal Protective Equipment, established Re-Entry Interval periods, etc.). When used according to EPA-approved labeling, concerns of adverse impacts are mitigated.

The scientific database for AITC is extensive. As a long-term food additive and very common component of foods, AITC has been evaluated extensively in health effects studies. These studies were used by the regulatory authorities to assess and approve the new use of oil of mustard as a biopesticide. The field-based studies on AITC substantiate the results of laboratory studies on AITC and MITC – that AITC should, and does, behave differently than its structurally-related counter-part, MITC.

The effects observed in oncogenecity studies are equivocal and represent anticipated endpoints for a strong irritant (responses to chronic irritation of direct contact tissues such as the skin and stomach, and the bladder, where chronic irritation occurs upon long term accumulation in the rat). These chronic exposures are not at all relevant to the proposed uses of AITC as a biopesticide, where chronic exposures will not occur for the reasons described above. None of the authoritative bodies that assess carcinogens, such as the International Agency for Research on Cancer (IARC) and National Toxicological Program (NTP), have concluded that AITC is a carcinogen. IARC list AITC as a Group 3, "Not classifiable as to its carcinogenicity to humans." NTP performed two comprehensive carcinogenicity studies on AITC, one in rats and the other in mice, and the authoritative agency has concluded that AITC should NOT be classified as a carcinogen. The National Institute of Health is evaluating AITC as a chemopreventive compound, "findings suggest that AITC may be most effective in the bladder as a cancer chemopreventive compound" (Zhang, Mol. Nutr. Food Res. 2010 January).

Additionally, safety measures are inherent as the EPA-approved label requires a 25-foot buffer zone following applications. The safety of this use of AITC has been bared out over the last few years, as numerous applications of the EPA-registered product, DOMINUS and DOMINUS 100, have been made without a single reportable adverse incident. Field-based studies evaluating the potential for AITC to emit out of the soils illustrate that *AITC emissions are significantly lower than any other fumigant used in agriculture today*.

Table 6. Acute Toxicity of AITC & MITC

Acute Toxicity Testing	AITC	MITC
Oral Toxicity	425 mg/kg	55 mg/kg
Dermal Toxicity	>200 <2,000 mg/kg	181 mg/kg
Inhalation Toxicity	>0.21 < 0.508 mg/L	0.54 mg/L
Dermal Irritation	Corrosive	Corrosive
Eye Irritation	Corrosive	Corrosive
Skin Sensitization	Yes	Yes
Green cells indicate AITC's more favorable toxicity footprint.		

(e) Effects on soil organisms, crops, or livestock.

Brassicas are suggested cover crops in organic production guides (Cornell Organic Strawberry Production). AITC naturally occurs in the cover crops broccoli and brussel sprouts used as biofumigant *suppressants* to various crop pathogens. "*Endemic soil microbial communities have been exposed to AITC for decades from the decomposing crops and [these microbes] have had ample time to adapt it [AITC] as a carbon source*" (Chellemi, et.al. 2015). AITC's major ecological function is as a feeding deterrent against insects and animals (Harborne and Baxter, 1993). *The differences between delivering AITC into the soil via "green manuring" methods versus direct application is that, in order to get sufficient concentration of AITC into the soil to achieve efficacy against target pests and diseases, the quantities of plant material required per acre is impractical for any commercial-scale efficacy control compared to more passive uses such as "green manuring: which delivers more suppression than control.* Additionally, green manuring can impede the cropping cycle while Isagro's AITC allows for recropping 10-14 days after application."

11. Safety information about the substance including a Safety Data Sheet (SDS) and a substance report from the National Institute of Environmental Health Studies. If this information does not exist, the petitioner should state so in the petition.

People are commonly exposed to dietary AITC since many vegetables contain either AITC or produce the precursor to AITC, sinigrin. Sinigrin is converted to AITC by the enzyme myrosinase when these plant cells are disrupted (Bhattacharya et al., 2010; Zhang, 2010). Vegetables that are notably high in sinigrin and/or AITC are cauliflower, kale, horseradish, wasabi, and mustard. Wasabi may contain up to 34 µmol sinigrin and/or AITC per gram wasabi (Zhang 2010). Brown mustard contains approximately 453 µg of AITC per gram, such that a 10 gram serving has 4,530 µg of AITC (Jiao et. al. 1994).

12. Research information about the substance which includes comprehensive substance research reviews and research bibliographies, including reviews and bibliographies which present contrasting positions to those presented by the petitioner in supporting the substance's inclusion on or removal from the National List.

AITC generated from Brassicas has been used in crop production and in organic production as a cover crop and green manure for its biofumigation properties. Research of Brassica for these purposes has resulted in mixed reviews for efficacy, lacking predictability and consistency for suppressing soil-borne pests. "Brassica crop rotations are recommended where *Verticillium* wilt is present or has been observed in the past. Brassica should be grown for a 2 year period and crop residues incorporated into the soil." "The *Verticillium* wilt fungus may persist many years in soil and is devastating to strawberries under conditions favorable for disease development. If possible, avoid sites where potatoes, tomatoes, eggplants, or brambles have recently been grown and, to a lesser extent, squash, cucumber, pepper, or melons (Cornell Strawberry Product Guide). Certain cover crops [Brassicacaea], when tilled into the soil as green manures and degraded by microbes, release volatile chemicals that have been shown to inhibit weeds, pathogens, and nematodes. Wait at least two weeks before planting a subsequent crop to reduce the potential for the breakdown product to harm the crop (phytotoxicity). This biofumigant effect is not predictable or consistent. The levels of the active compounds and ability to suppress disease can vary by season, cover crop variety, maturity at incorporation, soil microbial diversity, and microbe population density (Organic Production and IPM Guide for Potatoes; Cornell University). "Suppress soil-borne diseases and nematodes: when used as a green manure, researchers have found that mustards can suppress some diseases such as *Verticillium dahliae* and *Aphanomyces euteiches* (common root rot). Mustard green manures have also been found to suppress Columbia root-knot nematodes and may be effective against other types of nematodes, but until more research is done, mustard cover crops should be used to enhance, not eliminate, chemical control of nematodes. The effects of mustard green manures may vary due to differences in soil texture, organic matter levels, and quality; crop rotation; mustard variety and growth; initial pest levels; and other biological factors. (Washington State University Extension- Cover Crops for the Columbia Basin). Research has demonstrated the inconsistencies of low level ITCs from green manures have on the suppression of pest populations even confounding the notion of any benefit from low ITC concentrations. The University of California, Davis concluded that "Mustard cover crops are ineffective in suppressing soil-borne disease or improving processing tomato yield" stating "The effects of mustard green manures may vary due to differences in soil texture, organic matter levels, and quality; crop rotation; mustard variety and growth; initial pest levels; and other biological factors." Morra and Kirkegaard (2002) "reported that no more than 1% of ITC [isothiocyanates] predicted from tissue glucosinolate concentration was measured in soil amended with mustard leaf tissue."

Furthermore while AITC's major ecological function is as a feeding deterrent against insects and animals (Harborne and Baxter, 1993) Brassica cover crops can harbor and attract pest such as aphids, diamond back moth and nematodes.

As pesticide active ingredient since the early 1960's, AITC is allowed for use in organic production when derived from natural plant sources (e.g. Mustgrow 5-1-1 Fertilizer (OMRI 2015); Pescadero Gold Mustard Meal Fertilizer (OMRI listed 2015)). Natural sources of AITC are derived from essential oil of mustard (black mustard seed) and are in agricultural production at low concentrations (Dazitol and Bugitol). However, the concentration of AITC in those products (3.7% AITC) is not high enough to effectively terminate the crop and reduce pathogen and pest populations before the crop residue is redistributed in the field. Isagro's AITC provides a proven and consistent tool for organic farming.

The use of Isagro's AITC as part of the USDA phytosanitary program to treat substrates for nematodes and pathogens supporting the production of organic nursery stock and seed stock is a novel application for this compound. Low level AITC products are not being considered for this certification program.

13. Petition Justification Statement- Inclusion on the National List

Isagro's AITC is chemically indistinguishable from the natural sources of AITC. However, Isagro's AITC and the corresponding federally registered use patterns offer organic growers the only effective management tool for soil-borne diseases and pathogenic nematodes at levels that are commercially relevant. Future growth of organic food production depends on tools that are: commercially available for certified organic farm land, support proper crop rotations with minimal intrusion to cropping cycles, commercially obtainable organic nursery stock for a holistic organic crop and a proven, effective management tool which reduces the risk of financial loss incurred from soil-borne disease and nematodes. The addition of Isagro's innovative and economically viable source of oil of mustard (AITC) to the list of allowed substances under the NOP will enable AITC to be available to organic production agriculture, benefiting the long-term interest of organic farming operations with a long term biologically based disease and nematode control option.

The importance of crop rotation practices in organic production systems is essential for disease management in grower fields and is better served with the integration of AITC as a tool in a true IPM program. Future organic growth is limited by a shortage of certified organic farm land to support proper crop rotations and the risk of financial loss incurred from soil-borne disease. AITC is highly efficacious against a number of soil-borne pathogens. AITC is the only organic alternative for organic growers to manage infestations of significant soil-borne pathogens like *Verticillium* and *Fusarium* wilt, facilitating crop rotations for the critical management of soil-borne pathogens. *AITC is essential to the success of a systems-based approach and the ability to reduce pest pathogen populations to levels that are biologically manageable and for a well-balanced soil environment.*

AITC provides a novel methodology for organic nematicidal control as a post-harvest (crop-termination) application. The characterization of nematode-host interactions has a myriad of dependencies, however post-harvest applications of AITC has demonstrated a significant reduction in plant parasitic nematodes. Standard control measures for nematodes consist of pre-plant treatments and the use of resistant varieties. The high levels of infesting nematodes significantly diminish the efficacy of a pre-plant treatments protecting the next crop. By controlling parasitic nematode populations in and around the host plant, the novel post-harvest application methodology used to terminate the nematode infested (& pathogen infected) host crop (post-harvest) is unique to AITC. The post-harvest application of AITC provides organic producers an enhanced benefit of crop rotation and no-till cultural practices leaning to optimal growing conditions for organically produced commodities.

The NOP regulations allow for the use of nonorganic materials when there are no comparable organic pesticide options. AITC provides the only organic option to allow for the certification of organic nursery seed and nursery stock plants (e.g. strawberries) in commercial organic operations. AITC can be used to treat substrates for nematodes and pathogens supporting the production of organic nursery stock and seed stock. This would also support several state certification initiatives including the California Code of Regulations, Article 9, “Regulations for California Certified Strawberry Plants” and the “Nursery Stock Nematode Certification” program.

Additional AITC organic crop production benefits:

- Exemption from a required tolerance under 40 CFR; no crop residue profile.
- Improves soil profile; food source for soil microbes.
- An integrated management tool eliminating the 3 year re-cropping prohibition; supporting crop rotation with no re-crop restrictions.
- Provides an organic management tool for soil-borne pathogens and pests where no alternatives exist.
- Provides a proactive management practice as an approved management tool for production of organic seed and nursery stock.
- Supports and enhances the objectives of an Integrated Pest Management program.
- Environmentally sound production under the manufacturing facility’s Standard Operating Procedure considered all environmental, health, and safety aspects of the process and took these into account in the plant design.
- The formulation of AITC is a simple batch mixing process, and no excessive heat or materials are generated. There are no impurities formed during the processing and therefore no impurities of toxicological significance associated with the manufacturing of AITC.

14. References

- 40 Code Federal of Regulations (40CFR) Part 180.1167
- Bhattacharya, A., et.al.; Allyl Isothiocyante-rich mustard Seed Powder Inhibits Bladder Cancer Growth and Muscle Invasion, Carcinogenesis, 2010
- California Code of Regulations, Article 9, “Regulations for California Certified Strawberry Plants” and the “Nursery Stock Nematode Certification” program
- California Code of Regulations, Article 9, Regulations for California Certified Strawberry Plants

- California Code of Regulations; Approved Treatment and Handling Procedures to Ensure Against Nematode Pest Infestation of Nursery Stock
- California Code of Regulations; Regulations for Nursery Inspections and Nursery Stock Certificates
- California Department of Food and Agriculture (CDFA); Plant Health and Pest Prevention Services; 2008 Annual Report
- Chellemi, D, et al.; Development and Deployment of Systems-Based Approaches for the Management of Soilborne Plant Pathogens, Phytopathology Review, November 2015
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ELECTRONIC CODE OF FEDERAL REGULATIONS

e-CFR data is current as of June 10, 2016

Title 40 → Chapter I → Subchapter E → Part 180 → Subpart D → §180.1167

Title 40: Protection of Environment
PART 180—TOLERANCES AND EXEMPTIONS FOR PESTICIDE CHEMICAL RESIDUES IN FOOD
Subpart D—Exemptions From Tolerances

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§180.1167 Allyl isothiocyanate as a component of food grade oil of mustard; exemption from the requirement of a tolerance.

The insecticide and repellent Allyl isothiocyanate is exempt from the requirement of a tolerance for residues when used as a component of food grade oil of mustard, in or on all raw agricultural commodities, when applied according to approved labeling.

[61 FR 24894, May 17, 1996]

BIOPESTICIDES REGISTRATION ACTION DOCUMENT

Oil of Mustard and
Ally Isothiocyanate (ATIC)

PC Code: 004901

U.S. Environmental Protection Agency
Office of Pesticide Programs
Biopesticides and Pollution Prevention Division

(last updated September 11, 2013)

Table of Contents

BIOPESTICIDES REGISTRATION ACTION DOCUMENT (BRAD) TEAM

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I. EXECUTIVE SUMMARY

Allyl isothiocyanate (AITC) is a naturally occurring component of Oil of Mustard, which was first registered by the Agency for pesticidal use in 1962. As part of Oil of Mustard, AITC has been determined by the Agency to be the residue of concern and, as such, has been well characterized in the Reregistration Eligibility Decision for Flower and Vegetable Oils (EPA, 1993), the Biopesticides Registration Action Document for Oriental Mustard Seed (PC Code 014921) (EPA, 2008), and the Vegetable and Flower Oil Summary Document for Registration Review (EPA, 2010). AITC is produced naturally when enzymes of the mustard plant, myrosinase and glucosolinate, are in the presence of water. In addition to its presence in mustard, AITC can be found in food commodities such as cooked cabbage, kale, and horseradish. It is synthetically produced from allyl iodide and potassium thiocyanate. In pesticidal products, AITC is used as an insect and animal repellent, feeding suppressant, insecticide, fungicide, herbicide and nematicide.

Currently, pesticide product (MP), IR9804 (EPA File Symbol No. 89285-R) and end-use product (EP), IRF135 (EPA File Symbol 89285-E), are proposed to be registered. These products contain synthetic AITC at 99.8% and 96.3%, respectively. IRF135 is intended for use as an insecticide, fungicide, herbicide and nematicide to be applied (1) by tractor mounted shank injection at a depth of 8 to 15 inches, followed by tarp overlay, (2) by drip injection, also covered by tarp overlay, and (3) by deep injection to depths greater than 17 inches, with no tarp covering. IR9804 is intended for formulation into end-use products for soil treatment. The currently proposed label application methods are for pre-plant applications, which would be considered a non-food use. No residual activity is expected and the active ingredient and its degredates will dissipate prior to crop seeding.

The Agency has concluded that adequate mammalian toxicology data are available to support AITC (EPA, 1993; EPA 2010). The oral LD_{50} in rats is 339 mg/kg (EPA, 1993). Human exposure to AITC is expected to be minimal from the proposed MP and soil treatment EP, IR9804 (EPA File Symbol No. 89285-R) and IRF135 (EPA File Symbol 89285-E) (EPA, 2013). The active ingredient is not likely to result in adverse human health effects, based upon available reports and information.

AITC rapidly degrades in the environment by normal biological, physical and/or chemical processes that can be reasonably expected to exist where the pesticide is applied (EPA, 2013). In each case of registration of products containing AITC, sufficient data or information has been submitted to demonstrate that there will be no toxicity or adverse effects to nontarget organisms with the exception of certain insects and honey bees (EPA, 2008). The Agency has concluded that the honey bee toxicity issue can be appropriately addressed thru end-use product label mitigation.

On October 1, 2009, the U.S. Environmental Protection Agency (EPA or the Agency) announced a policy to provide a more meaningful opportunity for the public to participate in major registration decisions before they occur. According to this policy, EPA provides a public comment period prior to making a registration decision for the following types of applications: new active ingredients; first food uses; first outdoor uses; first residential uses; or any other registration actions for which EPA believes there may be significant public interest.

Consistent with the policy of making registration decisions more transparent, the public is being provided 15 days in which to submit comments to the Agency regarding its pending decision to register products containing AITC for use as a pre-plant soil treatment. The following documents are available for comment in the docket, identification number EPA-HQ-OPP-2013-0658: a draft of this Biopesticides Registration Action Document (BRAD), the draft product labels for IR9804 (EPA File Symbol 89285-R) and IRF135 (EPA File Symbol 89285-E), and the Agency science review memorandum for these products (EPA, 2013). **Note: The draft EP label will be revised, during this period, to include additional mitigation measures in accordance with those seen for similar application methods (soil fumigants) but as appropriate for this biopesticide. Intended revisions will include (1) an entry restricted period section on the label, (2) a fumigant management plan section, (3) clarification of restrictions for workers verses handlers, and (4) clarification of methods to determine soil and weather conditions.**

Altogether, the Agency believes that, based on the existing information in the Agency's database on AITC and the recent information submitted in support of the registration of pesticide products containing AITC for pre-plant soil treatment, it is in the best interest of the public to issue the registrations for IR9804 (EPA File Symbol 89285-R) and IRF135 (EPA File Symbol 89285-E). The basis for this decision can be found in the science review memorandum for these products (EPA, 2013) and the existing information in the Agency's database on AITC, both of which are characterized in this BRAD.

For definitions of scientific terms, please refer to http://www.epa.gov/pesticides/glossary/.

II. ACTIVE INGREDIENT OVERVIEW

Common Name:	Oil of Mustard
Chemical Names:	1-Propene, 3-isothiocyanato- 2-Propenyl isothiochyanate 3-Isothiocyanato-1-propene Allyl isosulfocyanate Allyl isothiocyanate Allyl mustard oil
Trade & Other Names:	Oil of Mustard Allyl isothiocyanate (AITC)
CAS Registry Number:	57-06-7
OPP Chemical Code:	004901
Type of Pesticide:	Biochemical Pesticide – insect and animal repellent, feeding suppressant, insecticide, fungicide, herbicide and nematicide

Biochemical Classification

Oil of Mustard, containing the residue of conern AITC, was first approved by the Agency for use in a registered product as a biochemical insecticide in 1962. For more information regarding product chemistry data requirements, please refer to Tables 1 thru 4 in Appendix A for this document.

III. REGULATORY BACKGROUND

A. Application for Pesticide Registration

On August 29, 2012, Technology Sciences Group, Inc., on behalf of Isagro USA, Inc. (hereafter referred to as "Isagro" or "applicant"), 430 Davis Drive, Suite 240, Morrisville, NC, 27560, submitted applications to register a new biochemical pesticide products, IR9804 (EPA File Symbol 89285-R) and IRF135 (EPA File Symbol 89285-E), containing AITC as their active ingredient. IRF135 is intended for use as an insecticide, fungicide, herbicide and nematicide to be applied to be applied (1) by tractor mounted shank injection at a depth of 8 to 15 inches, followed by tarp overlay, (2) by drip injection, also covered by tarp overlay, and 3) by deep injection to depths greater than 17 inches, with no tarp covering. IR9804 is intended for formulation into end-use products for soil treatment.

B. Food Clearances/Tolerances

AITC is exempt from the requirement of a tolerance as stated at 40 CFR § 180.1167:

> **40 CFR § 180.1167 Allyl isothiocyanate as a component of food grade oil of mustard; exemption from the requirement of a tolerance.**
>
> The insecticide and repellent Allyl isothiocyanate is exempt from the requirement of a tolerance for residues when used as a component of food grade oil of mustard, in or on all raw agricultural commodities, when applied according to approved labeling.

The proposed end-use product, IRF135 (EPA File Symbol 89285-E), is labeled for pre-plant soil application only. The active ingredient (synthetic AITC) and its degradates will dissipate prior to planting. The Agency considers this to be a non-food use and, therefore, a tolerance or exemption from the requirement of a tolerance is not required.

IV. RISK ASSESSMENT

A. Product Analysis Assessment (40 CFR § 158.2030)

Biochemical pesticide product analysis data requirements include product chemistry and composition, analysis and certified limits, and physical and chemical characteristics. Product chemistry and composition data include information about the identity of the active ingredient, the manufacturing process, and discussion of the potential for formation of unintentional ingredients. Analysis and certified limits data include information on analysis of samples and certification of limits. Physical and chemical characteristics data describe basic characteristics of the registered pesticide products, including color, physical state, odor, stability, miscibility, pH, corrosion characteristics, viscosity and density.

All product chemistry data requirements have been satisfied for the active ingredient (Oil of Mustard/AITC) and the proposed products, IR9804 (EPA File Symbol 89285-R) and IRF135 (EPA File Symbol 89285-E). Refer to Tables 1 thru 4 in Appendix A for a summary of product chemistry data specific to these products. Refer to the Vegetable and Flower Oil Summary Document for Registration Review (EPA, 2010) for a summary of product chemistry information for Oil of Mustard/AITC.

B. Human Health Assessment

1. Tier I Toxicology

AITC has already been assessed by the Agency and the Agency has concluded that adequate mammalian toxicology data are available to support this biochemical pesticide (EPA, 1993; EPA, 2008; EPA 2010). In addition, adequate mammalian toxicology data and information are available to support registration of IR9804 (EPA File Symbol No. 89285-R) and IRF135 (EPA File Symbol 89285-E). This information is summarized below and listed in Table 5 in Appendix A of this document.

Acute Toxicity for IR9804 (EPA File Symbol 89285-R) and IRF135 (EPA File Symbol 89285-E) ***(OCSPP Guideline Nos. 870.1100, 870.1200, 870.1300, 870.2400, 870.2500, and 870.2600; Master Record Identification (MRID) Nos. 488241-03 thru -07):***

The acute oral toxicity in rats for IF9804 (EPA File Symbol 89285-R), containing 99.8% AITC, is LD_{50} = 425.4 mg/kg. Acute dermal toxicity (rat) is LD_{50} > 200 mg/kg, and acute inhalation toxicity (rat) is LC_{50} > 0.21 mg/L. Therefore, IR9804 (EPA File Symbol 89285-R) is categorized as Toxicity Category II for acute oral toxicity, acute dermal toxicity, and acute inhalation toxicity. It is categorized as Toxicity Category I for primary eye irritation and primary dermal irritation due to its corrosivity, and is classified as a dermal sensitizer. No hypersensitivity incidents have been reported.

Guideline studies for acute human health toxicity testing were not submitted for the EP, IRF135 (EPA File Symbol 89285-E). In lieu of Guideline studies, the applicant submitted a request to bridge the acute toxicity data submitted in support of the TGAI/MP (containing 99.8% AITC) to support the acute toxicity data requirements for the EP (containing 96.5% AITC). The Agency has determined this request to be acceptable based upon the substantial similar formulation between these two products.

Subchronic Toxicity, Developmental Toxicity, and Mutagenicity Testing for IR9804 (EPA File Symbol No. 89285-R) (Tier I) ***(OCSPP Guideline Nos. 870.3100, 870.3250, 870.3465; 870.3700, 870.5100, 870.5300, 870.5375; MRID No. 48824108):***

A Guideline 90-day oral toxicity study was not submitted. In lieu of a study, the applicant cited a 90-day oral toxicity study conducted by the National Toxicology Program (NTP, 1982) on

F344/N rats dosed with 1.5 to 25 mg AITC/kg-body wgt/day, five days per week for 13 weeks which had a No Observed Adverse Effect Level (NOAEL) of 25 mg AITC/kg-body wgt/day, the highest level tested. No mortalities occurred during the course of the study and no treatment-related effects were observed on tissues obtained from the test animals when compared to non-treated controls. There were no differences in body weights between treated animals and non-treated controls (EPA, 2013).

A Guideline 90-day dermal toxicity study was not submitted. The applicant requested and was granted a waiver based on the fact that the product is not intended for application to human skin and prolonged or repeated dermal contact is not expected when EPs for pre-plant soil treatment are applied in accordance with Agency approved use directions and PPE (for handlers: coveralls worn over long sleeve shirt and long pants, chemical resistant footwear plus socks, chemical resistant gloves, protective eyewear, and an air purifying respirator). Similarly, a Guideline 90-day inhalation toxicity study was not submitted. The applicant requested and was granted a waiver based on the fact that repeated inhalation exposure to AITC aerosol, vapor or gas is highly unlikely and not expected, when the EPs for pre-plant soil treatment is applied in accordance with EPA approved label use directions and PPE.

A Guideline Prenatal Developmental Toxicity study was not submitted. In lieu of a study, the applicant cited a study in which AITC was one of 16 chemically-related compounds evaluated in order to correlate potential developmental toxicity with molecular structure. In this study, no difference in the percentage of abnormal fetuses in AITC-treated offspring were detected compared to control, and no difference between treated and control in the percentage of dead fetuses was detected. The authors concluded that AITC did not display any teratogenic potential at the NOAEL of 60 mg/kg. The 60 mg/kg dose would be equivalent to 4.2 g AITC for a standard 70 kg human (EPA, 2013).

Guideline Mutagenicity studies were not submitted. In lieu of a study, the applicant cited a battery of mutagenicity studies on AITC conducted by the National Toxicology Program (NTP). In this battery, two reverse mutation studies confirmed that mutagenicity responses were negative in all strains tested with and without S9 activation. In three *in vitro* mammalian gene mutation studies, a negative response was observed in the first trial using mouse lymphoma cells without S9 activation at concentrations ranging from 0.05 to 0.8 mg/mL AITC. A second trial without S9 exhibited a significant increase in average mutant frequency and significant reduction in relative total growth at AITC concentrations of 0.4, 0.6, and 0.8 mg/mL; 1.0 mg/mL was cytotoxic. A third trial without S9 also exhibited a significant increase in average mutant frequency at concentrations of 0.6 to 1.4 mg/mL and a significant reduction in growth; a concentration of 1.6 mg/mL was cytotoxic. It is noted that the positive results were observed without S9 activation and in the presence of substantial cytotoxicity. An *in vivo* mammalian chromosome aberration study was conducted with mice dosed intraperitoneally with 0, 25, or 50 mg/kg AITC and compared against mice dosed with a positive control, dimethylbenzanthracine (DMBA). Increases in chromosome aberrations were not observed in AITC treated mice when compared to non-treated (negative) controls, while a positive response was observed in DMBA-treated mice. The Agency has determined that the weight of evidence demonstrates that AITC is not likely to be a mutagen. In addition, the method of application and rapid degradation rate for the proposed pre-plant soil treatment, together with appropriate PPE, mitigates exposure to humans (EPA, 2013).

2. Tier II and Tier III Toxicity Studies

The biochemical pesticide Human Health Assessment data requirements for Tier II and Tier III were not required due to the low toxicity of the active ingredient and the low levels of exposure expected from its intended uses in EP products.

3. Effects on the Endocrine System

As required under FFDCA section 408(p), EPA has developed the Endocrine Disruptor Screening Program (EDSP) to determine whether certain substances (including pesticide active and other ingredients) may have an effect in humans or wildlife similar to an effect produced by a "naturally occurring estrogen, or other such endocrine effects as the Administrator may designate." The EDSP employs a two-tiered approach to making the statutorily required determinations. Tier 1 consists of a battery of 11 screening assays to identify the potential of a chemical substance to interact with the estrogen, androgen, or thyroid (E, A, or T) hormonal systems. Chemicals that go through Tier 1 screening and are found to have the potential to interact with E, A, or T hormonal systems will proceed to the next stage of the EDSP where EPA will determine which, if any, of the Tier 2 tests are necessary based on the available data. Tier 2 testing is designed to identify any adverse endocrine related effects caused by the substance, and establish a dose-response relationship between the dose and the E, A, or T effect.

Between October 2009 and February 2010, EPA issued test orders and data call-ins for the first group of 67 chemicals, which contains 58 pesticide active ingredients and nine inert ingredients. This list of chemicals was selected based on the potential for human exposure through pathways such as food and water, residential activity, and certain post-application agricultural scenarios. This list should not be construed as a list of known or likely endocrine disruptors.

AITC (as contained in Oil of Mustard) is not among the group of 58 pesticide active ingredients on the initial list to be screened under the EDSP. Under FFDCA section 408(p), the Agency must screen all pesticide chemicals. Accordingly, EPA anticipates issuing future EDSP test orders and data call-ins for all pesticide active ingredients.

For further information on the status of the EDSP, the policies and procedures, the list of 67 chemicals, the test guidelines and the Tier 1 screening battery, please visit our website: http://www.epa.gov/endo/.

4. Dose Response Assessment

No toxicological endpoints have been identified for Oil of Mustard or AITC; therefore, a dose-response assessment was not required.

5. Drinking Water Exposure and Risk Characterization

No significant exposure from drinking water is expected when products containing Oil of

Mustard or AITC are used according to the product label directions. AITC is a naturally occurring component of the human diet and degrades rapidly in the soil with a short half-life (T½) ranging from 20 to 60 hours. AITC transforms in sterilized soil at the same rate as intact soil, indicating that degredation is not dependent on soil microbial populations. Products containing AITC will not be directly applied to water. However, in an aqueous solution in the pH range between 6 and 8, AITC is proposed to degrade completely. Within this pH range, the primary decomposition products identified were: allyl thiocyanate (ATC); allylamine (AA); and carbon disulfide (CDS). ATC, an isomer of AITC, was identified at each pH and sampling interval; AA is expected to biodegrade quickly in the environment, and so if it is formed following AITC treatment of soil, human and animal exposure is unlikely. CDS is naturally occurring in the environment, and is released from tree roots, tidal marshes and soil. CDS is considered ubiquitous in the environment, and so formation of carbon disulfide from treating soil with AITC would not increase exposure to non-target organisms over levels currently in the environment (EPA, 2013).

6. Occupational, Residential, School and Day Care Exposure and Risk Characterization

a. Occupational Exposure and Risk Characterization

Occupational exposure to the proposed soil treatment EP, IRF135 (EPA File Symbol 89285-E), is not expected due to mitigation through precautionary language and personal protective equipment (PPE) on the label.For other products containing AITC, the Agency has required labels to include the appropriate signal word and precautionary statements, as PPE if applicable, to mitigate any risk of exposure.

b. Residential, School and Day Care Exposure and Risk Characterization

The proposed soil treatment EP, IRF135 (EPA File Symbol 89285-E), is for agricultural use only. Previously approved AITC products for outdoor residential use have been approved by the Agency based on minimal exposure to AITC when used according to label directions. No indoor residential, school, or day care uses are currently approved for products containing AITC.

7. Aggregate Exposure from Multiple Routes Including Dermal, Oral, and Inhalation

There is reasonable certainty of no harm to U.S. populations, including infants and children, from aggregate exposures to residues of AITC when used as proposed. This includes all anticipated dietary exposures and all other exposures for which there is reliable information. Moreover, potential non-occupational inhalation and dermal exposure is not likely to pose any adverse effects to exposed populations via aggregate and cumulative exposure.

a. Food Exposure

Dietary exposure of AITC is already occurring, given that this substance can be found in many foods commonly consumed by humans such as cooked cabbage, kale, horseradish, and mustard. AITC is exempt from the requirement of a tolerance for residues when used as a component of food grade oil of mustard, in or on all raw agricultural commodities, when applied according to approved labeling. Furthermore, the proposed use of synthetic AITC as a pre-plant soil treatment will not result on residues on food as the AITC, and its degradates, will readily degrade prior to planting (EPA, 2013).

b. Drinking Water Exposure

The proposed use of synthetic AITC as a pre-plant soil treatment will not result in water residues because this biochemical degrades rapidly in the soil with a short half-life (T½) ranging from 20 to 60 hours. Products containing AITC will not be directly applied to water. However, in an aqueous solution in the pH range between 6 and 8, AITC is proposed to degrade completely. Therefore, drinking water exposure from the proposed used pattern is not expected to pose incremental risk to adults, infants and children via drinking water consumption.

c. Other Non-occupational Exposure

The proposed soil treatment EP, IRF135 (EPA File Symbol 89285-E), is for agricultural use only. Previously approved AITC products for outdoor residential use have been approved by the Agency based on minimal exposure to AITC when used according to label directions. Other non-occupational use is not expected for products containing this active ingredient.

8. Cumulative Effects from Substances with a Common Mechanism of Toxicity

AITC has no demonstrated subchronic toxicity; thus, there is no reason to expect cumulative effects of exposure to Pear Ester and to other substances with common mechanism of toxicity.

9. Determination of Safety for United States Population, Infants and Children

AITC is exempt from the requirement of a tolerance for residues when used as a component of food grade oil of mustard, in or on all raw agricultural commodities, when applied according to approved labeling. Therefore, it is expected that no harm will result from aggregate exposure to the United States population, including infants and children, to the residues of AITC on food commodities. This includes all anticipated dietary exposures and all other exposures for which there is reliable information. Thus, there are not threshold effects of concern and consequently, provisions requiring additional margin of safety do not apply. Furthermore, the proposed use of synthetic AITC as a pre-plant soil treatment will not result on residues on food as the AITC, and its degradates, will readily degrade prior to planting (EPA, 2013).

10. Risk Characterization

The Agency considered human exposure to AITC in light of the relevant safety factors in FQPA and FIFRA. A determination has been made that no unreasonable adverse effects to the U.S. population in general, and to infants and children in particular, will result from the use of products containing AITC when label instructions are followed.

C. Environmental Assessment

1. Ecological Hazards

Oil of Mustard and AITC have already been assessed by the Agency and the Agency has concluded that adequate nontarget organism toxicology data and information are available to support these ingredients (EPA, 1993; EPA, 2008; EPA 2010). In addition, adequate nontarget organism toxicology data information were to support registration of IR9804 (EPA File Symbol No. 89285-R) and IRF135 (EPA File Symbol 89285-E). This information is summarized in Table 6, in Appendix A of this document.

2. Environmental Fate and Ground Water Data

Environmental fate and groundwater data are not required at this time because the results of the nontarget organism toxicity assessment (Tier I data requirements) did not trigger these Tier II data requirements.

3. Ecological Exposure and Risk Characterization

Exposure and risk from the registered and proposed (pre-plant soil treatment) uses of AITC are expected to be minimal for nontarget organisms, with the exception of honey bees (EPA, 2013). Exposure to honey bees will be mitigated by appropriate label language on end-use products.

4. Endangered Species Assessment

The Agency believes that Oil of Mustard and AITC will have "No Effect" on any currently listed threatened and endangered species, or any designated critical habitat, as listed by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) (EPA, 2010). EPA anticipates conducting no further analysis of potential risks to endangered or threatened species unless public comments during the Registration Review process alter the Agency's current position. The Registration Review for these active ingredients is ongoing as of the date of this document, September, 2013.

D. Product Performance Data

Product performance (efficacy) data must be developed for all pesticides to ensure that the products will perform as intended and that unnecessary pesticide exposure to the environment will not occur as a result of the use of ineffective products. The Agency reserves the right to require, on a case-by- case basis, the submission of efficacy data for any pesticide product registered or proposed for registration, but applications to register pesticide products intended to control a pest of significance public health importance, as defined in FIFRA section 28(d) and section 2(nn), must include such data. For further guidance on the product performance data requirement, refer to Pesticide Registration Notice (PR) Notices 96-7, 2002-1 and Explanation of Statutory Framework for Risk-Benefit Balancing for Public Health Pesticides (http://www.epa.gov/PR _Notices/pr1996-7.pdf) (http://www.ea.gov/PR_Notices/pr2002-1.pdf) and (http://www.epa.gov/pesticides/health/risk-benefit.htm).

Oil of Mustard and AITC are not intended to be formulated into products to control public health pests as defined in FIFRA section 28(d) and section 2(nn), and product performance (efficacy) was not evaluated by the Agency.

V. RISK MANAGEMENT DECISION

A. Determination of Eligibility for Registration

Section 3(c)(5) of FIFRA provides for pesticide product registration if it is determined that: (A) its composition warrants proposed claims; (B) its labeling and other materials comply with the requirements of FIFRA; (C) it will perform its intended function without unreasonable adverse effects on the environment; and (D) when used in accordance with widespread and commonly recognized practice, it will not generally cause unreasonable adverse effects on the environment.

The four eligibility criteria have been satisfied for the proposed pesticide products containing the active ingredient AITC (and for all previous registered pesticide products containing AITC and Oil of Mustard).

B. Regulatory Decision

The data submitted fulfill the requirements for the unconditional registration IR9804 (EPA File Symbol No. 89285-R) as an MP to be formulated into soil treatment products and IRF135 (EPA File Symbol 89285-E) as an EP for pre-plant soil treatment. For these product labels and for product-specific labels and information on other product containing Oil of Mustard and AITC, please refer to http://www.epa.gov/pesticides/pestlabels.

C. Environmental Justice

EPA seeks to achieve environmental justice—the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income—with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. At this time, EPA does not believe that products containing the active ingredients Oil of Mustard or AITC, or the use of AITC for pre-plant soil treatment will cause harm or a disproportionate impact on at-risk communities. For additional information regarding environmental justice issues, please visit EPA's website at *http://www.epa.gov/compliance/environmentaljustice/index.html*.

VI. ACTIONS REQUIRED BY REGISTRANTS

EPA evaluated all data submitted in connection with the registration of AITC for pre-plant soil treatment and determined that these data are sufficient to satisfy current registration data requirements. At this time, no additional data must be submitted to EPA for these particular products. For new uses and/or changes to existing uses, EPA may require additional data. Notwithstanding the information stated in the previous paragraph, it should be clearly understood that certain specific data are required to be reported to EPA as a requirement for maintaining the federal registration for a pesticide product. A brief summary of these types of data are listed below.

A. Reporting of Adverse Effects

Pursuant to FIFRA section 6(a)(2), reports of all incidents of adverse effects to the environment must be submitted to EPA.

B. Reporting of Hypersensitivity Incidents

Under the provisions of 40 CFR Part 158.2050(d), all incidents of hypersensitivity (including both suspected and confirmed incidents) must be reported to the Agency.

VII. Appendix A. Data Requirements (40 CFR Part 158-Subpart U)

TABLE 1. Product Chemistry Data Requirements for IR9804 (99.8% AITC) (40 CFR § 158.2030)			
OPPTS Guideline No.	**Study**	**Results**	**MRID**
830.1550 to 830.1670	Product identity; Manufacturing process; Discussion of formation of unintentional ingredients	Submitted data satisfy the requirements for product identity, manufacturing process, and discussion of formation of impurities. **ACCEPTABLE**	48824101
830.1700	Analysis of samples	Submitted data satisfy the requirements for analysis of samples. **ACCEPTABLE**	48824102
830.1750	Certification of limits	Limits listed in the CSF are A**CCEPTABLE**	-
830.1800	Analytical method	**ACCEPTABLE**	48824102

TABLE 2. Physical and Chemical Properties of IR9804 (99.8% AITC) (40 CFR § 158.2030)			
OPPTS Guideline No.	**Property**	**Description of Result**	**MRID**
830.6302	Color	Colorless or pale yellow liquid	48824101
830.6303	Physical State	Liquid	48824101
830.6304	Odor	Very pungent, irritating aroma	48824101
830.6313	Stability to Normal and Elevated Temperatures, Metals and Metal Ions	Reported stable.	48824101
830.6315	Flammability	Flashpoint = 46°C	48824101
830.6317	Storage Stability	Study in progress – anticipated completion date is the last quarter of 2013.	48824101
830.6319	Miscibility	Not Applicable; TGAI/MP is not an emulsifiable liquid and is not diluted with petroleum solvents.	-
830.6320	Corrosion Characteristics	Study in progress – anticipated completion date is the last quarter of 2013.	48824101
830.7000	pH	4-5	48824101
830.7050	UV/Visible Light Absorption	Refractive index 1.524-1.531; see http://www.fao.org/ag/agn/jefca-flav/img/img/1560.gif for the absorbance spectrum	48824101
830.7100	Viscosity	Not Applicable for TGAI/MP	-
830.7200	Melting Point/Range	-102.5°C	48824101
830.7220	Boiling Point/Range	150-151°C; 148-154°C	48824101
830.7300	Density	1.013-1.020; 1.0	48824101
830.7520	Particle Size, Fiber Length and Diameter Distribution	Not Applicable; TGAI/MP is not fibrous	-
830.7550 830.7560 830.7570	Partition Coefficient (n-Octanol/Water)	Log P = 2.11	48824101
830.7840	Water Solubility	Slightly soluble in water	48824101
830.7950	Vapor Pressure	1.33 kPa @ 38.3°C 0.493 kPa@ 20°C	48824101

TABLE 3. Product Chemistry Data Requirements for IRF135 (96.3% AITC) (40 CFR § 158.2030)			
OPPTS Guideline No.	**Study**	**Results**	**MRID Method/Reference**
830.1550 to 830.1670	Product identity; Manufacturing process; Discussion of formation of unintentional ingredients	Submitted data satisfy the requirements for product identity, manufacturing process, and discussion of formation of impurities. **ACCEPTABLE**	489194-01
830.1700	Analysis of samples	Not required for EP	489194-02
830.1750	Certification of limits	Limits listed in the CSF are **ACCEPTABLE**	489194-01
830.1800	Analytical method	Not required for EP	489194-02

TABLE 4. Physical and Chemical Properties of IRF135 (96.3% AITC) (40 CFR § 158.2030)			
OPPTS Guideline No.	**Property**	**Description of Result**	**MRID**
830.6302	Color	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.6303	Physical State	Liquid	489194-01
830.6304	Odor	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.6313	Stability to Normal and Elevated Temperatures, Metals and Metal Ions	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.6315	Flammability (flashpoint)	47ºC	489194-02
830.6317	Storage Stability	Study in progress– anticipated completion date is the last quarter of 2013.	489194-01
830.6319	Miscibility	Not applicable per 40 CFR 158.2030(e)(10) – EP is not an emulsifiable liquid and is not to be diluted with petroleum solvents.	-
830.6320	Corrosion Characteristics	Study in progress– anticipated completion date is the last quarter of 2013.	489194-01
830.7000	pH	4.87 (1% soln)	489194-02
830.7050	UV/Visible Light Absorption	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7100	Viscosity	0.6 centistokes @ 40°C 0.8 centistokes @ 20°C	489194-02
830.7200	Melting Point/Range	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7220	Boiling Point/Range	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7300	Density	1.019 g/mL @ 20°C	489194-02
830.7520	Particle Size, Fiber Length and Diameter Distribution	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7550 830.7560 830.7570	Partition Coefficient (n-Octanol/Water)	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7840	Water Solubility	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-
830.7950	Vapor Pressure	Not applicable per 40 CFR 158.2030(e) – Product is an EP.	-

Table 5. Mammalian Toxicology Data Requirements for IR9804 (EPA File Symbol 89285-R) (40 CFR § 158.2050)			
Study/OPPTS Guideline No.	**Results**	**Toxicity Category/Description**	**MRID**
Acute oral toxicity (rat) (870.1100)	LD_{50} = 425.4 mg/kg **ACCEPTABLE**	II	488241-03
Acute dermal toxicity (rat) (870.1200)	LD_{50} > 200 mg/kg **ACCEPTABLE**	II	488241-04
Acute inhalation toxicity (rat) (870.1300)	LC_{50} > 0.21 mg/L **ACCEPTABLE**	II	488241-05
Primary eye irritation (rabbit) (870.2400)	Waiver due to observed corrosiveness on skin **ACCEPTABLE**	I	1
Primary dermal irritation (rabbit) (870.2500)	Corrosive **ACCEPTABLE**	I	488241-06
Dermal sensitization (guinea pig) (870.2600)	Sensitizer **ACCEPTABLE**	-	488241-07
Hypersensitivity incidents (885.3400)	-	-	-
90-Day oral toxicity (870.3100)	Rationale submitted **ACCEPTABLE**		488241-08
90-Day dermal toxicity (870.3250)	Rationale submitted **ACCEPTABLE**		488241-08
90-Day inhalation toxicity (870.3465)	Rationale submitted **ACCEPTABLE**		488241-08
Mutagenicity (870.5100, 5300 and 5375)	Rationale submitted **ACCEPTABLE**		488241-08
Developmental toxicity (870.3700)	Rationale submitted **ACCEPTABLE**		488241-08

Table 6. Non-Target Organism Data Requirements for IR9804 (EPA File Symbol 89285-R) (40 CFR § 158.2060)			
Study/OPPTS Guideline No.	**Results**	**Toxicity Category/Description**	**MRID**
Avian Acute Oral/OPPTS 850.2100	Rationale submitted **ACCEPTABLE**	No acute oral exposure based on application method and rapid environmental degradation	48824108, p. 18
Avian Dietary/OPPTS 850.2200	Rationale submitted **ACCEPTABLE**	No dietary exposure based on application method and rapid environmental degradation	48824108, p. 20
Freshwater Fish LC50/OPPTS 850.1075	Rationale submitted 96-hr LC_{50} = 0.077 ppm **ACCEPTABLE**	Very Highly Toxic, but no aquatic exposure based on application method and rapid environmental degradation	48824108, pp. 22, 37-47
Freshwater Invertebrate/OPPTS 850.1010	Rationale submitted 48-hr EC_{50} = 0.73 ppm **ACCEPTABLE**	Very Highly Toxic, but no aquatic exposure based on application method and rapid environmental degradation	48824108, pp. 23, 216-221
Non-target Plants/OPPTS 850.4100 & 4150	Rationale submitted **ACCEPTABLE**	No non-target exposure based on application method and rapid environmental degradation	48824108, pp. 24-27
Non-target Insects	Rationale submitted **ACCEPTABLE**	No non-target exposure based on application method and rapid environmental degradation	48824108, pp. 28, 29

VIII. Appendix B. References

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IX. GLOSSARY OF ACRONYMS AND ABBREVIATIONS

a.i.	active ingredient
BPPD	Biopesticides and Pollution Prevention Division
BRAD	Biopesticide Registration Action Document
bw	body weight
CBI	Confidential Business Information
CFR	Code of Federal Regulations
cm^3	cubic centimeter
CSF	Confidential Statement of Formula
°C	degrees Celsius
EC_{50}	median effective concentration. A statistically derived single concentration in environmental medium that can be expected to cause an effect in 50% of the test animals when administrated by the route indicated (inhalation). It is expressed as a concentration in air or water (e.g. mg/L).
EDSP	Endocrine Disruptor Screening Program
EDSTAC	Endocrine Disruptor Screening and Testing Advisory Committee
EP	end-use product
EPA	Environmental Protection Agency (the "Agency")
FDA	Food and Drug Administration
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FQPA	Food Quality Protection Act
FR	Federal Register
g	gram
ha	hectare
kg	kilogram
Kow	octanol-water partition coefficient
L	liter
LC_{50}	median lethal concentration. A statistically derived single concentration in air or water that can be expected to cause death in 50% of the test animals when administrated by the route indicated (inhalation and environment). It is expressed as a concentration in air or water (e.g. mg/L).
LD_{50}	median lethal dose. A statistically derived single dose that can be expected to cause death in 50% of the test animals when administered by the route indicated (oral and dermal). It is expressed as a weight of substance per unit weight of animal (e.g., mg/kg).
MRID No.	Master Record Identification Number
mg	milligram
mPa	millipascal
mL	milliliter
MP	manufacturing-use product
N/A	not applicable
NE	"No Effect"
NIOSH	National Institute for Occupational Safety and Health

nm	nanometer
NOEL	no-observed-effect-level
NOF	notice of filing
NOR	notice of receipt
OPP	Office of Pesticide Programs
OCSPP	Office of Chemical Safety and Pollution Prevention
pa	pascal
PPE	personal protective equipment
PR Notice	Pesticide Registration Notice
TGAI	technical grade of the active ingredient
ug	microgram
USDA	United States Department of Agriculture
UV	ultra-violet

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Allyl isothiocyanate-rich mustard seed powder inhibits bladder cancer growth and muscle invasion

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Allyl isothiocyanate (AITC), which occurs in many common cruciferous vegetables, was recently shown to be selectively delivered to bladder cancer tissues through urinary excretion and to inhibit bladder cancer development in rats. The present investigation was designed to test the hypothesis that AITC-containing cruciferous vegetables also inhibit bladder cancer development. We focused on an AITC-rich mustard seed powder (MSP-1). AITC was stably stored as its glucosinolate precursor (sinigrin) in MSP-1. Upon addition of water, however, sinigrin was readily hydrolyzed by the accompanying endogenous myrosinase. This myrosinase was also required for full conversion of sinigrin to AITC *in vivo*, but the matrix of MSP-1 had no effect on AITC bioavailability. Sinigrin itself was not bioactive, whereas hydrated MSP-1 caused apoptosis and G_2/M phase arrest in bladder cancer cell lines *in vitro*. Comparison between hydrated MSP-1 and pure sinigrin with added myrosinase suggested that the anticancer effect of MSP-1 was derived principally, if not entirely, from the AITC generated from sinigrin. In an orthotopic rat bladder cancer model, oral MSP-1 at 71.5 mg/kg (sinigrin dose of 9 μmol/kg) inhibited bladder cancer growth by 34.5% ($P < 0.05$) and blocked muscle invasion by 100%. Moreover, the anticancer activity was associated with significant modulation of key cancer therapeutic targets, including vascular endothelial growth factor, cyclin B1 and caspase 3. On an equimolar basis, the anticancer activity of AITC delivered as MSP-1 appears to be more robust than that of pure AITC. MSP-1 is thus an attractive delivery vehicle for AITC and it strongly inhibits bladder cancer development and progression.

Introduction

Allyl isothiocyanate (AITC; 3-isothiocyanato-1-propene or 2-propenyl isothiocyanate) belongs to a family of naturally occurring isothiocyanates (ITCs) and is a promising cancer preventive agent (1). AITC occurs in many common cruciferous vegetables and is particularly abundant in mustard, horseradish and wasabi. Indeed, it is mainly responsible for the pungent flavor of these vegetables. AITC is synthesized and stored as sinigrin (a glucosinolate) and is subsequently generated from the latter through myrosinase-catalyzed hydrolysis of sinigrin. Myrosinase coexists with sinigrin in vegetables, but glucosinolate hydrolysis does not normally occur until the vegetable is damaged, such as by insect chewing, fungal invasion, chopping and human mastication. Myrosinase activity also exists in the intestinal microflora in both animals and humans, and glucosinolates that escape the action of vegetable myrosinase may be hydrolyzed *in vivo*. However, it is not known to what extent sinigrin is converted to AITC *in vivo*.

We have recently shown that AITC selectively targets human bladder cancer cells, while sparing normal human bladder epithelial cells, is selectively delivered to bladder cancer tissues through urinary excretion and potently inhibits bladder cancer development and muscle invasion in an orthotopic rat bladder cancer model (2). Thus, AITC is a highly promising agent for bladder cancer prevention and treatment. AITC may be especially valuable for prevention of recurrence and progression of superficial bladder cancers. Most human bladder cancers present as superficial cancer (no muscle invasion) at initial diagnosis and are exposed to urine. Existing therapeutic agents against recurrence of superficial bladder cancer, including immunotherapy with Bacillus Calmette–Guerin bacteria and chemotherapeutic agents not only have limited utility and efficacy (3,4) but also require urethral catheterization for intravesical delivery, to take advantage of the superficial nature of the cancer and to reduce systemic toxicity. In contrast, intravesical delivery of AITC is achieved through oral administration.

In light of the promising anticancer activity of AITC against bladder cancer and its ability to reach bladder cancer tissue selectively via urinary excretion, as described above, questions arose as to whether plants that are rich sources of AITC/sinigrin can also inhibit bladder cancer development, whether sinigrin can be sufficiently converted to AITC *in vivo* and whether the plant matrix interferes with absorption, urinary excretion and/or the anticancer activity of AITC. Mustard seed powder (MSP) is a well-known rich source of AITC with thousands of years' history of use in Chinese traditional medicine, Ayurvedic medicine and various other traditional folk medicines and cuisines. A previous study showed the chemopreventive effects of MSP on chemically induced turmorigenesis in forestomach and uterine cervix in mice (5). In the present report, we show that total ITC content varies greatly among commercial MSP preparations. Focusing on the MSP, which has the highest ITC content (MSP-1), we show that AITC is the predominant, if not the only ITC, and that all AITC is stored stably as sinigrin in the powder. Enough myrosinase is also present in MSP-1 to allow full conversion of sinigrin to AITC upon addition of water *in vitro* and after oral ingestion *in vivo*, but the myrosinase apparently has no catalytic effect on sinigrin in the original powder even though it may not be completely dry. We further show that MSP-1 possesses potent anticancer activity in both cultured bladder cancer cells and an orthotopic rat bladder cancer model *in vivo* and that the MSP matrix has no effect on absorption and urinary excretion of AITC. However, in animals given purified sinigrin, AITC yield *in vivo* is extremely low, indicating poor conversion from sinigrin to AITC by the myrosinase-like enzyme in the intestinal microflora, and if not hydrolyzed by myrosinase, sinigrin has no anticancer activity.

Materials and methods

Materials

Sinigrin and myrosinase were purchased from Sigma–Aldrich (St Louis, MO). The MSPs include hot oriental MSP (MSP-1) purchased from Spice House (Chicago, IL), MSP-2 from Frontier Natural Products (Norway, IA), MSP-3 from Raw Deal (Flanders, NJ) and MSP-4 from Viable Herbal Solutions (Langhome, PA). The powders have a particle size of ∼60 mesh and were prepared from the seeds of *Sinapis alba* or *Brassica juncea*, but the exact genotype and cultivar for each powder are not clear. Antibodies specific for cleaved caspase 3 (Cat. # 9661) and cleaved poly adenosine diphosphate ribose polymerase (PARP; Cat. # 9542) were purchased from Cell Signaling Technology (Beverly, MA). Antibodies specific for vascular endothelial growth factor (VEGF; Cat. # SC-152) and cyclin B1 (Cat. # SC-245) were purchased from Santa Cruz Biotechnology (Santa Cruz, CA). An antibody specific for

Abbreviations: AITC, allyl isothiocyanate; DADW, an equal volume mixture of dimethyl sulfoxide, acetonitrile, dimethylformamide and water; IC_{50}, half maximal inhibitory concentration; ITC, isothiocyanate; MMP, matrix metalloproteinase; MSP, mustard seed powder; PARP, poly adenosine diphosphate ribose polymerase; PBS, phosphate-buffered saline; VEGF, vascular endothelial growth factor.

glyceraldehyde 3-phosphate dehydrogenase (Cat. # MAB374) was purchased from Millipore (Billerica, MA).

Animals

Female F344 rats (8 weeks of age) were purchased from Harlan (Indianapolis, IN) and were acclimatized for ~1 week before use. The rats were maintained at 21–23°C and a 12 h light/dark cycle with free access of food (Harlan Teklad LM-485 mouse/rat sterilizable diet) and water. All animal protocols and procedures were approved by the Roswell Park Cancer Institute Animal Care and Use Committee.

Measurement of total ITC, glucosinolates and myrosinase in MSP

Total ITC level in each MSP was measured by the 1,2-benzenedithiol-based cyclocondensation assay (6). Each MSP was incubated with myrosinase in phosphate-buffered saline (PBS) (1 mg/ml) in the presence of exogenous myrosinase (0.1 IU/mg MSP) for 30 min at room temperature prior to ITC measurement. Pure sinigrin was used as a control to confirm full hydrolysis of glucosinolates in MSP. In a parallel experiment, an MSP-1 was incubated in PBS (1 mg/ml) without exogenous myrosinase at room temperature for specific times before ITC measurement to assess the effect of endogenous myrosinase. To measure the stability of MSP-1 as an ITC source, the total ITC level was rechecked after storage of this substance at room temperature for 10 months.

To measure sinigrin content, each MSP was thoroughly mixed at ~61 mg/ml in a mixture of four solvents, containing an equal volume of dimethyl sulfoxide, acetonitrile, dimethylformamide and water (DADW). This solvent mixture irreversibly inactivates myrosinase and efficiently extracts glucosinolates (7). The mixture was then cleared of insoluble materials by low-speed centrifugation and analyzed for sinigrin content by high-performance liquid chromatography, using a ZIC-HILIC hydrophilic interaction chromatography column from Sequant (Umea, Sweden; 150 mm × 4.6 mm, 5 μm, 200 Å) (8). Pure sinigrin was used as a chromatographic standard. In a parallel experiment, MSP or sinigrin was treated with myrosinase for 0.5 h at 30°C in an aqueous 1 ml solution, containing 1 μmol sinigrin or ~6 mg MSP, 0.2 ml of 100 mM sodium phosphate (pH 6.0), 0.01 ml of 50 mM ascorbic acid (an activator of myrosinase) (9), 0.02 IU myrosinase and 0.79 ml water. The digests were analyzed for disappearance of glucosinolates by ZIC-HILIC, as described above.

To measure the endogenous myrosinase activity, MSP was thoroughly suspended in water (~10 mg/ml) and cleared of insoluble materials by filtration through a Millipore Millex-HV filter. Myrosinase activity was measured in a 1 ml reaction solution by monitoring the initial rate of hydrolysis of sinigrin spectrophotometrically at 227 nm at room temperature (molar extinction coefficient of 6784 M^{-1} cm^{-1}). Each 1 ml reaction contained 50 μl sample, which contained 6.3 nmol of sinigrin in the case of MSP-1, 10 μl of 50 mM ascorbic acid in water, 200 μl of 100 mM sodium phosphate (pH 6.0) and 735 μl water, and 5 μl of 10 mM sinigrin in water was finally added to initiate the reaction. One unit of myrosinase activity equates to the hydrolysis of 1 μmol sinigrin/min.

Cell culture, proliferation assay, cell death enzyme-linked immunosorbent assay and flow cytometry

Human bladder cancer UM-UC-3 cells and rat bladder cancer AY-27 cells were used in the study. The sources of the cell lines as well as their culture conditions have been recently reported (2).

To determine the antiproliferative activity of MSP or sinigrin, cells were grown in 96-well plates (5×10^3 cells per well with 0.15 ml medium) for 24 h and then grown for 72 h in fresh medium (200 μl/well) containing MSP, sinigrin or vehicle. In the case of sinigrin, the culture medium was added with or without myrosinase (0.1 IU/ml). Cell growth was measured at the end of treatment using the 3-(4,6-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay (10), from which the half maximal inhibitory concentration (IC_{50}) of each substance was calculated.

Induction of apoptosis by MSP was measured using a Cell Death Detection ELISA^{plus} kit purchased from Roche Diagnostics (Indianapolis, IN), following the manufacturer's instruction. Briefly, cells were grown in 96-well plates and treated with MSP, as described above. At the end of treatment, the cells were lysed with lysis buffer, and after a low-speed centrifugation, a portion of the supernatant fraction was used for measurement of cytoplasmic levels of histone-associated mononucleosomes or oligonucleosomes.

Cell cycle arrest by MSP was analyzed by flow cytometry. Briefly, 1.5×10^6 cells were grown in a 10 cm plate with 10 ml medium for 24 h and then treated with MSP for 24 h before analysis by flow cytometry as described previously (11). Both MSP and sinigrin were freshly dissolved in a small volume of PBS.

Measurement of AITC bioavailability

Groups of five female F344 rats (10–12 weeks of age) were administered a single oral dose of MSP or sinigrin in ~0.5 ml water. The solutions were prepared fresh and given to the animals within 30 min of preparation. A control group of rats were given only water. The rats were immediately transferred to metabolism cages (Tecniplast, Exton, PA; 1 rat per cage) and were given free access to food and water for 24 h during which all urine was collected. Total urinary AITC equivalents were determined using the high-performance liquid chromatography-based cyclocondensation assay, as described previously (12).

An orthotopic rat bladder cancer model

The anticancer activity of MSP was evaluated in an orthotopic rat bladder cancer model. The details of this model have been recently reported (2). Briefly, female F344 rats (8–10 weeks of age) were inoculated orthotopically via a urethra catheter with AY-27 cells (1×10^6 cells in 0.5 ml serum-free medium per rat). One day after the inoculation, the rats were randomly assigned to receive by gavage vehicle control (3.3 ml water per kg or ~0.5 ml per rat) or MSP that was freshly prepared in an equal volume of water, once daily for 3 weeks. The MSP solution was given to the animals within 30 min of preparation. The animals were monitored and weighed daily and were euthanized 24 h after the last dose, and the bladders were quickly removed and weighed. Approximately half of each bladder was fixed in formalin for histological analysis and the other half was frozen in liquid nitrogen for western blot analysis.

Western blot analysis

Cells were grown in 10 cm plates for 24 h (1.5×10^6 cells per plate in 10 ml medium), treated with MSP (dissolved in culture medium) for 24 h and then harvested for analysis. Cells after harvest were washed with ice-cold PBS and lysed in radioimmunoprecipitation assay buffer supplemented with a protease inhibitor cocktail (Sigma–Aldrich). Bladder tumor samples were thoroughly washed in ice-cold PBS, frozen with liquid nitrogen, reduced to powder with a biopulverizer and finally homogenized in radioimmunoprecipitation assay buffer supplemented with a protease inhibitor cocktail mentioned above in glass homogenizers. Cell lysates and tissue homogenates were cleared of debris by low-speed centrifugation and measured for protein contents using the bicinchoninic acid kit (Pierce, Rockford, IL). The samples were then resolved by sodium dodecyl sulfate–polyacrylamide gel electrophoresis and transferred to polyvinylidene difluoride membranes, which were probed by specific antibodies and visualized using SuperSignal West Pico Chemiluminescence Detection System (Thermo Scientific, Rockford, IL) or ECL plus (GE Healthcare, Piscataway, NJ).

Histological analysis

Rat bladders fixed in formalin were paraffin embedded, cut to ~4 μm thickness and stained with standard hematoxylin and eosin. The slides were examined for bladder and tumor histology using a Nikon 50i light microscope. Tumor muscle invasion was assessed at high magnification (greater than or equal to ×200).

Statistical analysis

All results are expressed as mean ± standard error of the mean. Difference between the means of two groups was analyzed for statistical significance using unpaired two-tailed Student's *t*-test with $P < 0.05$ being considered significant (GraphPad Version 5.00; GraphPad Software, San Diego, CA).

Results and discussion

MSP as a vehicle for AITC delivery

In a preliminary experiment, MSP purchased from four different commercial sources were compared for total ITC content. Each MSP was suspended in PBS and treated with exogenous myrosinase for 30 min to fully hydrolyze glucosinolates to ITCs, which was followed by measurement of total ITC content by the high-performance liquid chromatography-based cyclocondensation assay. Longer incubation time with myrosinase did not increase ITC yield. Pure sinigrin was used to confirm full hydrolysis of glucosinolate by myrosinase. MSP-1 showed the highest ITC level (125.1 μmol/g powder), followed by MSP-2 (91.8 μmol/g), MSP-3 (5.1 μmol/g) and MSP-4 (3.9 μmol/g) (Figure 1A). Thus, total ITC levels in these powders vary by as much as 32-fold. Our subsequent experiments were restricted to MSP-1. Upon re-assay of this substance after storage at room temperature for 10 months, there was no decrease in total ITC level, indicating remarkable stability. Further analysis showed that a significant amount of myrosinase activity was also present in MSP-1 (29.2 ± 3.6 IU/g powder). Thus, incubation of the powder in PBS without exogenous myrosinase at room temperature yielded 91% (114 μmol/g)

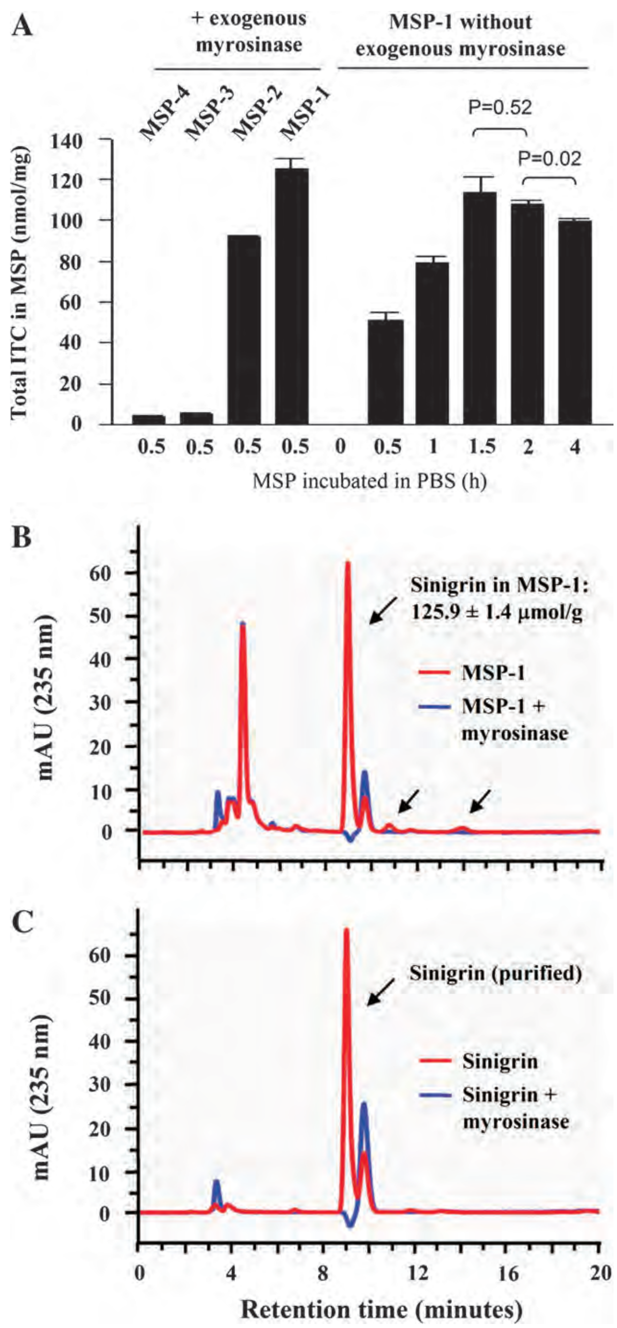

Fig. 1. Characterization of MSP. (**A**) Four different preparations (from four commercial sources) of MSP, including MSP-4, MSP-3, MSP-2 and MSP-1, were each incubated with exogenous myrosinase in PBS (1 mg powder per ml with 0.1 U myrosinase) for 30 min at room temperature (longer incubation time did not lead to further increase in ITC yield). MSP-1 was also incubated in PBS at room temperature for 0.5–4 h without exogenous myrosinase. At the end of incubation, total ITC levels in each solution were measured by the cyclocondensation assay. Each value is a mean ± SEM (n = 3). The result at the 0 time point was obtained by mixing MSP-1 with DADW, so that the endogenous myrosinase was inactivated and potential conversion from sinigrin to AITC was blocked. (**B**) MSP-1 was either mixed with DADW or incubated with exogenous myrosinase in phosphate buffer for 30 min before high-performance liquid chromatography. The arrows point to sinigrin and two potential minor glucosinolates of unknown identity. The compound or compounds representing the peak around 4 min has not been characterized, but it is not a glucosinolate, because myrosinase treatment had no effect on the peak. (**C**) Sinigrin was mixed in water with or without myrosinase in phosphate buffer for 30 min before high-performance liquid chromatography. The results are representative of at least three experiments.

of total ITCs, although a longer incubation time (1.5 h) was needed (Figure 1A). Further incubation of MSP-1 in PBS, however, led to a decrease in total ITC levels (Figure 1A), suggesting that some of the ITCs formed during the incubation might subsequently be further metabolized or degraded in the aqueous environment or lost due to evaporation (AITC is quite volatile).

We next measured sinigrin level in MSP-1. The powder was mixed with the DADW solvent mixture, which was shown previously to engender full extraction of glucosinolates and ITCs from vegetable powders while simultaneously inhibiting myrosinase-mediated hydrolysis of glucosinolates. Sinigrin was measured by an analytical ZIC-HILIC, and pure sinigrin was used as a positive control. For comparison, the powder was also incubated with exogenous myrosinase in an aqueous solution prior to sinigrin analysis. The sinigrin level was measured at 125.9 μmol/g powder but hydrolyzed completely after myrosinase treatment (Figure 1B). No ITC was detected in the DADW extracts (Figure 1A), indicating that sinigrin was maintained intact in MSP-1 despite the presence of myrosinase. Moreover, sinigrin content in MSP-1 was almost identical to the total ITC level measured after myrosinase treatment, as described above. Comparison of the HILIC chromatograms of MSP-1 with and without myrosinase treatment showed potential presence of two very minor glucosinolates (Figure 1, peaks indicated by the arrows), as would be expected based on previous work (13). Although the identities of these glucosinolates are not known, their small peak area (∼3% the area of the sinigrin peak; peak areas of glucosinolates roughly corresponds to molar concentrations), and the fact that sinigrin content in MSP-1 matches closely with total ITC generated after myrosinase treatment suggest that these glucosinolates may generate little if any ITC.

Sinigrin hydrolysis in vivo

Previous studies have shown that up to 40% of certain ingested glucosinolates may be hydrolyzed to ITCs by a myrosinase-like enzyme present in the intestinal microflora (14–16). ITCs are primarily metabolized *in vivo* through the mercapturic acid pathway, giving rise to dithiocarbamates (mainly *N*-acetylcysteine conjugates) that are excreted and concentrated in urine (1). To determine the extent to which sinigrin is hydrolyzed to AITC *in vivo*, groups of five rats were administered a single oral dose of either sinigrin at 5 and 50 μmol/kg or MSP-1 at the sinigrin dose of 9 and 90 μmol/kg. Higher doses of sinigrin from MSP-1 were used unintentionally due to initial underdetection of its level in the powder. The rats were immediately moved to metabolism cages (one rat per cage) for 24 h urine collection. For comparison, another group of rats were administered AITC at 10 μmol/kg before 24 h urine collection. Our previous rat study showed that >90% of urinary excretion of AITC equivalents (AITC plus its dithiocarbamate metabolites) occurred within 24 h of AITC dosing (17). AITC equivalents in urine were measured by the cyclocondensation assay. This assay does not detect sinigrin but detects both ITC and its dithiocarbamate metabolites. All measurements were adjusted by the basal urinary level of total ITC and dithiocarbamate (average concentration of 8.6 ± 2.3 μM or 0.05 ± 0.01 μmol in 24 h urine), which was measured in a group of rats that were administered only the vehicle. Urinary recovery as AITC equivalent in 24 h urine represented only 3–5% of the administered dose when sinigrin was used, whereas it increased to 53–56% of the administered sinigrin when MSP-1 was used, which was virtually identical to the 55% recovery detected in rats administered AITC (Figure 2A). MSP-1 was freshly suspended in water and given to the rats within 30 min. These results show that the conversion of sinigrin to AITC *in vivo* by the myrosinase-like enzyme in the gastrointestinal microflora is almost negligible, but the myrosinase carried by MSP-1 could fully hydrolyze sinigrin *in vivo*. These results also suggest that the MSP-1 matrix does not affect the absorption and urinary excretion of AITC generated from sinigrin. It is noteworthy that our previous study in female Sprague–Dawley rats showed that 70% of the AITC dose (25 μmol/kg) was recovered in 24 h urine (17), which is significantly higher than that in female F344 rats described above, suggesting potential species difference in absorption and/or urinary excretion of AITC.

Consistent with the marked difference in urinary AITC recovery rates described above between pure sinigrin and sinigrin carried in MSP-1, average 24 h urinary concentrations of AITC equivalents were 6.3 and 41.5 μM in rats given pure sinigrin at 5 and 50 μmol/kg, respectively, whereas the corresponding urinary concentrations were 140.5 and 1084.5 μM in rats given MSP-1 at the sinigrin doses of 9 and 90 μmol/kg (Figure 2B). The average 24 h urinary concentration of AITC equivalents was 100.7 μM in rats given AITC at 10 μmol/kg, which is not statistically different from that in rats given MSP at the sinigrin dose of 9 μmol/kg.

The anticancer effect of MSP-1 on bladder cancer cells in vitro

The anticancer activity of MSP-1 was first assessed *in vitro* using human bladder cancer UM-UC-3 cells and rat bladder cancer AY-27 cells, the latter of which were also used in the animal studies described later. The proliferation of both UM-UC-3 cells and AY-27 cells was inhibited by MSP-1 in a dose-dependent manner, with IC_{50} values of 10.8 and 8.6 μM of sinigrin (85.8 and 68.3 μg MSP-1 per ml culture medium), respectively (Figure 3A). Pure sinigrin was ineffective, but in the presence of myrosinase, its IC_{50} values of 13.3 μM (UM-UC-3) and 8.5 μM (AY-27) were comparable with that of MSP-1 calculated in sinigrin concentration (Figure 3A). As shown in Figures 1A and 2, adequate myrosinase is present in MSP-1 for full hydrolysis of its sinigrin. Collectively, these results suggest that AITC formed from sinigrin may account principally if not entirely for the anticancer activity of MSP-1.

Inhibition of cell proliferation by MSP-1 was associated with marked induction of apoptosis and cell cycle arrest. Thus, treatment of UM-UC-3 cells and AY-27 cells with MSP-1 at the sinigrin concentrations of 13 and 26 μM for 24 h resulted in up to 8.2- and 4.2-fold increases in apoptosis activity, respectively, for the two cell lines (Figure 3B). Up to 49.1% UM-UC-3 cells and 30.4% AY-27 cells were in G_2/M phase after MSP-1 treatment compared with 10.9–14.0% of control cells present in G_2/M phase (Figure 3C). Similar results were shown previously with AITC (2). These results show that the antiproliferative effect of MSP-1 on the bladder cancer cells resulted at least in part from activation of apoptosis and cell cycle arrest.

The effect of MSP-1 on bladder cancer growth and muscle invasion in vivo

MSP-1 was assessed for inhibition of bladder cancer *in vivo* in an orthotopic rat bladder cancer model, which closely resembles human bladder cancer development. Orthotopic bladder cancer growth was initiated by intravesical inoculation of bladder cancer AY27 cells (1 × 10^6 cells per rat) in female F344 rats. MSP-1 was administered by gavage once daily for 3 weeks, which was started 1 day after cancer cell inoculation. The animals were monitored closely, weighed daily and euthanized at the end of the treatment. The bladders were

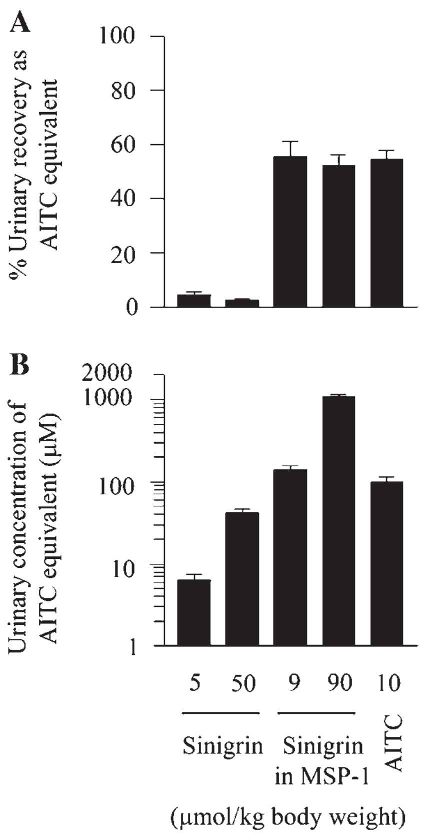

Fig. 2. Sinigrin hydrolysis and urinary excretion of AITC. Groups of five female F344 rats were administered a single oral dose of sinigrin, MSP-1 or AITC. Both sinigrin and MSP-1 were mixed in water, whereas AITC was mixed in soy oil, which were given to rats within 30 min of preparation. The rats were kept in metabolism cage for 24 h urine collection (1 rat per cage). Urinary levels of ITC equivalents were measured by the cyclocondensation assay. All values were adjusted by background urinary levels of ITC equivalents, which were 8.6 ± 2.3 μM (average 24 h urinary concentration) and 0.05 ± 0.01 μmol (24 h urine), determined in another group of rats. Each value is mean ± SEM (n = 5).

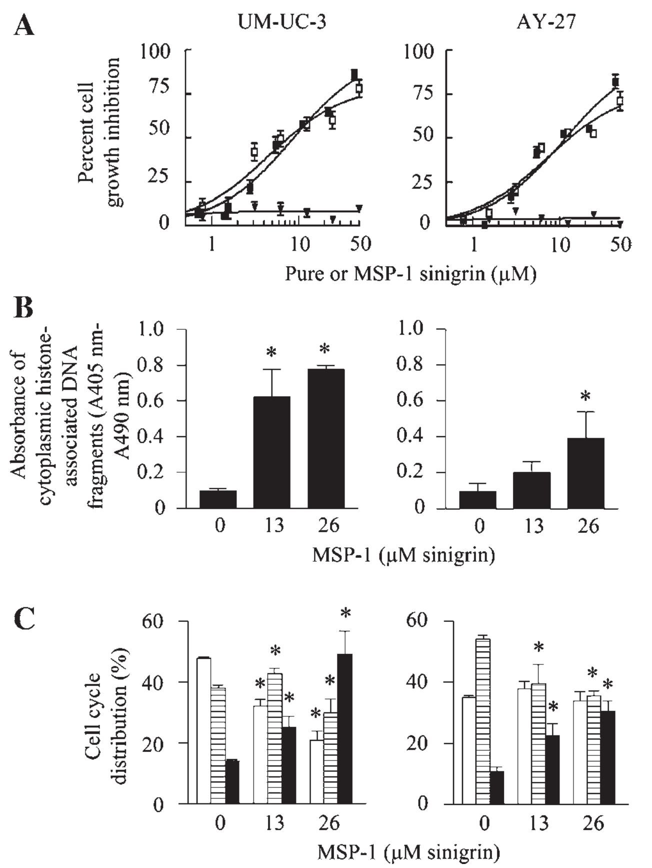

Fig. 3. The effect of sinigrin and MSP-1 on survival and proliferation of bladder cancer cells. (**A**) UM-UC-3 cells and AY-27 cells were grown in 96-well plates and treated with MSP-1 (filled sqaures), sinigrin (inverted filled triangles) and sinigrin plus myrosinase (open squares) for 72 h, followed by measurement of cell density by 3(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay. (**B**) Cells were grown in 96-well plates and treated with MSP for 24 h. Apoptosis was measured by an enzyme-linked immunosorbent assay. (**C**) Cells were grown in 10 cm dishes and treated with MSP-1 for 24 h. Cell cycle distribution was measured by flow cytometry (open bars, G_1; striped bars, S; filled bars, G_2/M). Each value is mean ± SEM (n = 3–8). $^*P < 0.05$ compared with the control.

removed promptly for assessment of potential impact of the test substance on tumor growth. The animals in all groups behaved normally and there was no significant difference in body weight gain over the experimental period among the groups (Figure 4A). Bladder tumors formed in nearly all rats. The tumors in the control group weighed 337.1 ± 48.6 mg (Figure 4A), which is five times the normal bladder weight (67.7 ± 1.8 mg), showing the explosive cancer growth rate. Moreover, tumors invaded the musculature in 71% of the tumor-bearing bladders (Figure 4B). Similar tumor growth and muscle invasion rates were previously seen (2). Treatment with MSP-1 at the sinigrin doses of 9 or 90 μmol/kg body wt (71.5 or 715 mg MSP-1 per kg body wt) reduced tumor weight by 35% ($P < 0.05$) and 23%, respectively. More interestingly, none of the tumor-bearing bladders of rats treated with the low-dose MSP-1 showed muscle invasion, whereas the muscle invasion rate in the high-dose MSP-1 group was 62%, which is only slightly lower than that in the control group (Figure 4C). Thus, MSP-1 at the low dose is more effective than the high dose. Although the reason is not known, we recently showed that AITC at 10 μmol/kg was also more effective than at higher doses in inhibiting bladder tumor development in the same model (2). However, compared with AITC, which at 10 μmol/kg inhibited bladder cancer growth rate by 30% and muscle invasion rate by 73% (2), the anticancer efficacy of MSP-1 appears to be more robust, particularly in blocking muscle invasion.

The ability of MSP-1 to completely block muscle invasion of bladder cancer is especially exciting because muscle invasion is the event that separates relatively benign superficial bladder cancer that is generally not life-threatening from more advanced cancer that requires aggressive therapy and has poor prognosis. Approximately a third of bladder cancers at diagnosis show muscle invasion, and 15–30% of high-grade superficial bladder cancers progress to muscle invasion within 5 years. Muscle invasive bladder cancer remains a therapeutic challenge. Patients with muscle invasive bladder cancer not only require debilitating radical cystectomy but also face a poor survival outlook (18)

Potential anticancer mechanism of MSP-1

In view of the complete inhibition of muscle invasion of bladder cancers in rats treated with MSP-1, several proteins that are known to promote cancer invasion and metastasis were examined in the bladder cancer tissues and cultured bladder cancer cells. Both matrix metalloproteinase (MMP)-2 and MMP-9 were readily detected in the tumor tissues, but treatment with MSP-1 had no effect on their expression (results not shown). Likewise, MMP-2 and MMP-9 were readily detected in both UM-UC-3 cells and AY-27 cells in culture but not affected by MSP-1 (result not shown). The potential effect of MSP-1 on other MMPs has not been examined. However, MSP-1 treatment caused a significant decrease in VEGF (VEGF-A) in both cultured bladder cancers and bladder cancer tissues (Figure 5). Interestingly, the inhibitory effect of MSP-1 on VEGF *in vivo* was detected only at the low dose (9 μmol/kg sinigrin) but not the high dose (90 μmol/kg sinigrin), which correlates with the markedly more effective inhibition of tumor invasion into the muscle by MSP-1 at the low dose as described above. However, the reason for the lack of effect at the high MSP-1 dose is not known. Other members of VEGF have not been examined. VEGF is well known to promote cancer angiogenesis, invasion and metastasis and is a widely recognized anticancer target, although VEGF-C was shown previously to promote invasion and metastasis of certain cancer cells (19). A previous study showed that VEGF expression level was higher in more advanced tumors and invasive tumors in human bladder cancer (20).

Moreover, MSP-1 also strongly activated caspase-3 and cleaved PARP in both UM-UC-3 cells and AY-27 cells (Figure 5), which is

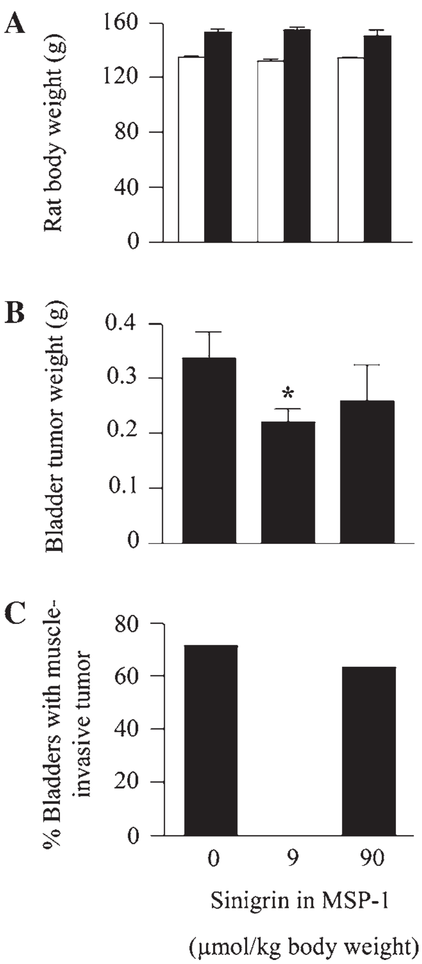

Fig. 4. Inhibition of bladder cancer development by MSP-1. Female F344 rats were inoculated with AY-27 cells intravesically via a urethra catheter to initiate development of orthotopic bladder cancer. Oral administration of MSP-1 or vehicle (water) once daily was started 1 day after cancer cell inoculation and ended 3 weeks later. The number of rats per group varied from 11–29. (**A**) Initial (open bars) and final (filled bars) body weights. (**B**) Tumor weight was calculated by subtracting the average normal bladder weight from tumor-bearing bladder weight. $^{*}P < 0.05$. Each value in A and B is mean ± SEM. (**C**) Percentage of bladder where the tumor invaded the muscle tissue.

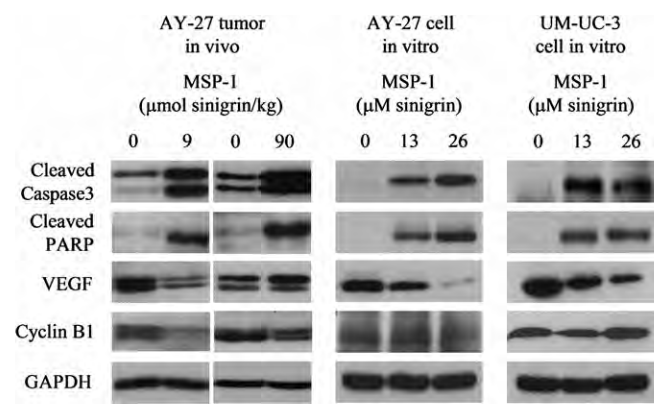

Fig. 5. The effect of MSP-1 on selected anticancer targets. UM-UC-3 cells and AY-27 cells in culture were treated with MSP-1 at the sinigrin concentrations of 13 or 26 μM for 24 h. The results are representative of at least two experiments. The bladder tumors were removed from rats, which were treated with vehicle or MSP-1 at the sinigrin doses of 9 or 90 μmol/kg once daily for 3 weeks, starting 1 day after cancer cell inoculation. The results are representative of tumors from other rats. Cell lysates and tumor homogenates were analyzed by western blotting, using glyceraldehyde 3-phosphate dehydrogenase (GAPDH) as a loading control.

consistent with induction of apoptosis by MSP-1 in these cells (Figure 3). Caspase-3 and PARP were also uniformly activated or cleaved in bladder cancer tissues of rats treated with MSP-1 (Figure 5). Interestingly, unlike VEGF, the low and high doses of MSP-1 showed similar effects on caspase-3 and PARP *in vivo*. There was a varying degree of activation of caspase-3 in ~10% of bladder tumors in the control group. The reason for this phenomenon is not clear, but there was no apparent difference in morphology (both gross morphology and hematoxylin/eosin-stained tissue slides) between these control tumors and control tumors showing no caspase-3 activation (results not shown). AITC showed similar effects on caspase-3 in bladder cancer cells *in vitro* and bladder cancer tissues *in vivo*, as previously reported (2).

MSP-1 also caused significant downregulation of cyclin B1, a key regulator of G_2/M phase, in cultured AY-27 bladder cancer cells and 67% bladder cancers (derived from AY-27 cells) *in vivo* (Figure 5). As in the case of caspase-3 and PARP, the low and high doses of MSP-1 showed similar effects on cyclin B1. Interestingly, the level of cyclin B1 in MSP-1-treated UM-UC-3 cells was not significantly different from that in control UM-UC-3 cells (Figure 5). But the result in UM-UC-3 cells should still be interpreted as cyclin B1 downregulation because cyclin B1 is selectively expressed in G_2/M phase and the proportion of cells in G_2/M phase after MSP-1 treatment increased up to 3.5-fold (Figure 3C). It is worth noting that AITC was shown previously to consistently downregulate cyclin B1 in both UM-UC-3 cells as well as in AY-27 cells *in vitro* and bladder tumors derived from AY-27 cells *in vivo* (2).

In summary, there is a considerable variation in AITC/sinigrin levels among commercial preparations of MSP. Restricting our experiments to MSP-1, which possesses the highest level of AITC/sinigrin, we show that all AITC is stored as sinigrin in the powder and that sinigrin is the predominant if not the only ITC-generating glucosinolate. Sinigrin is highly stable in MSP-1. However, significant myrosinase activity is also present, which catalyzes full conversion of sinigrin to AITC when the powder is mixed in water *in vitro* and after it is ingested *in vivo*. Moreover, the matrix of MSP-1 did not interfere with AITC absorption and urinary excretion. Thus, MSP-1 is a highly attractive delivery vehicle for AITC. While sinigrin itself is not bioactive, MSP-1 inhibits the growth of bladder cancer cells *in vitro*, which was associated with strong induction of apoptosis and G_2/M phase arrest. It also significantly inhibits bladder cancer growth and completely blocks muscle invasion *in vivo*. The anticancer effect of MSP-1 was accompanied by modulation of multiple well-known cancer therapeutic targets, including activation of caspase-3, cleavage of PARP and downregulation of both cyclin B1 and VEGF. Comparison of dose response *in vivo* between inhibition of tumor growth and muscle invasion by MSP-1 and its modulation of the above-mentioned proteins suggests that downregulation of VEGF may be critical for MSP-1 to inhibit tumor invasion into the muscle. Taken together, MSP-1 is a highly promising substance for prevention and treatment of bladder cancer. Further preclinical and clinical evaluation of this substance is warranted.

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NIPM Item #3

REGULATIONS FOR NURSERY INSPECTIONS AND NURSERY STOCK CERTIFICATES

Any person producing and/or selling nursery stock is required to comply with the standard of cleanliness and other requirements of this article. California Nursery Stock Certificates may be issued by the Commissioner or the Department for use on shipments of nursery stock, including seed, by any shipper complying with the requirements of this article. Shipments bearing valid certificates may move to counties without being held for inspection at destination. Specific County requirements and quarantine regulations may restrict movement of some kinds of nursery stock from certain areas.

3060. Nursery and Seed Inspection.

Definitions. The following definitions, in addition to those stated in Subarticle 10 Sections 25-49 and 5001-5008 of the Food and Agricultural Code, apply to this article.

(a) “Qualified nursery and seed inspector” means a representative of the County Agricultural Commissioner who:

> (1) Possesses a State certificate of qualification in Nursery and Seed Regulation and Plant Quarantine and Pest Detection, or
>
> (2) A member of a Commissioner's staff possessing required experience and education, studying for State certification, and working under the supervision of a qualified nursery and seed inspector.

(b) “Noxious weed seed” is as defined in Subarticle 10 Section 52256 of the Food and Agricultural Code.

(c) “Turf” means field cultivated turfgrass sod consisting of grass varieties, or blends of grass varieties, and Dichondra for use in residential and commercial landscapes.

Note: Authority cited for Sections 3060 through 3060.5: Sections 407, 6901-6904, 6961-6970, and 52333, Food and Agricultural Code.
Reference: Sections 5821-5827, 6901-6904, 6961, 6965, 6968, and 52333, Food and Agricultural Code.

3060.1. Inspection of Nurseries.

(a) Each Commissioner shall inspect nursery stock, other than seed, which is being grown or sold as often as is required to assure compliance with pest cleanliness.

Note: Authority cited: Sections 407, 6502, 6901, and 6902, Food and Agricultural Code.
Reference: Sections 6502, 6901-6904, and 6961, Food and Agricultural Code.

3060.2. Standard of Cleanliness.

Any person selling, handling or growing nursery stock, other than seed, produced, held, or offered for sale, shall maintain the following standard of cleanliness of nursery stock in his possession.

(a) All nursery stock shall be kept commercially clean in respect to established pests of general distribution. Commercially clean shall mean that pests are under effective control, are present only to a light degree, and that only a few of the plants in any lot or block of nursery stock or on the premises show any infestation or infection, and of these none show more than a few individuals of any insect, animal or weed pests or more than a few individual infestations of any plant disease.

(b) All nursery stock shall be kept free of:

(1) Pests of limited distribution including pests of major economic importance which are widely, but not generally distributed, except as provided in section 3060.4 (a)(1)(C) below; and

(2) Pests not known to be established in the State. Included in the meaning of this paragraph is that turf shall be kept free of noxious weeds.

(c) Where the Commissioner or Secretary determines that a history of weed pest problems exists, turf shall be grown on soil treated with methyl bromide in accordance with treatment and handling procedures approved by the Department. Weed pests established in and around the growing grounds shall be controlled to a point that they are not likely to infest the growing turf. In addition, the Commissioner or Secretary may require clean fallowing, trap cropping, or other cultural controls as may be necessary to assure the pest cleanliness of the turf when shipped.

Note: Authority cited: Sections 407 and 6901, Food and Agricultural Code.
Reference: Sections 6901-6904, Food and Agricultural Code.

3060.3. Plants That Are Pests.

A plant that is a pest does not meet the standards of cleanliness contained in Section 3060.2 and may not be produced, held or offered for sale as nursery stock.

(a) All plants defined as a noxious weed under Title 3, California Code of Regulations, Section 4500, are a pest plant.

Note: Authority cited: Sections 407, 5322 and 6901, Food and Agricultural Code.
Reference: Sections 403, 407, 5322 and 6901, Food and Agricultural Code.

3060.4. Enforcement.

(a) The Commissioner shall keep records of inspections made and of orders issued to enforce this article.

(1) Inspections of the growing grounds, storage yards, and sales places of nursery stock, other than seed, shall be performed by a qualified nursery and seed inspector who shall make a sufficient examination of all varieties and all lots or blocks of nursery stock and all established plants, appliances, and other things thereon as may be necessary to determine compliance with this article.

(A) The inspection shall be substantiated by the filing with the Commissioner of a report of such inspection showing the names of pests and infested or infected host plants and their location in the nursery, and the disposition of all blocks of stock found infested or infected to a degree greater than the minimum requirements of this article.

(B) The Commissioner or the Director may require by a written order that any nursery stock found infested or infected with a pest shall be isolated or safely delimited in a manner approved by the Commissioner or the Director, and may specify that the pest shall be controlled or eradicated, or that the infested or infected plants shall be disposed of in a manner satisfactory to the Commissioner or the Director within a reasonable specified length of time.

(C) The Secretary may permit nursery stock which may be infested with pests, subject to quarantine regulations or Section 3060.2(b)(1), to be sold for planting or for resale for planting, within the area under quarantine or area infested with a specified pest, where the nursery stock is offered for sale, provided that:

1. A quarantine or other pest shall not be eligible for movement as described in this section unless it has been so designated herein by the Secretary (the Secretary has designated Homalodisca vitripennis, glassy-winged sharpshooter, as eligible for movement as described in this section); and

2. The nursery stock is moved between points within the area under quarantine or within the area infested with the specified pest and involves no movement outside thereof; and

3. The pest is not under eradication in the quarantine or infested area; and

4. Movement of the nursery stock is not specifically prohibited by the quarantine regulation or local ordinance; and

5. The nursery stock is commercially clean.

(D) Nursery stock which does not meet the standards of cleanliness prescribed in Subarticle 10 Section 3060.2 shall not be sold except as provided in (C) above or under a written agreement between the buyer and seller which discloses the following:

1. Failure to comply with the standards of cleanliness;

2. Affirmation of the buyer's agreement to purchase the stock on an “as is” basis; and

3. Written agreement by the destination department of agriculture the stock for planting by the buyer or resale at retail for non-farm use in the destination county or state.

(2) Inspection of seed for the purpose of issuing nursery stock certificates shall be in accordance with the methods prescribed for official sampling and examination of seed for noxious weed seed under the California Seed Law. Sampling and examination shall be performed by a qualified nursery and seed inspector or by a seed botanist of the Department. The inspection is to be substantiated by the filing with the Commissioner of a report by the inspector for each six-month period showing that the shipper has complied with this article.

(b) Notification.

(1) When an application to sell nursery stock is received from a person not previously licensed at the location involved, the Director shall notify the Commissioner allowing 15 days for the Commissioner to make whatever recommendations he deems appropriate regarding the issuance of the license.

(2) Upon receipt of notice from the Commissioner that a licensee or applicant for a license has failed to comply with the standard of cleanliness set forth herein or has failed to comply with a written order issued by the Commissioner, the Director will take appropriate action against the application or license involved.

(3) The Commissioner shall notify the Director of the issuance, suspension, or revocation of nursery stock certificates to any shipper.

(4) The Commissioner shall notify the Director when a shipment of nursery stock from within the State is found infested or infected with a pest in violation of the standard of cleanliness herein established.

(c) Suspension. The use of nursery stock certificates shall be suspended, as to all nursery stock, other than seed, or as to infested or infected and exposed host plants:

(1) Upon finding in the nursery any new pest, determined by the Director to be of serious importance to agriculture or pending such determination, until isolation, clean up, or eradication in a manner approved by the Director is complied with; or

(2) Upon finding in the nursery any pest that is required by this article to be kept under intensive control until either

(A) All hosts or carriers likely to be infested or infected are prohibited movement by a written hold order or

(B) Adequate precautions or intensive control measures have been applied which will assure the pest cleanliness of hosts or carriers when shipped; or

(3) Upon finding in the nursery an infestation or infection or any established pest of general distribution in a degree greater than commercially clean, until such infestation or infection is controlled to the satisfaction of the Commissioner or Director.

(d) Revocation. Nursery stock certificates shall be revoked:

(1) As to nursery stock, other than seed, upon repeated findings within the preceding twelve months that the shipper has failed to maintain the standard of cleanliness herein prescribed;

(2) As to nursery stock, including seed, upon finding that the shipper has violated any law or regulation pertaining to nursery stock, including seed, or the requirements of this article.

(e) Refusal. Issuance of nursery stock certificates may be refused if during the preceding twelve months:

(1) An authorization of the shipper to use nursery stock certificates has been revoked; or

(2) The shipper has failed or refused to comply with any law or regulation pertaining to nursery stock or pests; or

(3) Conditions in or around the nursery have exposed nursery stock to infestation by pests, including weed seeds, and for which adequate precautions or control measures cannot be or have not been applied.

Note: Authority cited: Sections 407, 6901 and 6961, Food and Agricultural Code.
Reference: Sections 6901-6904 and 6961, Food and Agricultural Code.

3060.5. Certificates.

(a) Form of Certificates.

(1) Nursery stock certificates shall be in essentially the following form:

CALIFORNIA NURSERY STOCK CERTIFICATE FOR INTERSTATE AND INTRASTATE SHIPMENTS

No.:____________________

This plant material or nursery or premises from which this shipment was made has been inspected and found free from especially injurious plant pests and disease symptoms

THIS SHIPMENT NEED NOT BE HELD FOR INSPECTION IN CALIFORNIA

Issued by:______________________________
and California Department of Food and Agriculture
1220 N Street, Sacramento, CA 95814
66-119 (2-97)

(2) Certificates shall bear an identification number issued or Authorized by the Commissioner.

(3) A Commissioner may either issue certificates or authorize a shipper to reproduce a facsimile of the nursery stock certificate in the form and manner approved by the Commissioner. Such certificates shall be reproduced in a legible and conspicuous manner.

(b) Use of Certificates.

(1) No nursery stock certificate shall be used:

(A) On any shipment of nursery stock, other than seed, any portion of which was grown by a nursery not eligible to use nursery stock certificates, unless such portion of the shipment is duly inspected and found to meet the minimum requirements for pests set forth herein;

(B) By any person other than the shipper to whom issued;

(C) On any shipment of nursery stock for which movement from certain areas is restricted by specific California quarantine regulations unless accompanied by the required quarantine certificate or permit;

(D) On any shipment into any county where such movement is restricted by a requirement of the Commissioner of the county of destination pursuant to Subarticle 10 Sections 6505 and 6961 of the Food and Agricultural Code;

(E) On any shipment of plants not in compliance with the minimum standards of cleanliness prescribed in this article.

(2) The Commissioner may affix a nursery stock certificate on a noncommercial shipment of plants which the Commissioner inspects and finds to meet the requirements of this article.

Note: Authority cited: Sections 407, 6901-6904, 6961, and 52333, Food and Agricultural Code. Reference: Sections 6901-6904, 6961, and 52333, Food and Agricultural Code.

3060.6. Requirements of Shippers of Nursery Stock Removed from Established Plantings.

(a) Nursery stock also includes trees, shrubs, or other plants which are removed from established farm or landscape plantings or from their native habitat for planting, propagation or ornamentation. A license to sell nursery stock is required for sale of such nursery stock.

(b) Such nursery stock shall not be moved unless accompanied by a shipping permit issued by the Commissioner, or a nursery stock certificate if all conditions for its issuance have been met. Nursery stock found not in compliance with the standard of cleanliness, or for which an adequate inspection cannot be made, or on a property infested with a pest described in paragraph (b) of Subarticle 10 Section 3060.2, shall be placed under hold order until brought into compliance or adequately inspected, unless movement of such stock is permitted only under restriction with the knowledge of the Commissioner at point of destination and the person receiving the stock. The Commissioner shall notify the Director when finding nursery stock has been moved in violation of this article.

Note: Authority cited: Sections 407, 6901-6904, 6961, and 52333, Food and Agricultural Code. Reference: Sections 5701, 6721, 6901-6904, 6961, 6965, and 6968, and 52333, Food and Agricultural Code.

Regulations for California Certified Strawberry Plants

The following sections are extracts from the California Code of Regulations. They have been prepared by the Nursery, Seed, and Cotton Program, Pest Exclusion Branch, California Department of Food and Agriculture. These extracts are provided for information purposes only. For the official text, the user should consult the California Code of Regulations published by Barclays Law Publishers.

California Code of Regulations
Title 3. Food and Agriculture
Division 4. Plant Industry
Chapter 3. Entomology and Plant Quarantine
Subchapter 2. Nursery Stock
Article 9. Regulations for California Certified Strawberry Plants

3049. Disclaimer of Warranties and Financial Responsibility.

The provisions of Section 3069 shall apply to this article.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Sections 5821 and 5822, Food and Agricultural Code.

3049.1. Definitions.

(a) "Virus infected" means infected by a virus or having symptoms or behavior characteristic of a virus disease listed in Section 3049.3(a)(1)(B).

(b) "Index" means to test for virus infection by making a graft with tissue from the plant to be tested to an indicator plant or by other methods approved by the director. Information regarding such other methods may be obtained from the Department's Pest Exclusion Unit.

(c) "Off-type" means any strawberry plant different from the variety stated on the application for approval or certification.

(d) "Nuclear stock" means strawberry plants which were originally indexed and their progeny, which have been regularly reindexed and protected continuously from virus infection by Federal or State agencies.

(e) "Foundation stock" means strawberry plants that are first year propagation from plants that have been approved on the basis of annual indexing.

(f) "Registered stock" means strawberry plants that are first year propagation from foundation stock.

(g) "Certified stock" means strawberry plants that are first year propagation from registered stock.

(h) "Foundation block" means a planting of strawberry plants for the production of foundation stock.

(i) "Increase block" means a planting of strawberry plants for the production of registered stock.

(j) "Certified block" means a planting of strawberry plants for the production of certified stock.

(k) "Nuclear meristem stock" means strawberry plants which were propagated with meristematic tissue from a plant which had heat therapy and were originally index-tested and found free of known viruses by Federal or State agencies.

(l) "Clone" means a progeny of an individual strawberry plant which was produced asexually.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Sections 5821 and 5822, Food and Agricultural Code.

3049.2. General Provisions.

Participation in this program is voluntary and may be withdrawn at the option of the applicant.

Registration, certification, approvals and supervision shall be conducted by the Department.

(a) Except as otherwise provided, certification is based solely on visual inspections of sample plants from each planting.

(b) Responsibility of Applicant. The applicant shall be responsible for:

(1) The selection of the location and the proper maintenance of a planting being grown under the provisions of this article.

(2) Maintaining the identity of all nursery stock entered in the program.

(3) Notifying the Department at least one week in advance of planting and harvesting as to when they will commence and notifying the Department of the location where the plants will be trimmed and stored.

(4) Maintaining the identity of each lot of plants in the participant's possession and placing the required information on each certification tag furnished by the Department.

(c) Location of Plantings.

(1) General. Each planting location shall be in an area which is isolated from plantings for strawberry fruit production to prevent spread of infectious pests or virus diseases. Any land planted shall have been free of strawberry plants for the previous year, except when treated for soil-borne pests in an approved manner under the supervision of the Department. Any planting may be enclosed by an approved insect-proof screenhouse, and when this is done the distance from other plantings or plants as specified in this article to minimize spread of virus diseases shall not be required providing varieties, plant blocks and plants to be indexed are kept separate in an approved manner to maintain plant identity. Native strawberry plants presenting no evidence of virus infection are excluded from required isolation distances for planting.

(2) Foundation blocks shall be located at least one mile from any other strawberry plants except those in foundation blocks determined to be of equal pest status. Foundation blocks shall be clone planted. Each plant in a foundation block selected for testing by indexing together with its runners shall be kept separate from all other plants in the block by an open space of 12 inches or by an artificial barrier to maintain plant identity.

(3) Increase blocks shall be located at least one mile from any other strawberry plants to prevent spread of virus disease. When danger of possible spread of virus diseases from one block to another does not appear to exist the one mile distance may be waived and increase blocks and certified blocks may be planted adjacent to each other.

(4) Certified blocks shall be located at least one mile from any strawberry plants maintained for the purpose of commercial fruit production and not less than 500 feet from any other strawberry plants not entered in the program to maintain plant identity and prevent spread of virus diseases.

(d) Maintenance of Plantings.

(1) Any planting entered in this program shall be kept in a thrifty growing condition and pests shall be kept under intensive control. To maintain plant identity, each variety shall be planted at

least 12 feet from any other variety and runners shall not be permitted to cross over an open space of 12 inches maintained between such varieties. If a screenhouse is used for any planting, it shall be maintained in such condition that insect vectors cannot enter. Plants of each variety shall be harvested separately from all other varieties and continuously kept separate. In a foundation block each plant that has been tested by indexing, together with its runner plants, shall be harvested separately. Plants must be harvested after one growing season in order to be eligible for approval or certification.

(2) Any plant found to be off-type shall together with its runner plants be removed immediately from any planting.

(e) Eligibility for Planting.

(1) In a foundation block: To be acceptable for planting in a foundation block, a plant shall be (A) nuclear meristem stock; (B) nuclear stock; (C) foundation stock; or (D) registered stock, certified stock, or plants determined to have an equivalent known history providing each plant in the foundation block is to be tested by indexing or by other approved methods for the detection of virus infection. More than one variety may be planted in a foundation block providing they are of equal pest status.

(2) In an increase block: To be acceptable for planting in an increase block a plant shall be first year propagation from foundation stock produced in a foundation block.

(3) In a certified block: To be acceptable for planting in a certified block a plant shall be first year propagation from registered stock produced in an increase block or first year propagation from foundation stock produced in a foundation block.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Sections 5821 and 5822, Food and Agricultural Code.

3049.3. Inspection and Testing Procedures; Refusal or Cancellation of Approval or Certification.

(a) To Determine Eligibility for Approval or Certification:

(1) Inspection and testing procedures prescribed in this article shall be conducted by the Department in a manner and at times determined as suitable. The applicant will be notified of the findings of pests. Any plant in any planting may be tested by indexing or by other approved methods for the detection of virus infection. Testing procedures shall be conducted in a greenhouse.

(A) Each clone in a foundation block and a minimum of 3 percent of the plants planted therein shall be tested one or more times annually by indexing or by other approved methods for the detection of virus infection. All plants in a foundation block shall be tested in such a manner if the source of any of the propagating stock is registered stock or certified stock or has an equivalent known history.

(B) Foundation stock shall be tested for the specific virus diseases using the specific indicator plants listed below:

Indicator Plant	**Disease**
Fragaria virginiana selection	Mottle, Veinbanding, Leafroll, Witchesbroom
and/or	
Fragaria (alpine) vesca selection	Crinkle, Pallidosis, Necrotic shock, Tomato ringspot, Latent ••C", Feather leaf, Mild yellow edge, Pseudo mild yellow edge

(C) At least two visual inspections shall be made of each planting prior to harvest and in addition plants shall be inspected at digging time. Inspection for the detection of harmful nematode pests may be made using laboratory methods and is required for approval as foundation stock or as registered stock.

(b) Refusal or Cancellation of Approval or Certification:

(1) Failure to comply with the requirements of this article shall be cause for refusal or cancellation of approval of plants as “foundation stock,” “registered stock,” or certification as “California certified strawberry plants.”

(2) The certification or approval as foundation stock or as registered stock of a plant or plants in part or all of a planting shall be refused or cancelled when it is determined that:

(A) The plant is off-type;

(B) The plant, clone or planting is virus infected;

(C) The pest cleanliness requirements for nursery stock in Section 3060.2 of the nursery inspection regulations have not been met.

Reactions to indicator plants caused by unknown factors may also be cause to disqualify the specific foundation selection tested.

(3) Any plant or clone found virus infected or suspected of virus infection may be required to be rogued or may be refused for further propagation. Any planting in which a plant is found to be virus infected may be refused, if it is determined that spread of the virus may have occurred, except: (A) when the total of virus infected plants in a certified block does not exceed 0.5 percent; (B) aster yellows disease is found in a planting and it is determined that the infected plants are readily identifiable and can be removed under the supervision of the Department.

(4) Any planting in which off-type plants are found to exceed 0.2 percent shall be refused, except that in a planting which has been clone planted, the off-type plants may be removed under the supervision of the Department if it is determined that all of the off-type plants are readily identifiable and can be removed.

(5) Each plant together with all its runner plants shall constitute one unit, and the results of either field inspections or index tests or both may be used, as a basis for calculating percentages.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Sections 5821 and 5822, Food and Agricultural Code.

3049.4. Approval and Certification.

(a) Approval: The Department will approve as “foundation stock” or “registered stock” plants that have met the requirements of this article, and will, for their identification, authorize the use of official tags for “foundation stock” or “registered stock.”

(b) Certification: The Department will certify plants that have met the requirements of this article for certification and will authorize for the identification of such stock, the use of official certification tags.

(c) Identity: Any person selling “foundation stock,” “registered stock” or “California certified strawberry plants” is responsible for maintaining identity of the nursery stock bearing an official tag while the stock is in possession of the seller and for such nursery stock meeting the requirements of this article.

(d) Accountability: Persons issued tags authorized by this article shall account for sock produced and sold and tags used and shall record such production, sale, and use on an inventory sheet provided by the Department. The inventory sheet shall be submitted to the Department annually.

(e) Certification by a Second Party: Strawberry plants produced by a participant in the certification program in accordance with the provisions of this article may be eligible for certification by a second party provided:

(1) The second party submits an application, pays the required fees, and signs the agreement required by Section 3069;

(2) The certification tags are stamped by the second party with his name and address and the block number of the producer of the plants.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Sections 5821 and 5822, Food and Agricultural Code.

3049.5. Application and Fees.

(a) Application. The applicant shall furnish information requested and shall give consent to the Department to take plants from any planting for inspection or testing purposes. An application shall be submitted for the acceptance of any planting and for subsequent inspections, approvals or certification and may be refused unless made sufficiently in advance of the time of planting to permit the Department to establish the origin of the stock, determine the history of the location and supervise any treatment that may be required.

(b) Fees. The Department shall establish a schedule of fees for services provided in this article. Fees are payable in advance of the work to be done and are for the sole purpose of defraying expenses incurred in the inspection, approval and certification services provided and are not to obtain any right or privilege. Fees shall be submitted at the time of application, except that fees may be paid after planting upon prior approval by the Department.

(1) No fees shall be charged the University of California or the United States Department of Agriculture for registration or for the inspection and testing of plants provided there shall be no expense to the Department other than for observation of the inspection and testing required in the article, and for the keeping of records. When the procedures prescribed in the article are conducted by the University of California, or by the United States Department of Agriculture, they shall not be less than provided in this article, and the Department shall be notified each year of the plants to be entered or continued in the program.

(2) With respect to all of the fees, the Department may require a larger fee on any or all plantings entered when, because of conditions and total acreages entered, the fees will not cover the cost of the service. This may apply to districts or the entire State.

(c) Refunds. Fees paid for services that are not rendered shall be refunded to the applicant.

Note: Authority cited: Sections 407 and 5823, Food and Agricultural Code.
Reference: Section 5822, Food and Agricultural Code.

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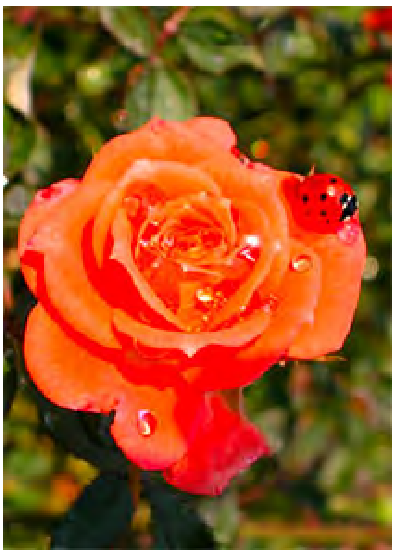
PEST EXCLUSION BRANCH (PE) - Nursery, Seed and Cotton Program

NURSERY PROGRAM

The mission of the Nursery Program is to prevent the introduction and spread of agricultural pests through nursery stock and to protect agriculture and the consumer against economic losses resulting from the sale of inferior, defective or pest-infested nursery stock. In 2008, the total value of nursery and floral products produced was $4 billion, an increase of 2.5% over the previous year. The cost to run the nursery program for the 2007-08 fiscal year was $2.3 million. Nursery program activities are funded entirely from revenue received in the form of license and acreage fees and registration and certification fees. Revenue received in FY 2007-08 totaling $2.2 million was used to offset the costs of all program activities.

NURSERY REGULATORY AND INSPECTION ACTIVITIES



Financed primarily through license and acreage fees, nursery regulatory activities are conducted by the county agricultural commissioners and their staff and are an integral part of the State's agricultural pest prevention system. Nursery inspection and regulatory activities have prevented numerous pests from being disseminated throughout agricultural and suburban communities by preventing and/or eradicating pests at the nursery level. The quality of nursery stock has improved as a direct result of the regulation of nursery stock.

In 2008, there were 11,867 licensed sales locations, with 891 production (growing grounds) locations. Since 2007, the budget for nursery inspection contracts has been set at $600,000. In addition, any disencumbered funds from the previous year's nursery contracts are added to the next annual allocation. The amount added to the allocation for this year was $51,962, resulting in a total of $651,962 to be divided among the counties for the 2008-09 fiscal year contracts.

REGISTRATION AND CERTIFICATION SERVICES FOR PLANT MATERIALS

CDFA Code authorizes the Department to establish plant registration and certification (R & C) programs (see Table 1). These programs are implemented by the California Code of Regulations and enforced by the Secretary. In 2008, CDFA staff performed over 830 inspections for R & C, including site approvals, growing season inspections, sampling for various purposes and harvest inspections. In addition to making inspections to meet R & C requirements, all nursery stock must also meet the general nursery regulatory standards for pest cleanliness.

R & C programs are voluntary programs developed at the request of various segments of the agricultural industry for the exclusion of specific plant pests that are not readily detected by ordinary inspections. These programs are the result of close-working relationships between the University of California, USDA and the Department, with the added support of the agricultural industry. Specific viruses, viroids, fungi, soil-borne pathogens and nematodes are the targeted pests of the nursery stock registration and certification programs.

The criteria for establishing these programs are: 1) an established need; 2) sufficient by available technical information; 3) an established source of "clean" propagating stock; and 4) developed to assure the continued pest cleanliness of the stock.

California presently has nine "clean stock" (registration and certification) programs available for use by various segments of the agricultural industry.

Table 1. Registration and Certification Programs

PROGRAMS	PLANTING TYPE (BLOCKS)	TARGET PEST	TESTING OR TREATMENT REQUIRED
Avocado Certification	Certified	Phytophthora cinnamomi	Hot water treatment of seed and soil fumigation
Avocado Registration	Registered (tree) Increase	Sun Blotch Viroid	Foundation tree index-testing for sun blotch viroid (UC)
Citrus Registration and Certification	Foundation, Scion, & Seed (tree) Increase Certified (nursery row)	Citrange stunt, concave gum, exocortis, psorosis, tatterleaf, seedling yellow tristeza, tristeza vein enation and yellow vein viruses.	Index-testing (UC) + individual tree identification index-testing (CDFA)
Deciduous Fruit and Nut Tree Registration and Certification	Foundation, Mother, Scion, & Seed (tree) Increase Seed (bed) Certified (nursery row)	Various virus diseases, including prunus ringspot virus (PRSV) and prune dwarf virus (PDV)	Index-testing (UC) + index-testing for PRSV and PDV (CDFA) (Participant)
Grapevine Registration and Certification	Foundation & Increase (vineyard) Certified (nursery row)	Fanleaf, fleck, asteriod mosaic, leafroll, yellow vein (Tomato ring-spot) and corky bark virus	Nematode sampling (CDFA)
Seed Garlic Certification	Increase Certified	Stem and bulb nematode (Ditylenchus dipsaci) and white rot	Nematode sampling (CDFA)
Pome Fruit Tree Registration and Certification	Foundation & Mother (tree) Increase & Stool Certified (nursery row)	Various virus diseases	Index-testing (USDA & UC) fumigation
Strawberry Nursery Stock Certification	Foundation Increase Certified	Mottle, vein-banding, crinkle, mild yellow-edge, necrotic shock, pallidosis, tomato ring-spot, witches-broom, pseudo mild yellow-edge, latent "c," leafroll and feather-leaf viruses.	Index-testing (UC & CDFA) Nematode sampling
Nematode Certification	Nursery plantings produced for on-farm planting	Various plant-parasitic nematodes	Nematode sampling, fumigation supervision and commodity treatment (CAC & CDFA)

The primary tools developed for maintaining pest cleanliness of the stock in these programs are: 1) biological indexing (use of indicator plants which exhibit symptoms of virus or virus-like diseases) and enzyme-linked immunosorbent assay (ELISA); 2) laboratory techniques for the detection of nematodes; 3) eradication treatments (thermotherapy, fumigation and hot water treatments); and 4) visual field inspections targeted to specific life cycles of the pests and plants.

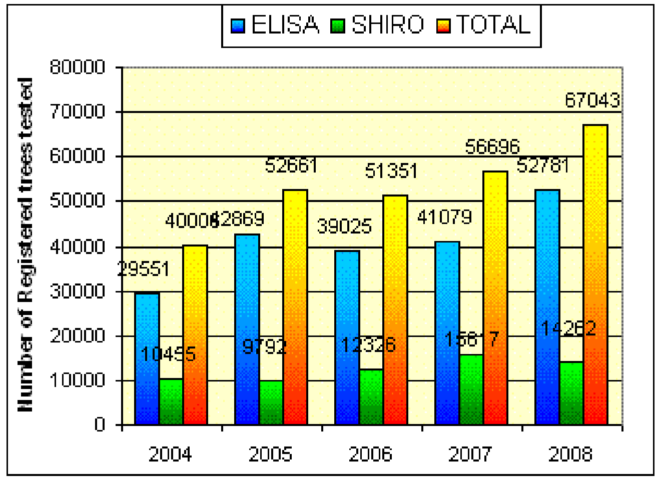
The costs of services to carry out these programs are borne by the participants. Fees are charged for the inspections, testing and treatments. In addition, the Fruit Tree, Nut Tree and Grapevine Improvement Advisory Board (IAB) provides partial to full funding for annual testing and inspections required by the Deciduous Fruit and Nut Tree R & C, Pome R & C and Grapevine R & C programs.

Avocado Registration and Certification Program

This program provides the registration of avocado rootstock and Scion wood sources when inspected and tested for sun blotch virus. The Avocado Certification Program provides the certification of avocado nursery stock when grown under specific guidelines and inspected for freedom from Phytophthora cinnamomi, avocado root rot. Currently, one nursery is participating in the registration program and three nurseries are participating in the certification program.

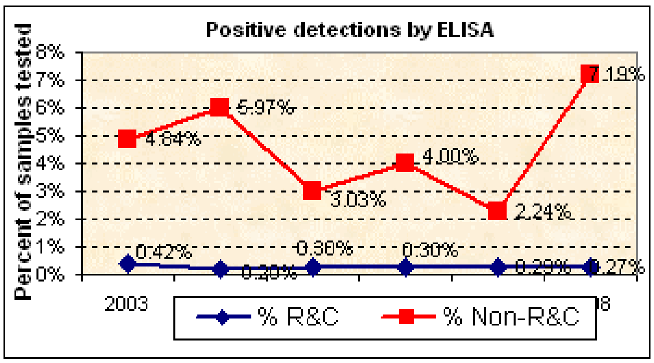
Deciduous Fruit Tree and Nut Tree Registration and Certification Program

In the R & C program for deciduous fruit and nut trees, all trees in a Registered Mother Block, Registered Scion Block and Registered Seed Block are tested annually for viruses. Testing may be done by biological indexing using Shirofugen cherry as an indicator plant or by ELISA, an approved laboratory technique. Trees are tested for Prunus Necrotic Ring-Spot virus and Prune Dwarf Virus by biological indexing at least once every five years and by ELISA for these viruses and others in the other four years. Tested trees may be used as a source of certified propagative material in the year following testing.

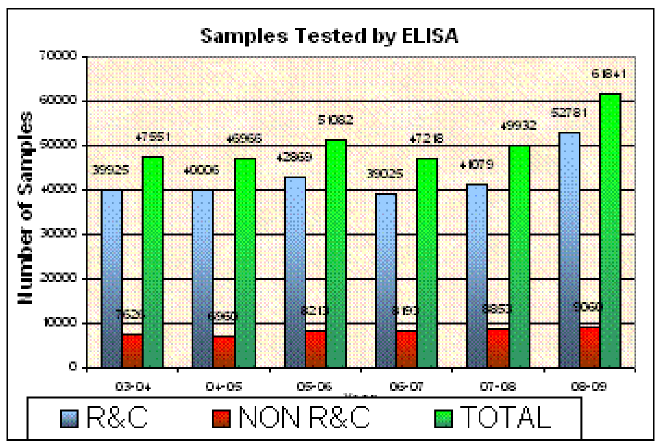


In 2008, 19 nurseries participated in the program. The total number of registered trees tested was 67,043 (52,781 by ELISA and 14,262 by Shirofugen indexing), compared to an average of 50,179 per year for the 2004-2007 growing seasons.

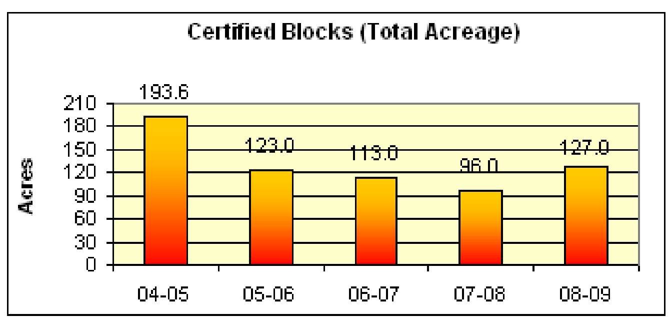
The total number of trees tested using the ELISA technique was 61,841 (52,781 registered trees and 9,060 service samples). The service samples are obtained from non-registered trees and tested as a service to the industry.



Of the 61,841 trees tested by ELISA, 794 (1.3%) were found positive for viruses. Only 142 (0.27%) of the registered samples tested positive for viruses, while 652 (7.19%) of the service samples tested positive for viruses.

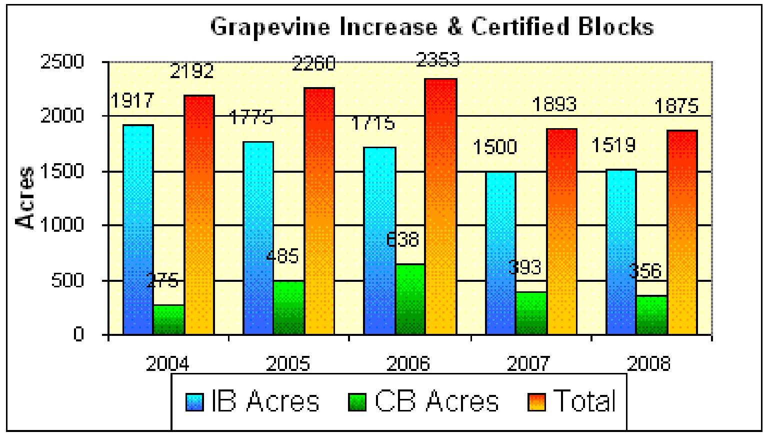


Of the samples taken from registered trees, 122 (0.85%) tested positive for viruses using the Shirofugen cherry biological indexing technique. Certified nursery planting acreage totaled 127 acres in 2008, compared to an average of 131.4 acres over the previous four years.



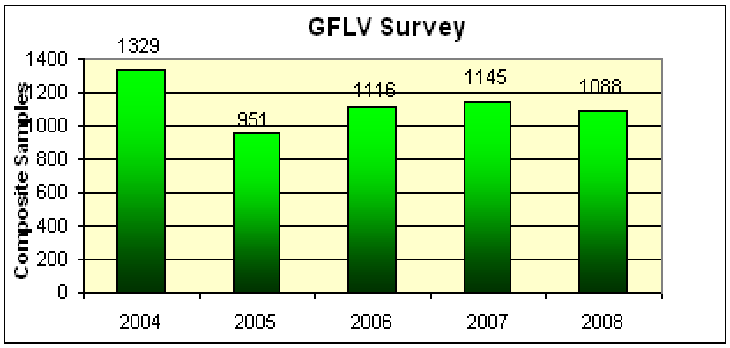
Grapevine Registration and Certification Program

Thirty four nurseries participated in the program in 2008. Grapevine Increase Block plantings totaled over 1,519 acres, an increase of 9 acres (1.26%) over the previous year. Grapevine certified blocks (nursery plantings) totaled 356 acres and four greenhouse blocks, a 37 acres (9.41%) decrease from the previous year's 393 acres.

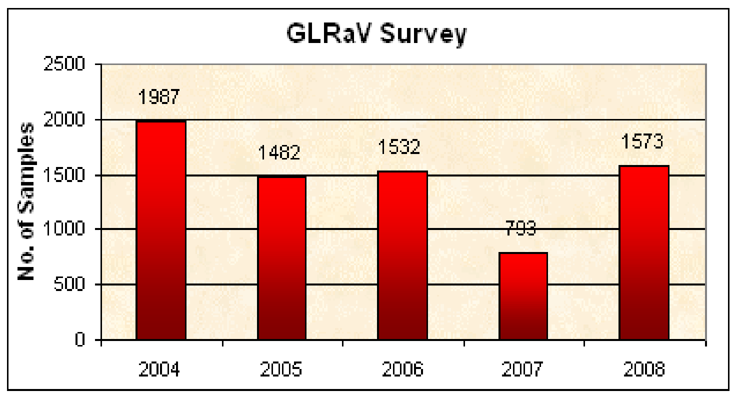


CDFA collected and tested 1,088 composite samples (each is a composite sample from 5 vines) for grapevine fan leaf virus (GFLV). Plants were selected randomly for testing. However, if plants exhibiting typical GFLV symptoms were seen, those plants were also included in the survey. Of the total samples tested, none were positive for GFLV.

In 2008, 1,573 vines were sampled and tested for grapevine-leafroll-associated viruses (GLRaV). In total, 56 samples tested positive (3.56%) for leafroll virus - 3 in comparison to 48 out of 793 samples (6.0%) that tested positive in 2007.



In 2004, the Fruit Tree, Nut Tree and Grapevine Improvement Advisory Board (IAB) began supporting trapping for vine mealybug (VMB). The shipment of grapevine nursery stock within California became a problem as some northern counties were contemplating ordinances. Traps were deployed in certified (both Increase and Certified Blocks) and in non-certified plantings. Eight counties assisted CDFA in trapping by doing non-certified plantings and, in some cases, plantings in CDFA's Grapevine R & C Program. There were 1,570 acres and three greenhouses of non-certified plantings. This represented 85 traps deployed in late May and checked over the following six months. There were 1,750 acres and four greenhouses of plantings entered in the R & C programs for 90 traps deployed. Male VMBs were found at twelve locations due to association with nearby vineyards. There was no positive find for female VMB following intense inspections.



Citrus Registration and Certification Program

The Citrus R & C program provides for the testing of propagative source trees for tristeza to meet the requirements of the Citrus Tristeza Quarantine. Other diseases of importance being tested as part of the registration and certification program include exocortis and psorosis. In 2008, 30 citrus nurseries participated in the program. A total of 2,370 citrus seed and Scion source trees were sampled and tested for tristeza and other viroids, a decrease of of 1,327 trees from 2007.

Strawberry Nursery Stock Registration and Certification Program

Nine nurseries participated in the Strawberry Nursery Stock R & C Program in 2008. The strawberry program differs from other registration programs in that foundation stock is maintained by nurserymen in their isolated plantings rather than by the Foundation Plant Services of the University. Strawberry plants in foundation plantings are index-tested annually using Fragaria vesca and Fragaria virginiana strawberry indicator hosts for the following viruses: mottle, vein-banding, crinkle, mild yellow-edge, necrotic shock, pallidosis, tomato ringspot, witches broom, pseudo mild yellow-edge, latent C, leafroll and featherleaf. CDFA nursery staff index-tested 6,088

foundation plants at the Department's greenhouse facility in Sacramento; an 8% increase was seen over the previous year. Thirty nine plants that were indexed tested positive for viruses and were rejected from the program. CDFA staff visually inspected over 898 acres of registered and certified strawberry nursery stock for the presence of virus diseases and other pests and collected and processed nematode samples.

Pome Fruit Registration and Certification Program

The Pome Fruit Tree R & C Program provides for the registration of rootstock and Scion sources for the propagation of certified nursery stock when inspected and tested for virus diseases and other important pests. Three nurseries are currently participating in the program. In 2008, CDFA staff inspected and registered over 3,246 trees as propagative source trees. Over five acres of nursery plantings were inspected and approved for sale as certified nursery stock.

Seed Garlic Registration and Certification Program

The Seed Garlic Certification Program provides for the registration of seed garlic for the propagation of certified nursery stock when found free from stem and bulb nematode, Ditylenchus dipsaci, and when inspected and found free of white rot fungus, Sclerotium cepivorum. One nursery participated in 2008. A total of 68 acres were inspected and registered, a decrease of 229 acres (22.9%) from 2007.

FRUIT TREE, NUT TREE AND GRAPEVINE IMPROVEMENT ADVISORY BOARD

The Fruit Tree, Nut Tree and Grapevine Improvement Advisory Board (IAB) element of the Nursery Program administers an industry-requested assessment (Food and Agricultural Code, Section 6981) on the production of nursery plants such as deciduous pome and stone fruit trees, nut trees and grapevines. The mission of the IAB is to improve the quality and pest-free fruit tree, nut tree and grapevine nursery stock offered for sale. The assessment is used to fund research on plant pests, breeding varieties that are resistant to plant pests, plant pest diagnostics, varietal identification and disease elimination. The University of California Foundation Plant Services (FPS) provides support and serves as a source of clean planting stock. The FPS carries out activities related to the development of planting materials for pome and stone fruit trees, nut trees and grapevines, and subvents the costs to carry out Department programs concerning the registration and certification of pome and stone fruit trees, nut trees and grapevines. The assessment is collected with the nursery license renewal. In 2008, the total assessment collected on gross sales of fruit trees, nut trees and grapevines was $1,315,202, a 14.3% increase over the collection of $1,150,000 in 2007.

In 2008, the IAB approved funding for 12 research proposals totaling $ 271,537, funding of FPS in the amount of $524,827 and payment to the Nursery Program to subvent R & C activities in the amount of $297,750. The total budget approved was $1,139,114. As revenues still remain low relative to the past five years, the IAB recommended a lower level of funding for research, the FPS and the CDFA R & C program.

SEED SERVICES

The Seed Services Program administers seed law enforcement throughout California and is funded entirely through an annual assessment on the value of agricultural, vegetable, and grass seed sold in California. Staff of the Seed Services Program assist county agricultural commissioners in all seed-related enforcement activities and evaluate compliance at the local and statewide level. CDFA associate agricultural biologists conduct seed sampling and coordinate enforcement activities of assigned counties, as well as investigate seed complaints. The Seed Services Program interacts with agricultural departments in other states, the United States Department of Agriculture (USDA), industry representatives, and the California Crop Improvement Association, which is the authorized seed certifying agency for California. An advisory board of nine seed industry members and two public members provides oversight of the Seed Services Program for the Department.

The value of seed sold for planting in California exceeded $482 million in FY 2007-08, an all-time high. The total number of firms registered to sell seed in California increased from 416 in FY 2006-07 to 504 firms in FY 2007-08.

The expenditures by the Seed Services Program for FY 2007-08 were $1,336,141. Significant program expenditures were the funding of the Department's Seed Laboratory ($410,208), the Seed Biotechnology Center at the University of California, Davis ($200,000) and the Seed Subvention contracts paid to agricultural commissioners ($120,000). In order to cover these expenses, the Seed Advisory Board recommended an assessment rate of $0.32 per hundred dollars of gross sales in California during the reporting period. The funds generated by the current assessment rate are adequate to cover expenditures in 2008. Recent enforcement efforts by county agricultural commissioners and Seed Services Program staff have resulted in increased collections from firms previously not reporting seed sales in California.

The subvention to county agricultural commissioners for the enforcement of the California Seed Law remains at $120,000, provided annually by Food and Agricultural Code, Section 52323. This voluntary program uses annual performance measures to establish the funding for each county. The commissioners are required to maintain an 85% compliance level of all seed offered for sale or labeled in their respective counties. In FY 2007-08, county personnel evaluated 5,000 labels of seed offered for sale. In addition, 3,374 unique labels of seed lots from out-of-state seed suppliers were inspected by county staff for compliance to the California Seed Law.

The Seed Services Program also administers an alternative dispute resolution process for farmers and labelers in dispute over seed performance. Participation in conciliation and mediation is a mandatory prerequisite before pursuing legal remedy in court for seed complaints. In FY 2007-08, the Seed Services Program received eight inquiries about possible seed complaints. One formal seed complaint was filed and is currently being investigated with the assistance of the Federal Seed Regulatory Testing Branch at USDA.

CDFA agricultural biologists stationed throughout the State continue to perform compliance monitoring through the annual collection of over 600 seed samples. The samples are analyzed by the CDFA Seed Laboratory in Sacramento. A recent analysis of the laboratory results revealed that greater than 94% of the samples were in compliance with the California Seed Law, while only 6% were found to be out of compliance. Of the non-compliant samples, about 78% were misrepresenting germination by a slight amount, while the remaining 23% had slight misrepresentations of the percent purity.

The Seed Services Program is continuing its efforts to prevent violations of the Plant Variety Protection Act (PVPA) and Certified Seed standards. New inspection forms have assisted inspectors in the identification of PVPA violations and Certified Seed lots. The Seed Services Program will work with the Federal Seed Regulatory and Testing Branch, and the California Crop Improvement Association to implement additional measures that ensure seed sold in California is of the best quality and the maximum benefit to growers.

QUALITY COTTON PROGRAM

The Quality Cotton Program has the primary responsibility of enforcing the San Joaquin Valley Cotton District (District) laws and regulations. The District consists of all counties in the San Joaquin Valley. The 28-member San Joaquin Valley Cotton

Board (Board), composed of cotton growers, cotton industry representatives and public members administers the program. Cotton growers and industry members are elected to the Board by their peers. One of the Board's major duties is to establish quality standards for San Joaquin Valley Acala and Pima varieties. To accomplish this, the Board has an extensive multi-location cotton variety-testing program. The Board meets at least four times a year to review the progress of its variety-testing program and determines which new varieties meet or exceed existing quality standards and are superior in some meaningful respect, such as improved yield or resistance to disease. The exceptional quality and yield of the cottons in the District are a reflection of the Board's sound decisions. Throughout the year, board committees examine major cotton issues in order to make well-researched recommendations to the full Board.

In 2008, CDFA's Pink Bollworm Program reported another huge drop in total cotton acreage in the San Joaquin Valley. Pima acreage was 152,190, down almost 42% and Upland acreage (including Acala) was 105,380, down 38% from 2007. The total cotton acreage was 257,570, a drop of 171,155 acres. Most experts predict that the acreage will drop at least 75,000 acres in 2009.

Due to this continued pattern of declining acreage in the San Joaquin Valley and the resulting funding issues, the Board is considering ways to further reduce operations of the program.

In 2008, the assessment rates for the San Joaquin Valley Cotton District were set by the Department's Secretary, upon recommendation from the Board, at $6.00 per hundredweight of undelinted cotton seed sold or planted within the District. The assessments are the primary source of income for the Board's testing program and the enforcement of the San Joaquin Valley Quality Cotton District Laws and Regulations.

wedge image PE - PHYTOSANITARY EXPORT CERTIFICATION | wedge image PEST DETECTION / EMERGENCY PROJECTS

NIPM Item #7

APPROVED TREATMENT AND HANDLING PROCEDURES TO ENSURE AGAINST NEMATODE PEST INFESTATION OF NURSERY STOCK

In accordance with the Regulations for the Nursery Stock Nematode Control Program, California Code of Regulations (CCR) Sections 3055 to 3055.6 and Section 3640, the California Department of Food and Agriculture (CDFA) hereby specifies soil treatment and handling procedures which, when verified and documented, are approved to ensure nematode cleanliness of both field and container grown nursery stock. These procedures are not aimed at control of soil pathogens, weeds, or other soil-borne pests. The "Report of Supervision of Nursery Fumigation and Other Approvals" (form 64-054) is to be used to document compliance with these approved procedures. This report must be submitted monthly along with the "Nursery Stock Nematode Certification Report Form" (form 64-086).

Section 3640, CCR, makes it mandatory that nursery stock for farm planting be commercially clean with respect to economically important nematodes. Exempted from this requirement are garlic, mint, onion, and seed potato nursery stock and any nursery stock grown only in non-soil media.

FIELD GROWN STOCK

Soil preparation is the most important factor affecting the success of fumigation. The County Agricultural Commissioner or the CDFA shall verify to ensure that all of the following requirements for pre-treatment preparation, treatment, and post-treatment handling of soils have been met.

1. Trash Removal. Trash (crowns, stems, roots) from the previous crop must be removed as completely as possible, to eliminate or minimize plant residues that may harbor nematodes during the waiting period. After trash removal, the land should be disked thoroughly to reduce the size of the remaining plant tissues and to hasten its decomposition. The waiting period may not begin until trash removal has been completed. Soil treatment cannot be approved if trash removal has not been completed.

2. Waiting Period. After trash removal and before soil treatment, a crop-free, clean-fallow waiting period shall be observed as follows:

    a. Not less than 24 months following removal of an orchard or vineyard that has been in place for more than one year;

    b. Not less than 9 months following removal of a woody nursery crop which has been in place for more than one year;

    c. Not less than 6 months following removal of a nematode host crop (including seedling or June-budded fruit trees, grapevine or strawberry nursery stock, cotton, or alfalfa) which has been in place for less than one year.

    d. No waiting period is required after the removal of an annual vegetable crop, provided that the vegetable crop residue is removed prior to soil treatment.

3. Pre-Treatment Soil Preparation. The following pre-treatment soil preparations may be verified up to three days (72 hours) prior to soil treatment:

   a. Deep tillage - The soil should be plowed or subsoiled 2 to 3 feet by plow or chisels to break up hardpan or plowsole.

   b. Soil moisture - Soil moisture should be adequate to prepare soil to seed bed tilth. Large fluctuations in temperature or rainfall may require re-verification.

   c. Cultivation - The top 6 to 8 inches of soil should be cultivated to break up clods and render the soil in seed bed condition.

4. Treatment. The treatment shall be verified and documented by the County Agricultural Commissioner or the CDFA to ensure compliance with the required treatment and handling procedures.

   a. Application - All applications of pesticides must be made in strict compliance with all applicable laws and regulations.

   b. Material and Schedule of Dosages - The rate per acre for the fumigant used shall not be less than the minimum prescribed by the CDFA.

   c. Soil temperature - May be verified up to three days (72 hours) prior to start of soil treatment. Soil temperature measured at the depth of injection shall be between 40˚F and 80˚F. If the soil temperature is between 81˚F and 85˚F, the dosage of methyl bromide should be increased by 5 percent over the minimum specified by the CDFA **(provided this will not exceed maximum allowable application rates)**.

   d. Clay soils - There are no recommended treatments for soils which contain more than 30% clay. Clay soil treatments cannot be approved.

   e. Approval duration - Treatments made and approved in accordance with these procedures shall be good for 18 months from the date of treatment to the date of planting provided that the treated area is clean-fallowed and otherwise not exposed to nematode reinfestation.

5. Application Methods.

   a. Dual Application (applies to methyl bromide and Telone II™). Apply the first treatment by injecting the chemical at a minimum depth of 20 inches (51 cm) at a chisel spacing of 30 inches (76 cm) or less; wait at least 7 days (methyl bromide) or at least 14 days (Telone II™), then turn under the top 12 inches (31 cm) of soil with a plow. (Alternatively, soil may be flipped just prior to the second treatment provided the appropriate waiting period has passed.) Apply the second treatment in the same manner as the first application. Seal the surface with a ring roller immediately after each application. Wait at least 14 days following the second treatment before disturbing the soil. (Methyl bromide fumigations must abide by and made in accordance with CCR, Section 6450.3)

   b. Tarping (applies to methyl bromide and Telone II™). Tarping refers to the post-application covering of soil with plastic tarpaulins. For methyl bromide applications, tarpaulins must be approved by the California Department of Pesticide Regulations (see CCR, Section 6450 (e) for details). Two methods may be used to accomplish a complete coverage of the production area. "Solid tarping" accomplishes coverage in one step using equipment which glues together the overlapping edges of the plastic strips. The outside edges are buried at least 6 inches (15 cm) deep. "Strip tarping" is used in a two-step soil treatment. Soil strips approximately 12 feet (3.7 meters) wide are fumigated and mechanically covered with a plastic tarpaulin, all edges of which should be buried at least 6 inches (15 cm). These strips are alternated with untreated, untarped strips about 10 feet (2.8 meters) wide. After 48 hours the tarps are removed from the treated soil strips and treatment and tarping are applied to the alternate and previously untreated strips.

Methyl bromide and methyl bromide/chloropicrin formulations (mixtures) should be injected at a depth of 10 to 15 inches (25 to 38 cm) on a 12 inch (31 cm) spacing, with the total dosage applied at one time. Tarps should be applied simultaneously with treatment or immediately following. The outside edges of the tarp should be buried at least 6 inches deep. The tarp shall not be cut until a minimum of 5 days (120 hours) following application and tarp removal shall not begin sooner than 24 hours after tarp cutting (see CCR, Section 6450.3 (3) for details). [1]

CONTAINER, FLAT, AND FRAME GROWN NURSERY STOCK

1. Used containers (flats, frames, pots) not cleaned to the satisfaction of the CDFA or the County Agricultural Commissioner, recycled potting mixes or planting materials, and soil, shall be treated prior to planting.

2. Approved Treatments.

   a. Aerated steam in a closed chamber until temperature of all soil reaches at least 140˚ F that is maintained for a minimum of 30 minutes.

   b. Steam in a closed chamber or under a tarpaulin until temperature of all soil reaches 180˚ F.

   c. Fumigation with methyl bromide at the rate of 2 pounds per 100 cubic feet under a plastic tarpaulin or in a gas-tight chamber for 24 hours. Soil temperature should not be below 50˚ F when treated. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS**.

   d. Solarization of soil using a “double-tent” setup until temperature of all soil reaches a minimum of 158˚F (70˚C) that is maintained for at least 30 continuous minutes, <u>or a minimum of 140˚F (60˚C) that is maintained for at least 60 continuous minutes</u>. Soil must be either in polyethylene planting bags or in piles not more than 12 inches high. Soil in piles must be placed on a layer of polyethylene film, concrete pad, or other material, which will not allow reinfestation of soil, and covered by a sheet of clear polyethylene film. An additional layer of clear polyethylene film must be suspended over the first layer to create a still air chamber over the soil to be treated. Soil moisture content must be near field capacity. Soil temperature at the bottom center of the pile or bag must be monitored and recorded to ensure that the minimum temperature of 158˚F (70˚C) for 30 minutes, or <u>140˚F (60˚C) for 60 minutes</u> is achieved.

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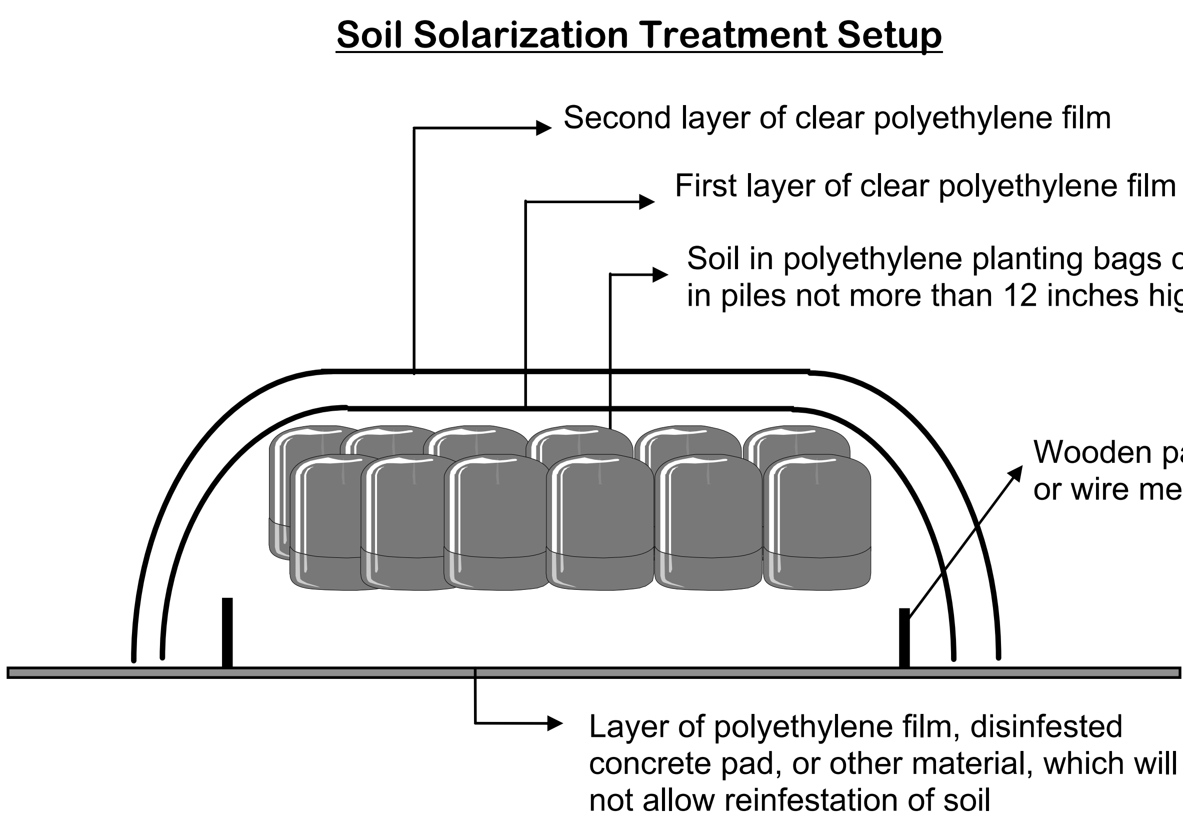
[1] Pesticide regulations may require a longer period. If so, pesticide regulations or permit conditions will govern the time the tarp must remain in place. Coordination with county pesticide use enforcement officials is necessary.

3. Following treatment, the soil and containers shall be protected from reinfestation by nematodes.



PLANTING STOCK AND POST-HARVEST HANDLING

1. Planting Stock. Any rooted nursery stock for planting in approved treated soil must meet the Nursery Stock Nematode Certification regulations. If not, it must be sampled and found free of economically important plant-parasitic nematodes or the approved soil treatment will be nullified. (CCR 3055.1)

2. Post-Harvest. Nursery stock produced in accordance with approved procedures shall be stored, healed-in, or calloused in media, beds or storage areas approved by the Department or County Agricultural Commissioner. Treatment as necessary to protect against nematode infestation may be required.

NON-SOIL MEDIA

Non-Soil Media. These growing media include bark, cinders, gravel, peat moss, perlite, rock wool and vermiculite. Other media may be considered non-soil but will be identified on a case-by-case basis..

Schedule A. Treatments in Schedule A shall be required for all properties:

(a) Known to be infested with plant-parasitic nematodes, or not previously treated in accordance with approved treatment and handling procedures and for which the nematode pest status is unknown; and

(b) Upon which the previously grown crop was a nematode host.

This dosage schedule is for nematode control only. It is not recommended for control of soil-borne pathogens such as *Phytophthora* spp. Treatment recommendations for the latter should be obtained from local Farm Advisor(s). **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

		DOSAGE PER ACRE (HECTARE)[1]	
Material	Application Method	Sandy Soils	Clay Loam Soils
Methyl bromide[2] (actual CH_3BR)	Tarped[4]	300 lbs (336 kg)	400 lbs (448 kg)
Methyl Bromide (actual CH_3BR)	Dual Application[3] Untarped	Application #1 300 lbs (336 kg)	Application #1 400 lbs (448 kg)
		Application #2 150 lbs (168 kg)	Application #2 150 lbs (168 kg)

1 One pound per acre equals 1.12 kg per hectare.

2 Formulations (mixtures) of methyl bromide and chloropicrin may be used provided that the actual amount of methyl bromide is not less than the amounts shown in this schedule.

3 Two treatments are required; see item 5.a. on page 2. Applications must be made in accordance with label and permit requirements.

4 See item 5.b. on page 2.

Schedule B. Protection for a 26-month crop and June-budded trees. Treatments in schedule B are approved only for properties on which at least two field-grown crops have been produced, for each of which:

(a) An approved soil treatment to ensure against nematode infestation has been applied, or no nematode infestation has been detected using laboratory methods; and

(b) The property has not been exposed to nematode infestation during the interval between crops.

This dosage schedule is for nematode control only. It is not recommended for control of soil-borne pathogens such as *Phytophthora* spp. Treatment recommendations for the latter should be obtained from local Farm Advisor(s). **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

		DOSAGE PER ACRE (HECTARE)[1]	
Material	Application Method	Sandy Soils	Clay Loam Soils
Methyl bromide[2] (actual CH_3BR)	Tarped[4]	300 lbs (336 kg)	400 lbs (448 kg)
Methyl Bromide (actual CH_3BR)	Dual Application[3] Untarped	Application #1 300 lbs (336 kg)	Application #1 400 lbs (448 kg)
		Application #2 150 lbs (168 kg)	Application #2 150 lbs (168 kg)
Telone II™	Dual Application[3] Untarped	Application #1 313 lbs (351 kg) a.i.	None
		Application #2 142 lbs (159 kg) a.i.	

1 One pound per acre equals 1.12 kg per hectare; one gallon per acre equals 9.35 liters per hectare.
2 Formulations (mixtures) of methyl bromide and chloropicrin may be used provided that the actual amount of methyl bromide is not less than the amounts shown in this schedule.
3 Two treatments are required; see item 5.a. on page 2. Applications must be made in accordance with label and permit requirements.
4 See item 5.b. on page 2.

Schedule C, Chart I. Treatments in schedule C may be approved for use in growing shallow-rooted nursery plants such as strawberry, June-budded fruit trees, or vegetable plants, which ordinarily are in place for only one season's growth.

This dosage schedule is for nematode control only. It is not recommended for control of soil-borne pathogens such as *Phytophthora* spp. Treatment recommendations for the latter should be obtained from local Farm Advisor(s). **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

		DOSAGE PER ACRE (HECTARE)[1]	
Material	Application Method	Sandy Soils	Clay Loam Soils
Methyl bromide[2] (actual CH_3BR)	Tarped[4]	200 lbs (224 kg)	300 lbs (448 kg)
Methyl Bromide (actual CH_3BR)	Dual Application[3] Untarped	Application #1 300 lbs (336 kg)	Application #1 400 lbs (448 kg)
		Application #2 150 lbs (168 kg)	Application #2 150 lbs (168 kg)
Telone II™	Dual Application[3] Untarped	Application #1 285 lbs (319 kg). a.i.	None
		Application #2 142 lbs (159 kg) a.i.	

1 One pound per acre equals 1.12 kg per hectare; one gallon per acre equals 9.35 liters per hectare.
2 Formulations (mixtures) of methyl bromide and chloropicrin may be used provided that the actual amount of methyl bromide is not less than the amounts shown in this schedule.
3 Two treatments are required; see item 5.a. on page 2. Applications must be made in accordance with label and permit requirements.
4 See item 5.b. on page 2.

Schedule C, Chart II. Protection for a 26-month crop. Telone II™, single application, tarped.

This dosage schedule is for nematode control only. It is not recommended for control of soil-borne pathogens such as *Phytophthora* spp. Treatment recommendations for the latter should be obtained from local Farm Advisor(s). **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

		DOSAGE PER ACRE (HECTARE)[1]	
Material	Application Method	Sandy Soils	Clay Loam Soils
Telone II™	Single Application Tarped	332 lbs (372 kg) a.i.	None

[1] One pound per acre equals 1.12 kg per hectare; one gallon per acre equals 9.35 liters per hectare. Applications must be made in accordance with label and permit requirements.

Schedule D. Schedule D treatments (Charts I - VII) may be used instead of schedules A, B, or C at lower dosages where appropriate soil moistures, soil textures, and soil temperatures allow. If soil conditions are such that Schedule D cannot be used, the appropriate schedule A, B or C must be used.

Procedure for Schedule D:

A = Tare Weight
B = Fresh Soil Weight (including Tare Weight)
C = Dried Soil Weight (including Tare Weight)
D = Difference Between Fresh and Dried Soil Weights
E = Dried Soil Weight Minus Tare Weight
F = % Soil Moisture

Procedure for Selection of Treatment Rates and Methods

1. Use local experience or a soils map to locate the site where the highest soil moisture is expected. The wettest site is usually of finer texture or has a hard pan layer within the soil profile.
2. Take soil samples at each 12-inch increment down to 5 feet. Sub-samples are not necessary. Determine, by the feel method, the soil texture at each depth and record on the data sheet. Place each soil sample (pint each) into a moisture-tight container. Seal and label according to site and depth.
3. Record the soil temperature at the 12 inch depth only. Allow 5 minutes for equilibration before recording on the data sheet.
4. Now select an area of the field which you estimate is representative of the nursery site relative to field moisture. Repeat steps 2 and 3 above and record data.
5. At the location of the scales and microwave oven, mix each soil sample and place 100 to 150 grams of soil into each weighing dish. Weigh immediately, record weights and place into oven with lids off. About 10 soil samples can be dried simultaneously. An open vessel of water should not be placed in the oven when using a modern microwave oven. The oven should be run at high range (650 watts) for 15 minutes.
6. Oven-dried samples will absorb moisture from the atmosphere if they are allowed to sit in the open. Therefore, weigh each dish quickly and record the dry weights of the samples.
7. Calculate the difference in weight between the fresh and dried soil (B minus C = D).
8. Subtract the tare weight from the dried soil weight (C minus A = E).
9. Divide the difference in weight by the dried soil weight to compute the % of soil moisture (D/E) x 100 = F).
10. You now have a record of soil texture, temperature, and moisture within the 5-foot soil profile. A fumigation is limited by the highest soil moisture. For example, if a soil profile has a silt layer at the 3 ft. depth, which exceeds the fumigation range on the fumigation charts, do not expect to kill nematodes below the 3 ft. depth. In every case except one, the treatment must be delivered to the 5 ft. depth. The one possible exception is a soil which has a hardpan layer which does not contain old roots. In such a case, control to the hardpan layer is all that is necessary. However, many hardpan layers have fracture points which may contain old roots.
11. Additional soil samples may be helpful if there is disparity across the field due to high moisture areas or if the field is quite large (more than 20 acres). Additional sampling is at the discretion of the inspector.

Schedule D, Chart I. Protection for a 26-month crop. Methyl bromide with a high barrier tarp such as HBF-1. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25˚C				10 to 20˚C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	200 lbs. a.i					
3 to 8%		200 lbs. a.i				
4 to 10%			200 lbs. a.i			
10 to 12%			300 lbs. a.i			
6 to 14%				300 lbs. a.i		
14 to 18%				400 lbs. a.i		
8 to 12%					300 lbs. a.i	
12 to 18%					350 lbs. a.i	
18 to 22%					400 lbs. a.i	
15 to 22%						400 lbs. a.i
22 to 35%						

TOO DRY

TOO WET

- Numbers indicate the pounds per acre of methyl bromide. Highest soil moisture percent in the top five feet of soil shall be considered.

<u>Schedule D, Chart II</u>. Protection for a 26-month crop. Telone II™, soil flipped at 10 to 12" depth after 14 to 30 days and retreated with Telone II™. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25°C		10 to 25°C		15 to 20°C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	285/190 lbs. a.i					
3 to 6%		285/190 lbs. a.i				
6 to 8%						
4 to 7%			285/190 lbs. a.i			
7 to 10%						
10 to 12%						
6 to 14%						
14 to 18%						
8 to 12%						
12 to 18%						
18 to 22%						
15 to 22%						

TOO DRY

TOO WET

- Numbers indicate pounds of actual ingredient of Telone II™ (94% <u>or</u> 97.5% 1,3-dichloropropene) to apply per acre at a minimum depth of 16 inches and a chisel spacing of 30 inches (76 cm) or less. Second application 14 to 30 days later at the lower dosage. Treatment followed by ring roller or compaction device. Highest soil moisture percent in the top five feet of soil shall be considered.

Schedule D, Chart III. Protection for a 26-month crop. Telone II™, not flipped, followed within 7 to 21 days (on or after 7th day but not later than the 21st day) with 20 gallons metam-sodium rototilled into the top 4 inches or sprinkled in with 3 inches of water. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25˚C		10 to 25˚C		15 to 20˚C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	332 lbs. a.i					
3 to 8%		332 lbs. a.i				
4 to 8%			332 lbs. a.i			
8 to 12%			475 lbs. a.i			
6 to 14%				475 lbs. a.i		
14 to 18%				570 lbs. a.i		
8 to 12%					570 lbs. a.i	
12 to 18%					665 lbs. a.i	
18 to 22%					760 lbs. a.i	
15 to 22%						760 lbs. a.i

TOO DRY

TOO WET

- Numbers indicate the pounds of actual ingredient of Telone II™ (94% <u>or</u> 97.5% 1,3-dichloropropene) to apply per acre at a minimum depth of 16 inches and a chisel spacing of 30 inches (76 cm) or less. Treatment followed by ring roller or compaction device. Highest soil moisture percent in the top five feet of soil shall be considered.

Schedule D, Chart IV. Protection for a 14-month crop. Methyl bromide, not tarped, followed by Nemacur (Fenamiphos) or Vydate (Oxamyl) at 1 pound active ingredient monthly through emitter tubing with 12 inch or less emitter spacings (drip irrigation). Do not use Chart IV if pencil-sized or larger viable roots are present in the top 12 inches of soil. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25°C				10 to 20°C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	200 lbs. a.i					
3 to 8%		200 lbs. a.i				
4 to 10%			200 lbs. a.i			
10 to 12%			300 lbs. a.i			
6 to 14%				300 lbs. a.i		
8 to 17%					300 lbs. a.i	
17 to 22%					400 lbs. a.i	
15 to 22%						400 lbs. a.i
22 to 35%						

TOO DRY

TOO WET

- Numbers indicate the pounds of methyl bromide applied per acre with shanks 18 or more inches deep. Highest soil moisture percent in the top five feet of soil shall be considered. It is not necessary to apply monthly applications of Nemacur and Vydate until the crop is planted and the soil temperature exceeds 14°C at a depth of 12 inches.

<u>Schedule D, Chart V</u>. Protection for a 14-month crop. Telone II™, not flipped, followed by 1 pound active ingredient Nemacur (Fenamiphos) or Vydate (Oxamyl) monthly through emitter tubing with 12 inch or less emitter spacings (drip irrigation). Do not use Chart V if pencil-sized or larger viable roots are present in the top 12 inches of soil. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25˚C		10 TO 25˚C		15 to 20˚C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	190 lbs. a.i					
3 to 8%		190 lbs. a.i				
4 to 9%			190 lbs. a.i			
9 to 12%			285 lbs. a.i			
6 to 9%				190 lbs. a.i		
9 to 14%				285 lbs. a.i		
14 to 18%						
8 to 12%					285 lbs. a.i	
12 to 18%						
18 to 22%						
15 to 35%						

TOO DRY

TOO WET

- Numbers indicate the pounds of actual ingredient of Telone II™ (94% <u>or</u> 97.5% 1,3-dichloropropene) to apply per acre at a minimum depth of 16 inches and a chisel spacing of 30 inches (76 cm) or less. Treatment followed by ring roller or compaction device. Highest soil moisture percent in the top five feet of soil shall be considered. It is not necessary to apply monthly applications of Nemacur and Vydate until the crop is planted and the soil temperature exceeds 14˚C at a depth of 12 inches.

<u>Schedule D, Chart VI</u>. Protection for a 14-month crop. Methyl bromide with shanks no more than 2.7 feet apart, not tarped, and only if the surface 8 inches of soil is in the "too dry" category. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25˚C		
Soil Moisture	Sand	Loamy Sand	Sandy Loam
2 to 6%	300 lbs. a.i		TOO DRY
3 to 8%	TOO WET	300 lbs. a.i	
4 to 10%			300 lbs. a.i

- Numbers indicate the pounds of methyl bromide applied per acre with shanks 18 or more inches deep. Highest soil moisture percent in the top five feet of soil shall be considered.

<u>Schedule D, Chart VII.</u> Protection for a 26-month crop. Telone II™, applied simultaneously with 20 gallons of metam-sodium rototilled into the top 4 inches or sprinkled in with 3 inches of water. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	5 to 25°C		10 to 25°C		15 to 20°C	
Soil Moisture	Sand	Loamy Sand	Sandy Loam	Loam	Clay Loam	Clay
2 to 6%	332 lbs. a.i					
3 to 8%		332 lbs. a.i				
4 to 8%			332 lbs. a.i			
8 to 12%			475 lbs. a.i			
6 to 14%				475 lbs. a.i		
14 to 18%				570 lbs. a.i		
8 to 12%					570 lbs. a.i	
12 to 18%					665 lbs. a.i	
18 to 22%					760 lbs. a.i	
15 to 22%						760 lbs. a.i

TOO WET

TOO DRY

- Numbers indicate the pounds of actual ingredient of Telone II™ (94% <u>or</u> 97.5% 1,3-dichloropropene) to apply per acre at a minimum depth of 16 inches and a chisel spacing of 30 inches (76 cm) or less. Treatment followed by ring roller or compaction device. Highest soil moisture percent in the top five feet of soil shall be considered.

***__Schedule E, Chart I.__ Protection for a 26-month crop. 235 lb/ac of methyl iodide, at 18-22” inch depth plus 150 lb/acre Chloropicrin, at 26-30” depth plus 110 lb/ac of metam-sodium. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
3 to 6%	235/150/110						
4 to 8%		235/150/110					
5 to 10%			235/150/110				
6 to 12%				235/150/110			
7 to 12%					235/150/110		
8 to 10%						235/150/110	
12 to 18%							
18 to 20%							

TOO WET

TOO DRY

#Pluot, plum prune and cherry scions can exhibit iodide toxicity in sandy soils.
__*Not currently registered for use in California.__**

*****<u>Schedule E, Chart II.</u>** Protection for a 26-month crop. *25 gpa Telone II™, at 18-22" inch depth plus 25 gpa Telone II™, at 26-30" depth plus 110 lb/ac of metam-sodium. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
5 to 10%							
6 to 12%							
10 to 15%						25/25/110	
12 to 15%					25/25/110		
15 to 19%							

*Must use Buessing winged shank in soil pre-ripped to 4 ft on 2 ft centers.
<u>*Not currently registered for use in California.</u>**

Schedule E, Chart III. Protection for a 26-month crop. *33.7 gpa Telone II™, at 18-22" plus 250 lb/ac Chloropicrin, at 26-30" depth plus 110 lb/ac of metam-sodium or tarp. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
5 to 10%							
6 to 12%							
10 to 15%					33.7/250/110		
12 to 15%						33.7/250/110	

*Must use Buessing winged shank in soil pre-ripped to 4 ft on 2 ft centers.

***__Schedule E, Chart IV.__ Protection for a 26-month crop. **235 lb/ac methyl iodide, at 18-22" plus 300 lb/ac Chloropicrin at 26-30" depth then 110 lb/ac of metam-sodium or tarp. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
5 to 10%							
6 to 12%							
10 to 15%							
12 to 15%					235/300/110		
15 to 19%						235/300/110	

** Must use Buessing winged shank in soil pre-ripped to 5 ft on 2 ft centers.
#Pluot, plum, prune and cherry scions can exhibit iodide toxicity in sandy soils.
__*Not currently registered for use in California.__**

***<u>**Schedule E, Chart V.**</u> Protection for a 26-month crop. **33.7 gpa Telone II™, at 18-22" plus 350 lb/ac Chloropicrin at 26-30" depth then 110 lb/ac of metam-sodium or tarp. **CHECK WITH COUNTY PESTICIDE USE ENFORCEMENT OFFICIALS PRIOR TO TREATMENT TO ENSURE COMPLIANCE WITH CURRENT STATE / COUNTY PESTICIDE USE RESTRICTIONS.**

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
5 to 10%							
6 to 12%							
10 to 15%							
12 to 15%							
15 to 19%						33.7/350/110	

** Must use Buessing winged shank in soil pre-repped to 5 ft on 2 ft centers.

***__Schedule E, Chart VI.__ Protection for a 26-month crop. **33.7 gpa Telone II™, at 18-22” plus 350 lb/ac Chloropicrin at 26-30” depth then 110 lb/ac of metam-sodium or tarp.

Temperature	**5 to 25 C°**		**10 to 25 C°**			**15 to 25 C°**	
Soil Moisture	Sand	Loamy Sand	Coarse Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
5 to 10%							
6 to 12%							
10 to 15%							
12 to 15%							
15 to 19%						33.7/33.7/110	

** Must use Buessing winged shank in soil pre-ripped to 5 ft on 2 ft centers.
***__**Not currently registered for use in California.**__

NURSERY SITE PRETREATMENT SOIL CONDITIONS DOCUMENTATION FORM

Site	Depth	Temperature	Texture	Tare Wt.	Fresh Soil Wt.	Dried Soil Wt.	Difference	Dried Wt. Minus Tare Wt.	% Soil Moisture
				A	B	C	D	E	F
Wettest		˚C							
	1'								
	2’								
	3’								
	4’								
	5'								
Driest		˚C							
	1’								
	2’								
	3’								
	4’								
	5’								

SOIL TEXTURAL CLASS CHARACTERISTICS

Notes:

(1) The Natural Resources Conservation Service (NRCS) of the USDA has characterized the soil textures of almost all nursery sites in California. Their soil texture analyses provide a definitive guide to prevailing soil textures. However, the NRCS surveys could not evaluate and characterize the small localized textural differences that may be present in every field. Therefore, soil textural descriptions are provided below to serve as an in-field aid for confirming NRCS determinations or for modifying them as appropriate.

(2) The following soil type characteristics may not all occur with any particular soil type because of differences in clay and organic matter content, exchangeable cation ratios, or amount of soluble salts present.

SAND OR LOAMY SAND

Dry: Loose, single grained; gritty; no or very weak clods.

Moist: Gritty; forms easily crumbled ball; does not ribbon.

Wet: Lacks stickiness, but may show faint clay staining (loamy sand especially). Individual grains can be both seen and felt under all moisture conditions.

SANDY LOAM

Individual grains can be seen and felt under nearly all conditions.

Dry: Clods break easily.

Moist: Moderately gritty to gritty; forms ball that stands careful handling; ribbons very poorly.

Wet: Definitely stains fingers; may have faint smoothness or stickiness, but grittiness dominates.

LOAM

This is the most difficult texture to place since characteristics of sand, silt, and clay are all present but none predominates. Suggests other textures.

Dry: Clods slightly difficult to break; somewhat gritty.

Moist: Forms firm ball; ribbons poorly; may show poor fingerprint.

Wet: Gritty; smooth, and sticky all at same time. Stains fingers.

SILT OR SILT LOAM

Grittiness of sand is well masked by other separates. (Texture most likely SILT LOAM, there are a few SILT soils.)

Dry: Clods moderately difficult to break and rupture suddenly to a floury powder that clings to fingers; shows fingerprint.

Moist: Has smooth, slick, velvety, or buttery feel; forms firm ball; may ribbon slightly before breaking; shows good fingerprint.

Wet: Smooth with some stickiness from clay; stains fingers.

SANDY CLAY LOAM

Dry: Clods break with some difficulty.

Moist: Forms firm ball that dries moderately hard; forms ½" ribbons that hardly sustain own weight; may show poor to good fingerprint.

Wet: Grittiness of sand and stickiness of clay about equal, masking smoothness of silt; stains fingers.

CLAY LOAM

Dry: Clods break with difficulty.

Moist: Forms firm ball that dries moderately hard; ribbons fairly well, but ribbons barely support own weight; shows fair to good fingerprint.
Wet: Moderately sticky with stickiness dominating over grittiness and smoothness; stains fingers.

<u>SILTY CLAY LOAM</u>

Resembles SILT LOAM but with more stickiness of clay.
Dry: Clods break with difficulty.
Moist: Shows a good fingerprint; forms a firm ball; drying moderately hard; ribbons ½"-1" that can be fairly thin.
Wet: Stains fingers; has sticky-smooth feel with little grittiness of sand.

<u>SANDY CLAY</u>

Dry: Often cloddy, clods broken only with extreme pressure.
Moist: Forms very firm ball, drying quite hard; shows fingerprint; squeezes to thin, long, somewhat gritty ribbon.
Wet: Stains fingers; clouds water; usually quite sticky and plastic, but has some grittiness present.

<u>SILTY CLAY</u>

Dry: Same as SANDY CLAY.
Moist: Forms very firm ball; becoming quite hard on drying; shows fingerprint; squeezes out to a thin, long, smooth ribbon.
Wet: Stains fingers, clouds water, stickiness dominates over smoothness, grittiness is virtually absent.

<u>CLAY</u>

Dry: Cloddy, clods often cannot be broken even with extreme pressure.
Moist: Forms firm, easily molded ball; drying very hard; squeezes out to a very thin ribbon 2-3" long.
Wet: Stains fingers, clouds water; usually very sticky with stickiness masking both smoothness and grittiness; wets slowly.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

December 28, 2015

Jonathan Janis
Regulatory Manager
Isagro USA, Inc.
430 David Drive, Suite 240
Morrisville, NC 27560

Subject: Non-PRIA (Pesticide Registration Improvement Act) Labeling Amendment – Acceptable Amendment to Make Editorial Changes and Amend Directions for Use
Product Name: IRF135
EPA Registration Number: 89285-2
Application Date: November 9, 2015
OPP Decision Number: 511072

Dear Mr. Janis:

The amended labeling referred to above, submitted in connection with registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, is acceptable.

This approval does not affect any terms or conditions that were previously imposed on this registration. You continue to be subject to existing terms or conditions on your registration and any deadlines connected with them.

A stamped copy of your labeling is enclosed for your records. This labeling supersedes all previously accepted labeling. You must submit one (1) copy of the final printed labeling before you release this product for shipment with the new labeling. In accordance with 40 CFR § 152.130(c), you may distribute or sell this product under the previously approved labeling for 18 months from the date of this letter. After 18 months, you may only distribute or sell this product if it bears this new revised labeling or subsequently approved labeling. “To distribute or sell” is defined under FIFRA section 2(gg) and its implementing regulation at 40 CFR § 152.3.

Should you wish to add/retain a reference to your company’s website on your label, then please be aware that the website becomes labeling under FIFRA and is subject to review by the U.S. Environmental Protection Agency (EPA). If the website is false or misleading, the product will be considered to be misbranded and sale or distribution of the product is unlawful under FIFRA section 12(a)(1)(E). 40 CFR § 156.10(a)(5) lists examples of statements the EPA may consider false or misleading. In addition, regardless of whether a website is referenced on your product’s label, claims made on the website may not substantially differ from those claims approved through the registration process. Therefore, should the EPA find or if it is brought to our attention that a website contains false or misleading statements or claims substantially differing from the EPA-approved registration, the website will be referred to the EPA's Office of Enforcement and Compliance Assurance.

Your release for shipment of this product constitutes acceptance of these terms. If these terms are not complied with, this registration will be subject to cancellation in accordance with FIFRA section 6.

If you have any questions, please contact Andrew Reighart of my team by phone at (703) 347-0469 or via email at reighart.andrew@epa.gov.

Sincerely,

For

Andrew C. Bryceland, Team Leader
Biochemical Pesticides Branch
Biopesticides and Pollution
Prevention Division (7511P)
Office of Pesticide Programs

Enclosure

ACCEPTED
12/28/2015
Under the Federal Insecticide, Fungicide and Rodenticide Act as amended, for the pesticide registered under EPA Reg. No. 89285-2

IRF135

(Alternate Brand Name: “DOMINUS®”**)**

Biopesticide for Agricultural Soil Treatment Use

A BROAD SPECTRUM PRE-PLANT SOIL BIOFUMIGANT FOR THE CONTROL OF CERTAIN SOIL BORNE FUNGI, NEMATODES, WEEDS and INSECTS

ACTIVE INGREDIENT:
Allyl isothiocyanate.. 96.3%
OTHER INGREDIENTS:.. 3.7%
TOTAL:.. 100.0%

Contains 8.19 lbs. active ingredient (allyl isothiocyanate) per gallon. This product weighs 8.5 lbs. per gallon.

KEEP OUT OF REACH OF CHILDREN
DANGER/PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle.
If you do not understand the label, find someone to explain it to you in detail.

FIRST AID	
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, and then continue rinsing. • Call a poison control center or physician for treatment advice.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15 minutes. • Call a poison control center of doctor for treatment advice.
If swallowed	• Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by the poison control center or doctor. • Do not give anything to an unconscious person. • Call a poison control center or physician for treatment advice.
If Inhaled	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. • Call a poison control center or doctor for further treatment advice
NOTE TO PHYSICIAN	
Probably mucosal damage may contraindicate the use of gastric lavage.	
HOTLINE NUMBER	
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For Chemical Emergency Spill Leak Fire Exposure or Accident Call CHEMTREC Day or Night Domestic North America 800-424-9300; International 703-527-3887 (collect calls accepted).	

EPA Reg. No. 89285-2 **EPA Est. No.** XXXXX-XXX-XXX

Net Contents:

(Batch Code/Lot No: *will be placed on the container*)
Manufactured for:
Isagro USA, Inc.
430 Davis Drive, Suite 240
Morrisville, NC 27560

Table of Contents

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

DANGER. Corrosive. Causes irreversible eye damage and skin burns. May be fatal if swallowed, absorbed through skin, or inhaled. Do not get in eyes, on skin or on clothing. Do not breathe vapor. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using tobacco or using the toilet. Remove and wash contaminated clothing before use.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

When performing activities with the potential for liquid contact all handlers (including applicators) must wear:

- Coveralls worn over long sleeve shirt and long pants
- Chemical-resistant footwear plus socks
- Chemical-resistant (such as nitrile or butyl) gloves
- Protective eyewear
- Respirator (see below)

Where liquid contact is a potential all handlers (including mixers, loaders and applicators) in addition to the above listed PPE must wear an air purifying respirator with an organic-vapor removing cartridge with pre-filter approved for pesticides (MSHA/NIOSH approval number prefix TC-23C), or a canister approved for pesticides (MSHA/NIOSH approval number prefix TC-14G), or a NIOSH approved respirator with an organic vapor (OV) cartridge or canister with any N, R, P or HE pre-filter.

When cleaning equipment, wear a chemical resistant apron.

Follow the manufacturer’s instructions for cleaning/maintaining PPE. If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry. Discard any clothing and or PPE that have been drenched or heavily contaminated with this product’s concentrate. Do not reuse clothing or PPE that has been drenched or heavily contaminated.

ENGINEERING CONTROLS

When handlers use closed systems or enclosed cabs in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides, the handler PPE requirements may be reduced or modified as specified in the WPS at 40 CFR Part 170.

USER SAFETY RECOMMENDATIONS

- Users should remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Users should remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

For terrestrial uses only. Do not apply directly to water or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment wash water or rinsate.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling. Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirement specific to your State or Tribe, consult the State/Tribal agency responsible for pesticide regulation.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification, and emergency assistance. The requirements in this box apply to uses of this product that are covered by the Worker Protection Standard.

No instruction elsewhere on this labeling relieve user from complying with the requirements of the WPS.

For the entry restricted period and notification requirements, see the *Entry Restricted Period and Notification* section of this labeling. PPE for entry during the Entry Restricted Period that is permitted by this labeling is listed in the Personal Protective Equipment (PPE) section of this labeling.

Assure that labels and SDS are on-site and readily available for employees to review.

ENTRY RESTRICTED PERIOD AND NOTIFICATION

Entry Restricted Period: Entry into the application block (including early entry that would otherwise be permitted under the WPS) by any person other than a correctly trained and PPE-equipped handler is PROHIBITED from the start of the application until 5 days after application is complete.

Notification: Notify workers of the application by warning them orally and by posting Biofumigant Treated Area signs. The sign must state:

1. "DANGER/PELIGRO"
2. "Areas under fumigation. DO NOT ENTER/NO ENTRE"
3. Allyl Isothiocyanate biofumigant in use
4. Date and time of fumigation
5. Date and time entry restricted period is over
6. IRF135 and (*name of co-application*)
7. Name, address and telephone of applicator in charge

Post the Biofumigant Treated Area sign instead of the WPS sign for this application, but follow all WPS requirements pertaining to location, legibility, text size and sign size (40 CFR § 170.120).

Post Biofumigant Treated Area signs defining the fumigation buffer zone, at all entrances to the application block no sooner than 24 hours prior to application and remain in place until at least 24 hours from the start of the application. Signs placed at the corners or on the edges of the treated area must remain posted for at least 5 days (120 hours) from the start of the application, e.g. for no less than the duration of the entry restricted period.

TERMS USED IN THIS LABELING

Application Block: The area within the perimeter of the fumigated portion of a field (including furrows, irrigation ditches, and roadways). The perimeter of the application block is the border that connects the outermost edges of the total area treated with the biofumigant product.

Start of the Application: The time at which the biofumigant is first delivered/dispensed into the soil in the application block.

Application is Complete: The time at which the biofumigant has stopped being delivered/dispensed into the soil and the soil has been sealed; drip lines have been purged (if applicable).

Entry Restricted Period: This period begins at the start of the application and expires depending on the application method and if tarps are used when the tarps are perforated and removed.

Entry into the application block during this period is only allowed for appropriately PPE-equipped handlers performing handling tasks. See the *Entry Restricted Period* and *Notification* sections of this label for additional information.

Buffer Zone: An area established around the perimeter of each application block. The buffer zone must extend outward from the edge of the application block perimeter equally in all directions.

Buffer Zone Period: Begins at the start of the application and lasts for a minimum of 24-hours after the application is complete. Non-handlers must be excluded from the buffer zone during the buffer zone period.

Roadway: The portion of a street or highway improved, designed or ordinarily used for vehicular travel, exclusive of the sidewalk or shoulder even if such a sidewalk or shoulder is used by persons riding bicycles. In the event that a highway includes two or more separated roadways, the term Roadway shall refer to any such roadway separately.

PRODUCT INFORMATION

Apply IRF135 as a preplant soil treatment only and as a part of an integrated pest management (IPM) program to aid in reducing or controlling the damaging effects of soil borne pests and diseases.

USE PRECAUTION

The product must only be used in a well-ventilated area. Do not use IRF135 if it cannot be applied according to the use patterns on the label.

APPLICATION WITH OTHER PRODUCTS

IRF135 may be applied with other pesticides or fertilizers by co-injection or co-application via the application methods outlined in this label. Consult specific product labels for additional information or restrictions concerning mix partner compatibility. Treat a small area first to ensure compatibility. Observe the most restrictive of the labeling limitations and precautions of all products used in mixtures.

SOIL TREATMENT APPLICATION METHODS

Apply as a preplant shank injection, broadcast/flat fume application, or raised bed application either shank injected into the row or in a raised bed or non-bedded strip injected through the drip irrigation system. Specific directions for each application method are provided below. Always follow label instructions to achieve optimum performance.

TARP REMOVAL, PERFORATION AND PLANTING INTERVAL

- Leave the soil undisturbed for at least 5 days after application is complete and prior to tarp cutting or perforation.
- For tarped applications, complete the cutting of the tarp or perforation/hole-punching 2 to 24 hours prior to tarp removal or planting to assist in IRF135 dissipation.
- Tarp cutters and removers shall wear long-sleeved shirt, long pants and gloves when removing tarps following application prior to planting.
- Cold, wet, or cold and wet soils can significantly decrease dissipation of IRF135 and can require a longer soil exposure period before soil conditions are favorable for planting of crop(s) following application of IRF135.
- After shank application is complete, wait 10 days under normal moisture conditions and at least 14 days when soils are wet/saturated prior to planting. After all other applications wait 10 days prior to planting.
- In addition to the 10-14 day waiting period, use of a Jar Seedling and/or Transplant tests may be needed to verify crop safety prior to planting the field to the next crop.

SOIL TREATMENT TIMING AND APPLICATION RATES

- **Number of applications per year:**

- IRF135 may be applied to soil as a pre-plant soil treatment prior to planting with subsequent applications allowable to the same soil within the same year provided the previous crop is completely harvested prior to application.
- IRF135 may be applied to soil as an end of season crop termination application with subsequent applications allowable to the same soil within the same year provided harvest of the crop is complete prior to crop termination application.

- **Open field:** Use 10 - 40 gallons of IRF135 /A (85 - 340 lb/A).
- **Greenhouse:** Use 10 - 40 gallons of IRF135 /A (85 - 340 lb/A) or 0.23 gal / 1,000ft^2 – 0.92 gal/1,000ft^2.
- **End of season crop termination in open field or greenhouse:** Use 3 – 20 gallons of IRF135 /A (26 – 170 lb/A) or 0.069 gal/1,000ft^2 to 0.45 gal/1,000ft$^{2.}$

TABLE 1. PRE-PLANT SOIL APPLICATION RATES

TREATMENT SITE	**BROADCAST RATES (GAL/A)***	**BROADCAST RATES (LBS PRODUCT/A)***
Field soils to be planted to: Asparagus, brassica vegetables (broccoli, cauliflower), cereal grains, cucurbit crops (cucumber, squash, melons), fruiting vegetables (e.g. eggplant, peppers, tomatoes), herbs and spices, leek, leafy vegetables (lettuce), legume vegetables, pineapples, root and tuber vegetables (carrot, garlic, onion, potato, sweet potato)	10 - 40	85 - 340
Field soils to be planted to: Strawberries, berries (cane fruit) , fruit and nut crops, citrus, pome fruit trees, stone fruit trees, tree nuts, tropical and subtropical fruits, vineyards	10 - 40	85 - 340
Nursery, Turf, and Ornamental Soils to be planted to: Turf, lawns, parks, golf greens, athletic fields, recreational turf area, ornamentals, floral crops, forest tree seedlings	10 - 40	85 - 340
Greenhouse soils to be planted to: Food and Non-food crops	10 - 40	85 - 340
Seed or Transplant beds to be planted to: Food crops and non-food crops	10 - 40	85 - 340
*Use the higher labeled rates for muck and heavy clay soils, as well as for those pests and or diseases such as cyst forming nematodes, *Macrophomina, Fusarium or Phytophthora* or hard coated weed seeds for example Malva, Clover or Nutsedge		

TABLE 2. END OF SEASON CROP TERMINATION TREATMENT RATES

TREATMENT SITE	BROADCAST RATES (GAL/A)	BROADCAST RATES (LBS PRODUCT/A)
Soils that were planted with the following crops: Asparagus, brassica vegetables (broccoli, cauliflower), cereal grains, cucurbit crops (cucumber, squash, melons), fruiting vegetables (e.g. eggplant, peppers, tomatoes), herbs and spices, leek, leafy vegetables (e.g. lettuce), legume vegetables, root and tuber vegetables (carrot, garlic, onion, potato, sweet potato), strawberries, berries (cane fruit)	3 - 20	25.5 – 170

APPLICATION SITE CONDITION DIRECTIONS

Soil temperature: Minimum of 60°F and maximum of 90°F at a typical application depth

Soil preparation (Pre-Plant Applications):

- Ensure the soil is well prepared and generally free at the surface of large clods. Large clods can prevent efficient soil sealing and reduce effectiveness of the product.
- Cultivate the soil to a minimum depth of 5-8" and/or equal to the desired treatment depth.
- Thoroughly incorporate plant residues into the soil to allow decomposition prior to treatment. Leave little or no plant residue present on the soil surface. Undecomposed plant material can harbor pests that will not be controlled and can interfere with the soil seal after application. Let crop residue that is present lie flat to permit the soil to be sealed effectively.
- Where applicable, fracture compacted soil layers (plow pans) within the desired treatment zone before or during application of IRF135.

Soil moisture:

- It is critical to achieve adequate soil moisture before treatment. Plan soil treatment for seasons, crop rotations, or irrigation schedules which leave adequate moisture in the soil.
- The soil must be moist (typically with enough moisture to allow weed seeds to become imbibed) from 1.5 inches below the soil surface to at least the minimum desired depth of the target treatment zone. The amount of moisture needed (typically greater than 50% Available Water Content* at 9 inches) in this zone will vary according to soil type. Use the USDA Feel and Appearance Method (http://www.oneplan.org/Water/soilmoist.pdf) or a device that will accurately measure soil moisture. The surface soil generally dries very rapidly and is not considered in this determination.

Weather Conditions:

- Prior to soil treatment the weather forecast for the day of application and the 48-hour period following the soil treatment must be checked to determine if unfavorable weather conditions exist or are predicted (such as no wind speed or the potential for inversion layers) and whether soil treatment can begin.
- If significant rainfall occurs within 24 hours after IRF135 application (enough to saturate soil that has been treated with IRF135), a reduction in pest control can occur.
- Apply IRF135 in the presence of wind speeds of at least 2 mph at the start of the applications or projected to reach at least 5 mph during the application.
- Check weather forecasts 48 hours prior to application to ensure proper conditions are

present at the time of application. Weather conditions and or advisories can be downloaded online at http://www.nws.noaa.gov.

Buffer Zones: Do not apply IRF135 within 25' of any occupied structure, such as a school, daycare, hospital, retirement home, business or residence.

PRE-PLANTING AFTER APPLICATION OF IRF135

Recontamination Prevention:

- IRF135 will control pests that are present in the soil treatment zone at the time of soil treatment. It will not control pests that are introduced into the soil after soil treatment period has ended. To avoid re-infestation of treated soil, DO NOT use irrigation water, transplants, seed pieces, or equipment that could carry soil-borne pests from infested land into the treated area. Avoid contamination from moving infested soil onto treated beds through cultivation, movement of soil from outside the treated zone, dumping contaminated soil in treated fields and soil contamination from equipment or crop remains. Clean equipment carefully before entering treated fields.

Testing of Treated Soils Prior to Planting:

- Allow IRF135 to dissipate completely within and out of the treated soil before planting the crop.
- When determining the appropriate time interval before planting, consideration of factors that impact IRF135 dissipation include rate of application, depth of injection, soil temperature, soil preparation and type, soil moisture and use of various plastic films and or water sealing.
- Use of a lettuce seed and or tomato/pepper transplant test can be used to determine if sufficient time has elapsed between soil treatment and planting as described below.

Lettuce Seed Test

- After a minimum of 7 days after application proceed with the following Seed Jar test.
- Use a trowel to dig into the treated soil to a depth at or just beneath the depth of IRF135 injection and remove 2 to 5 samples with enough soil to fill a quart sized jar half-way, mix lightly, apply moisture enough to germinate seeds, sprinkle seeds evenly over the soil surface and seal immediately with a lid for air tight conditions.
- Sample the field in several areas, especially those areas that are not representative of the general field conditions and or having higher moisture content, different soil texture or areas where rate delivery is different.
- Prepare another similar sample of untreated soil for comparison.
- Keep the jars out of direct sunlight and at a temperature of 65^{o} to 85^{o}F. (Direct sunlight can overheat and kill the seedlings). Lettuce seed will not germinate in the dark so place in diffuse sunlight.
- After 1 to 3 days, check each jar for seed germination.
- If seeds in the treated jar germinate and grow similar to the untreated soil sample then the treated area is safe for planting.

Tomato/Pepper Transplant Test

- After a minimum of 7 days after application proceed with the following transplant test.
- Transplant 5 to 10 healthy, actively growing tomato or pepper seedlings into treated beds at normal planting depth and several locations within the treated area. If available repeat in an area of field *not treated* with IRF135 for comparison. If a wetter, heavier area of the treated field is available place the transplants there.
- Inspect the transplants in 3 days for plant injury including wilt, chlorosis, or leaf and root tip burn. Ensure that proper soil moisture conditions exist for transplants to remain free

from water stress. If plants in the treated area are asymptomatic and or are similar in growth and appearance to plants in the non-treated area it is safe to plant.

IRF135 DRIP (TRICKLE) CHEMIGATION APPLICATION USE DIRECTIONS

Drip (Trickle) Chemigation Use Precautions:

- The following applies to drip (trickle) irrigation systems.
- Crop injury and a reduction in efficacy can result from non-uniform distribution of IRF135 in irrigation water used to treat soil.
- For questions related to equipment calibration, consult your local State Extension Service specialist, equipment manufacturer or dealer.

Soil preparation:

- Ensure compacted soil layers (plow pans) within the desired treatment zone are tilled and/or fractured if it is considered normal practice before application of IRF135 to ensure adequate soil drainage. Note that conditions where soil layers (plow pans) exist and are not tilled can result in reduced pest control, differences in planting interval or plant growth as a result of compacted or shallow soil conditions.
- The application site must be in seedbed condition. Ensure beds are listed, shaped and ready for planting.
- Ensure initial soil moisture is at ~50% of field capacity at 2 to 3 inches and down to 9 inches depth at the time of IRF135 application. Soil texture and amount of water to be applied will impact the desired initial % field capacity necessary for drip injection.

IRF135 Dosage:

- Determining IRF135 dosage is based on consideration of the intended crop to be planted, treated area conditions, preparation, application method, target pest, and soil type.
- Use drip emitters with spacing of 4 to 12 inches with shallow subsurface placement to ensure thorough wetting of the soil area being treated by IRF135 drip injection.
- IRF135 must be metered at a target concentration between - 1000 – 3000 ppm (calculated by: total volume of product to be applied / total amount of water to be applied) x 1,000,000 into the water supply line and passed through a mixing device such as a centrifugal pump with by-pass agitation or static mixer to assure proper agitation and mixing to a target concentration (ppm) for even distribution before distribution into the drip irrigation system. The concentration of IRF135 should not exceed 3000 ppm at any time during the injection period within the drip line.
- The volume of irrigation water to deliver to the treated area is dependent upon the soil type, % soil moisture or the % of field capacity at the start of the application and the target moisture level following application and equipment rising.
- Determine the irrigation water flow and adjust the flow rate of IRF135 to meet the target ppm in irrigation water. Insert a static mixer or similar device immediately after the IRF135 injection point to insure adequate mixing with the irrigation water.

Chemigation Application Information:

1. Apply this product only through drip (trickle) irrigation systems. Do not apply this product through any other type of irrigation system.
2. Crop injury or lack of effectiveness can result from non-uniform distribution of treated water.
3. If you have questions about calibration, contact State Extension Service specialists, equipment manufacturers or other experts.
4. Do not connect an irrigation system (including greenhouse systems) used for pesticide

application to a public water system unless the pesticide label-prescribed safety devices for public water systems are in place.

5. A person knowledgeable of the chemigation system and responsible for its operation or under the supervision of the responsible person, shall shut the system down and make necessary adjustments should the need arise.

Chemigation Systems Connected to Public Water Systems:

1. Public water system means a system for the provision to the public of piped water for human consumption if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year.
2. Chemigation systems connected to public water systems must contain a functional, reduced-pressure zone, back flow preventer (RPZ) or the functional equivalent in the water supply line upstream from the point of pesticide introduction. As an option to the RPZ, the water from the public water system should be discharged into a reservoir tank prior to pesticide introduction. There shall be a complete physical break (air gap) between the flow outlet end of the fill pipe and the top or overflow rim of the reservoir tank of at least twice the inside diameter of the fill pipe.

Equipment Considerations for Drip (Trickle) Chemigation Systems:

1. The irrigation system (main line, headers, and drip tape) must be thoroughly inspected for leaks before the application starts. The leak detection process requires that the irrigations system be at full operating pressure. The time required at full operating pressure will vary according to the system design and layout, soil type and target ppm concentration. Signs of leaks may include puddling along major pipes and at the top or ends of rows and/or on the bed surface or movement or shifting of beds due to bed collapse in over saturated conditions. Any leaks discovered must be repaired prior to application of IRF135. For leaks discovered during application of IRF135, immediately stop injection, wear all appropriate PPE and repair the line insuring that the problem is corrected before commencing with the drip applied injection.
2. The system must contain a functional check valve (back flow prevention device), vacuum relief valve, and low pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from back flow.
3. The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump.
4. With use of injection pumps (e.g. Diaphragm or Centrifugal type pumps) the pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down.
5. The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops or in cases where there is no water pump, when the water pressure decreases to the point where pesticide distribution is adversely affected.
6. The irrigation line or water pump must include a functional pressure switch which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected.
7. To inject IRF135, use a metering device (such as a positive pressure system, positive displacement injection pump, diaphragm pump, or a Venturi system) effectively designed and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock.
8. Use of an inert gas such as nitrogen or dry compressed air is acceptable for use in a

positive pressure system.

Injection System Flush After IRF135 Application:

- **After IRF135 injection, continue drip irrigation with clean water to flush remaining IRF135 completely out of the system.** Apply 3 times (3X) the volume of water equivalent to the capacity of the drip injection system from the point of injection to the ends of the drip tape to ensure IRF135 is completely voided from the injection lines and drip tape.
- Do not allow any IRF135 to remain in the system after application.
- If common lines are used for both the IRF135 application and to apply the water seal (if applied), the lines must be adequately flushed before starting the water seal and/or normal irrigation practices.

Soil Sealing or Tarp Use:

- When tarps are used with drip injection application, they must be in place prior to injection of IRF135.
- Tarp edges must be buried along the row furrow and at the ends of each row.

***Untarped* Drip (Trickle) Chemigation Applications:**

- Use of shallow buried drip tape, i.e. >1 inch is acceptable when applying via Drip (trickle) Chemigation.

Planting Interval for Raised Bed Drip Applications:

- After application, leave the soil undisturbed for at least 10 days after the application is complete. Planting of the target crop is allowed at a minimum of 10 days following the completion of the application.
- Extremely cold, wet, or cold and wet soils can decrease dissipation of IRF135 and can require a longer soil exposure and/or aeration period.
- For tarped applications, where tarp perforation or hole punching occurs allow 2 to 24 hours aeration prior to planting to assist in IRF135 dissipation.
- Use of a Jar Seedling and/or Transplant test for crop safety can be performed prior to planting the target crop.

Tarped or Non-Tarped Drip (Trickle) End of Season Crop Termination Chemigation Applications:

- Use instructions listed above for preparation and application conditions for pre-plant drip (trickle) chemigation, with the exception of those instructions for soil preparation which are not applicable for this treatment. Use the following additional steps:
- Use existing drip or trickle tape in the bed.
- Ensure that all drip (trickle) tape is completely functional and without leaks or tears.
- Application is for soil already covered with plastic (with or without plant holes) and drip tape is buried at a depth of >1 inch.
- Apply IRF135 at 3 – 20 gallons/acre.
- IRF135 broadcast application rate is not to exceed 20 gallons/acre.
- IRF135 ppm concentration range in irrigation water (500 – 1,500 ppm).
- Dispose of all crop and / or plant residues following treatment by removal, tillage or other appropriate means.
- The terminated crop must not be used for any food or feed purposes after the product has been applied.

Requirements for Greenhouse Soil Treatment

- Applications methods for use in greenhouse soil treatment may be applied as drip injection or tractor mounted shank where applicable according to the methods described for open field with exceptions listed below:

- o All applications must be tarped or double water sealed (delivered via overhead sprinkler). Double water sealed is defined as twice the amount of water to deliver the soil treatment without causing over saturation of the soil or delivering enough water to maintain up to 80% soil moisture for 24 hours following application.
- o During the application, keep doors, vents and windows to the outside open and keep fans or other mechanical ventilation systems running within the application area.
- o Areas by which gases could enter adjacent enclosed areas must be sealed prior to application and remain closed for up to 48 hours post application.

IRF135 TRACTOR MOUNTED SHANK RAISED BED AND BROADCAST/FLAT FUME APPLICATION USE DIRECTIONS

Soil moisture:

- For tractor mounted shank applied treatments of IRF135 do not apply to dry soils. Target a soil moisture reading of 25 to 60% Available Water Content* to a depth of 8 to 9 inches present for at least 24 to 48 hours prior to and until the start of the application.

* Available Water Content (or Capacity) is the amount of water that a soil can store that is available for use by plants (USDA Soil Quality Information Sheet).

Soil temperature at application:

- Maximum of 60°F and a maximum of 90°F at application depth.

Application Methods and Equipment:

- Apply IRF135 using chisels spaced no more than 12 inches apart and no more than 3 outlets evenly spaced per chisel (rear and forward facing type shank). The top most outlets must be no less than 4 inches from the final air soil interface.
- For shank applications the use of tarps or a water cap does not eliminate the need to remove chisel traces. If chisel traces are not adequately closed by the application equipment the use of a press board, ring roller or other device to effectively close chisel traces must be performed.

Application Depth:

- The point of injection must be a minimum of 4 inches from the final soil/air interface.
- The point of deep injection must be at a minimum of 18 inches from the final soil/air interface. Use deeper placement when fumigating soil to be planted to deep-rooted plants, such as perennial fruit and nut crops, or to control deeply distributed pests.

Application Type	Injection depth	Single Sweep Chisel Spacing	Noble Plow Injector Outlet Spacing	Yetter Rig Injector Spacing	Tarped Type Sealing, Applied immediately after application*	Non-Tarped Type Sealing
Broadcast Shallow Shank	4 – 15 inches	6 – 12 inches**	6 – 12 inches	4 – 6 inches	PE, VIF, TIF	Overhead sprinkler, water cap and/or Roller/Packer to compact soil surface, and close chisel traces

Application Type	Injection depth	Single Sweep Chisel Spacing	Noble Plow Injector Outlet Spacing	Yetter Rig Injector Spacing	Tarped Type Sealing, Applied immediately after application*	Non-Tarped Type Sealing
Broadcast Deep Shank	> 17 inches	18 – 24 inches	NA	NA	NA	Roller/packer to compact soil surface
Raised Bed shallow shank or Strip Application	4 – 15 inches	6 – 12 inches**	NA	4 – 6 inches	PE, VIF, TIF	Overhead Sprinkler, water cap and/or Roller/Packer to compact soil surface, and close chisel traces

* PE = Polyethylene film; VIF = Virtually Impermeable Film; TIF = Totally Impermeable Film

** Use of no more than 3 nozzles per sweep with 4 – 5 inches / nozzle and bottom nozzle at no more than 15 inches from soil surface.

Prevention of End Row Spillage:

- Do not apply or allow IRF135 to spill onto the soil surface. Each injection line either needs a check valve located as close as possible to the soil injection point to avoid dripping or spillage. If a check valve system is not in place purge and drain the injection line prior to lifting the injection shanks from the ground.
- Only lift the injection shanks from the ground when the shut-off valve has been closed, and the IRF135 injection line has been depressurized to passively drain remaining IRF135 or when the system has been actively purged (e.g. via air compressor).

Injection Rig Calibration, Set-up, Repair, and Maintenance:

- IRF135 application equipment must be calibrated and all control systems working properly. Proper calibration is critical to ensure IRF135 application rate and soil placement. Refer to the equipment manufacturer’s instructions to properly calibrate the injection equipment. The equipment dealer, local Cooperative Extension Service, crop advisor or IRF135 dealer can provide assistance.
- Flush all equipment with water after each day’s use; disassemble valves and clean carefully. All rinsate should be properly applied to the field.

Planting Interval for Raised Bed Shank and Broadcast/Flat Fume Application

- After application, leave the soil undisturbed for at least 5 days after application prior to tarp cutting or perforation/hole punching.
- For tarped applications, complete cutting of the tarp for removal or perforation/hole punching 2 to 24 hours prior to tarp removal or planting to assist in IRF135 dissipation.
- Tarp cutters and removers shall wear long-sleeved shirt, long pants and gloves when there is no waiting or aeration period between tarp cutting and removing the tarp following application and prior to planting.
- Soil under un-tarped shanked applications must remain undisturbed for a minimum of 5 days following completion of the applications before tillage and or planting of the crop.
- Soil can be planted with the target crop at a minimum of 10 days following drip application.
- Soil can be planted with the target crops at a minimum of 10-14 days following shank applications only if conditions are favorable for soil moisture and dissipation of IRF135 in the soil.

- Cold and or wet soils can decrease dissipation of IRF135 and can require a longer soil exposure and or aeration period.
- Use of a Jar Seedling and/or Transplant test for crop safety can be performed prior to planting the target crop.

PESTS CONTROLLED FROM SOIL TREATMENT USES

Nematodes

Common Name (if applicable)	Scientific Name
Pin nematode	*Paratylenchus*
Ring nematode	*Mesocriconema* (=*Criconemoides*, =*Criconemella*)
Root knot nematode	*Meloidogyne*
Root-lesion nematode	*Pratylenchus*
Spiral nematode	*Helicotylenchus*
Sting nematode	*Belonolaimus*
Stubby-root nematode	*Paratrichodorus*
Stem and bulb nematode	*Tylenchus*

Soil Borne Fungi

Common Name (if applicable)	Scientific Name
Charcoal rot	*Macrophomina phaseolina*
Clubroot organism	*Plasmodiophora*
Corky root	*Pyrenochaeta*
Fusarium wilt	*Fusarium spp.*
Phytophthora	*Phytophthora spp.*
Pythium	*Pythium spp.*
Rhizoctonia	*Rhizoctonia spp.*
Southern blight	*Sclerotium rolfsii*
Verticillium wilt	*Verticillium dahliae*

Insects in the Soil at the Time of Treatment

Common Name (if applicable)	Scientific Name (if applicable)
Cutworms	
Japanese beetles	
June beetles and larva	
Symphylan (centipedes)	
White grubs	
Wireworms	

Weeds

Common Name (if applicable)	Scientific Name
California burclover	*Medicago lupulina*
Common chickweed	*Stellaria media*
Common mallow	*Malva neglecta*
Common purslane	*Portulaca oleracea*
Field bindweed	*Convolvulus arvensis*
Annual grass spp.	
Morningglory spp.	*Ipomoea spp.*
Prostrate knotweed	*Polygonum aviculare*
Purple nutsedge*	*Cyperus rotundus*
Yellow nutsedge*	*Cyperus esculentus*
* Suppression under wet conditions and heavy pest populations.	

Mollusks

Slugs and Snails.

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage and disposal.

PESTICIDE STORAGE

Store in original container in a cool, dry place.

PESTICIDE DISPOSAL

Waste resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

CONTAINER HANDLING for non-refillable containers

This is a non-refillable container. Do not reuse or refill this container. Empty the package completely and triple rinse container (or equivalent pressure rinse) promptly after emptying with water to be used for application. Then dispose of the empty container according to state and local regulations. Place in trash or offer for recycling if available or return it to the Seller, or, if allowed by state and local authorities, by burning. If burned stay out of smoke.

TRIPLE RINSING INSTRUCTIONS:

For rigid, nonrefillable containers small enough to shake (with capacities equal to or less than 5 gallons):

Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container one-fourth full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times.

For rigid, non-refillable containers that are too large to shake (with capacities greater than 5 gallons):

Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank. Fill the container one-fourth full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Turn the container over onto its other end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Repeat this procedure two more times.

PRESSURE RINSE PROCEDURE (all sizes):

Pressure rinse as follows: Empty the remaining contents into application equipment or a tank mix and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment or mix tank or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container, and rinse at about 40 PSI for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

CONTAINER HANDLING for rigid, refillable containers

Refillable container. Refill this container with IRF135 pesticide only. Do not reuse this container for any other purpose. Cleaning the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller. To clean the container before final disposal, empty the remaining contents from this container into application equipment or mix tank. Fill the container about 10 percent full with water. Agitate vigorously or recirculate water with the pump for 2 minutes. Pour or pump rinsate into application equipment or rinsate collection system. Repeat this rinsing procedure two more times.

LIMITATION OF WARRANTY AND LIABILITY

Read the entire label before using this product, including this Limitation of Warranty and Liability.

If the terms are not acceptable, return the product at once unopened for a refund of the purchase price.

This Company warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes set forth in the Directions for Use, subject to the inherent risks described below, when used in accordance with the Directions for Use under normal conditions.

TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, ISAGRO MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS OR MERCHANTABILITY OR ANY OTHER EXPRESS OR IMPLIED WARRANTY.

Buyers and Users of this product must be aware that there are inherent unintended risks associated to the use of this product, independent from the control of Isagro. These risks include, but are not limited to, weather conditions, soil factors, moisture conditions, diseases, irrigation practices, condition of the crop at the time of application, materials which are present in the tank mix with this product or prior to the application of it, cultural practices or the manner of use or application, all risks which are impossible to eliminate. The Buyers and Users should be aware that these factors may cause: ineffectiveness of the product, reduction of harvested yield of the crop (entirely or partially), crop injury or injury to non-target crops or plants or to rotational crops caused by carryover in the soil, resistance of the target weeds to this product. Therefore additional care, treatment and expense are required to take the crop to harvest.

If the Buyer does not agree with the acceptance of these risks, then THE PRODUCT SHOULD NOT BE APPLIED. To the extent consistent with applicable law, by applying this product the Buyer acknowledges and accepts these inherent unintended risks and AGREES THAT ALL SUCH RISKS ASSOCIATED WITH THE APPLICATION AND USE ARE ASSUMED BY THE BUYER.

To the extent consistent with applicable law, ISAGRO or Seller shall not be liable for any incidental, consequential or special damages resulting from the use or handling of this product (including claims based in contract, negligence, strict liability, and other tort or otherwise). To the extent consistent with applicable law, the exclusive remedy of the User or Buyer and the exclusive Liability of Isagro or Seller shall be the return of the purchase price of the product, or at the election of Isagro or Seller, the replacement of the product.

To the extent consistent with applicable law, this Company does not warrant any product reformulated or repackaged from this product except in accordance with this Company's stewardship requirements and with express written permission from this Company.

Isagro or its Seller must have prompt notice of any claim so that an immediate inspection of Buyer's or User's can be made. To the extent consistent with applicable law, if Buyer and User do not notify Isagro or Seller of any claims, in proper time, it shall be barred from obtaining any remedy.

To the extent consistent with applicable law, Buyers and Users are deemed to have accepted the terms of this Limitation of Warranty and Liability, which may not be modified by any verbal or written agreement.

DOMINUS is a registered trademark of Isagro USA, Inc.

Safety Data Sheet for use in USA Date: October 28, 2015

1. IDENTIFICATION OF THE PRODUCT AND OF THE COMPANY

Trade name:	Dominus® (also IRF135)
Product type and Use:	Agricultural and general soil treatment use as biofumigant (biopesticide)
Company:	Isagro USA- 430 Davis Dr., Suite 240, Morrisville NC 27560
	Subsidiary of: Isagro S.p.A. – Via Caldera, 21 – 20153 Milano, Italy
Emergency Telephone Numbers:	Isagro USA (919) 321-5200 / CHEMTREC (800) 424-9300

2. HAZARDS IDENTIFICATION

OSHA Hazard Communication Standard Classification (29 CFR 1910.1200)

Signal Word: Danger

Pictograms:

Hazard Statements and Categories:

Acute Oral Toxicity: Harmful if swallowed – Wash hand thoroughly after handling. Do not eat, drink or smoke when using this product. If swallowed: call a poison center if you feel unwell. Rinse mouth.

Acute Dermal Toxicity: Toxic in contact with skin – Wear protective gloves and clothing. If on skin: wash with plenty of water. Call a poison center or doctor if you feel unwell. Take off immediately all contaminated clothing and wash if before reuse. Store locked up.

Acute Inhalation Toxicity: Irritating to respiratory system – Do not breathe mist, vapor or spray. Use only outdoors or in a well-ventilated area. In case of inadequate ventilation wear respiratory protection. If inhaled: remove person to fresh air and keep comfortable for breathing. Immediately call a poison center or doctor. Take off immediately all contaminated clothing and wash it before reuse. Store in a well-ventilated place. Keep container tightly closed. Stored locked up.

Skin Irritation: Causes severe skin burns and eye damage – Do not breathe mists. Wash hands thoroughly after handling. Wear protective gloves and clothing, eye and face protection. If swallowed: rinse mouth. Do not induce vomiting. If on skin: take off immediately all contaminated clothing. Rinse skin with water or shower. If inhaled: remove person to fresh air and keep comfortable for breathing. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

Eye irritation: Causes serious eye damage – Wear eye and face protection. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center or doctor.

Flammable liquid – Keep away from open flames. No smoking. Keep container tightly closed. Use only non-sparking tools. Take precautionary measures against static discharge. Wear protective gloves, eye and face protection. If on skin: take off immediately all contaminated clothing. Rinse skin with water or shower.

3. COMPOSITION/INFORMATION ON ACTIVE INGREDIENTS

96.3% allyl isothiocyanate (AITC) CAS: 57-06-7

4. FIRST AID MEASURES

If in Eyes: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, and then continue rinsing. Call a poison control center or physician for treatment advice.

If on Skin or Clothing: Take off contaminated clothing. Rinse skin immediately with plenty of water for 15 minutes. Call a poison control center of doctor for treatment advice.

If Swallowed: Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by the poison control center or doctor. Do not give anything to an unconscious person. Call a poison control center or physician for treatment advice.

If Inhaled: Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.

Note to Physician: Probably mucosal damage may contraindicate the use of gastric lavage.

5. FIRE-FIGHTING MEASURES

Flash Point: 47˚C

Extinguishing Media: Small fire - CO_2, dry chemical, dry sand, alcohol-resistant foam. Large fire – Water spray, fog or alcohol-resistant foam.

Unusual Fire & Explosion Hazards: Do not inhale explosion and combustion gases which, at high temperatures, may contain toxic substances such as COx, NOx, SOx. Burning produces heavy smoke.

Fire-Fighting Procedures: Use appropriate extinguishing media for combustibles in the area. Wear full protective clothing and self-contained breathing apparatus. Evacuate nonessential personnel from the area to prevent human exposure to fire, smoke, fumes or products of combustion. Prevent use of contaminated buildings, area, and equipment until decontaminated. Water runoff can cause environmental damage. If water is used to fight fire, dike and collect runoff.

Hazardous Decomposition Products: May release irritating and toxic gases due to thermal decomposition.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions: Wear personal protection equipment. Wear breathing apparatus if exposed to vapors/dusts/aerosols. Provide adequate ventilation. Use appropriate respiratory protection.

Environmental Precautions: Follow good practice (allowed dose/use) in order to prevent environmental pollution. Retain contaminated washing water and dispose it. Suitable material for taking up: absorbing material, organic, sand

Methods and materials for containment and cleaning up: Wash with plenty of water.

7. HANDLING AND STORAGE

Do not contaminate water, food, or feed by storage or disposal.

Handling Precautions: Avoid contact with skin and eyes, inhalation of vapors and mists. Use localized ventilation system. Don't use empty container before they have been cleaned. Before making transfer operations, assure that there aren't any incompatible material residuals in the containers. Contaminated clothing should be changed before entering eating areas. Do not eat or drink while working. See also section 8 for recommended protective equipment.

Storage Precautions: Keep away from food, drink and feed. Incompatible materials: None in particular. Instructions as regards storage premises: Adequately ventilated premises.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls: Refer to product label. Provide local exhaust or process enclosure ventilation system.

Eye/Face Protection: To protect against accidental eye contact, goggles/face-shield should be worn.

Skin Protection: Long-sleeved shirt and long pants. Chemical-resistant gloves, such as butyl rubber, natural rubber, neoprene rubber, or nitrile rubber. Shoes plus socks.

Respiratory Protection: When needed, based on the conditions of use, wear a MSHA/NIOSH approved air purifying respirator with an organic-vapor removing cartridge with any N, R, P or HE pre-filter.

Additional Protective Measures: Discard clothing and other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them. Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

Follow the manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry. Discard any clothing and or PPE that have been drenched or heavily contaminated with this product's concentrate. Do not reuse clothing or PPE that has been drenched or heavily contaminated.

User Safety Recommendations:

- Users should remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Users should remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

Exposure Limit:
Allyl isothiocyanate (AITC) CAS: 57-06-7: 1 ppm (STEL) (WEEL)*
* US, Workplace Environmental Exposure Levels

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Color: Colorless or pale yellow liquid

Odor: Very pungent, irritating aroma

pH: 4 - 5 (aqueous suspension 1%)

Flash Point: 47˚C

Boiling Point: 150-151˚C

Density: 1.103 – 1.020

Partition Coefficient: LogP -2.11

Water Solubility: Slightly soluble in water

Vapor Pressure: 1.33 kPa@38.3˚C

10. STABILITY AND REACTIVITY

Stability: Stable under normal handling and storage conditions.

Incompatibilities: Strong acids, strong bases and oxidation agents

Hazardous Decomposition: It may generate flammable gases on contact with elementary metals (alkalis and alkaline earth, alloys in powder or vapours) and powerful reducing agents. It may generate toxic gases on contact with oxidizing mineral acids, and powerful oxidizing agents. It may catch fire on contact with oxidizing mineral acids, and powerful oxidizing agents.

Hazardous Polymerization: Will not occur.

11. TOXICOLOGICAL INFORMATION

Acute Toxicity/Irritation Studies: (Based on the active ingredient of IRF 135)
Acute Oral Toxicity LD50: 425.4 mg/kg
Acute Dermal Toxicity LD50 : > 200 mg/kg and < 2000 mg/kg
Acute Inhalation Toxicity LC50 (4h) : >0.21 mg/L and <0.508 mg/L
Eye Irritation: Corrosive
Skin Irritation: Corrosive
Dermal Sensitization: A positive skin sensitizer

Other Toxicological Information: (Based on the active ingredient of IRF 135)
Chronic Toxicity: No data available
Carcinogenic Effects: No carcinogenic effect
Reproductive Toxicity: No data available
Teratogenic Effect: No teratogenic effect
Mutagenic Effects: Negative in vivo

12. ECOLOGICAL INFORMATION

Environmental Hazards: For terrestrial uses only. Do not apply directly to water or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when cleaning equipment or disposing of equipment wash water or rinsate.

Ecotoxicological Information: (Based on the active ingredient allyl isothiocyanate)
Fathead Minnow LC50 (96h): 85.6µg/L

13. DISPOSAL CONSIDERATIONS

Recover if possible. Send non-recoverable product, absorbent material, and rinsate solids to authorized disposal plants or for incineration under controlled conditions. In so doing, comply with the local and national regulations currently in force.

14. TRANSPORT INFORMATION

US DOT Classification

UN No.:	1545
Proper Shipping Name:	Allyl isothiocyanate, stabilized
Class:	6.1 (3)
Packaging Group:	II
Marine Pollutant:	No

IMO Classification

UN No.:	1545
Proper Shipping Name:	Allyl isothiocyanate, stabilized
Class:	6.1 (3)
Packaging Group:	II
Marine Pollutant:	Yes

IATA Classification

UN No.:	1545
Proper Shipping Name:	Allyl isothiocyanate, stabilized
Class:	6.1 (3)
Packaging Group:	II

15. REGULATORY INFORMATION

FIFRA Information:
This chemical is a pesticide product registered by the Environmental Protection Agency and is subject to certain labeling requirements under federal pesticide law. These requirements different from the classification criteria and hazard information for safety data sheet, and for workplace labels of non-pesticide chemicals. Following is the hazard information as required on the pesticide label.

DANGER Corrosive Causes irreversible eye damage and skin burns. May be fatal if swallowed, absorbed through skin, or inhaled. Do not get in eyes, on skin or on clothing. Do not breathe vapor. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using tobacco or using the toilet. Remove and wash contaminated clothing before use.

US Federal Regulations:

SARA Title III Classification:

Section 302:	Not applicable.
Section 311/312:	Acute health hazard (immediate) Fire Hazard
Section 313:	Not applicable.

CA PROPOSITION 65: Not applicable

CERCLA RQ: Not applicable

RCRA CLASSIFICATION: Under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste.

TSCA STATUS: The ingredients of this product are listed on the TSCA inventory or are exempt.

US EPA Registration Number: 89285-2

16. OTHER INFORMATION

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality. It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended. This SDS cancels and replaces any preceding released for use in the US.

DOMINUS is a registered trademark of Isagro USA, Inc.

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Pesticide Programs
Biopesticides and Pollution Prevention Division (7511P)
1200 Pennsylvania Avenue NW
Washington, DC 20460

NOTICE OF PESTICIDE:
X Registration
___ Reregistration
(under FIFRA, as amended)

EPA Reg. Number:	Date of Issuance:
89285-1	
Term of Issuance:	**Unconditional**
Name of Pesticide Product:	**IR9804**

Name and Address of Registrant (include ZIP Code):

Amy Plato Roberts
Isagro USA, Inc
P.O. Box 990
Hailey, ID 83333

Note: Changes in labeling differing in substance from that accepted in connection with this registration must be submitted to and accepted by the Biopesticides and Pollution Prevention Division prior to use of the label in commerce. In any correspondence on this product always refer to the above EPA registration number.

On the basis of information furnished by the registrant, the above named pesticide is hereby registered under the Federal Insecticide, Fungicide and Rodenticide Act.

Registration is in no way to be construed as an endorsement or recommendation of this product by the Agency. In order to protect health and the environment, the Administrator, on his motion, may at any time suspend or cancel the registration of a pesticide in accordance with the Act. The acceptance of any name in connection with the registration of a product under this Act is not to be construed as giving the registrant a right to exclusive use of the name or to its use if it has been covered by others.

This registration does not eliminate the need for continual reassessment of the pesticide. If EPA determines at any time that additional data are required to maintain in effect an existing registration, the Agency will require submission of such data under section 3(c)(2)(B) of FIFRA. This product is unconditionally registered in accordance with FIFRA Sec. 3(c)(5) provided you:

1. Submit and/or cite all data required for registration of your product under FIFRA section 3(c)(5) when the Agency requires all registrants of similar products to submit such data.

2. Revise the EPA Registration Number to read, "EPA Reg. No. 89285-1."

3. Submit two (2) copies of the final printed labeling before you release the product for shipment. Refer to the A-79 enclosure for a further description of final printed labeling.

A stamped copy of the label is enclosed for your records.

Signature of Approving Official:

J E Leahy Jr.
for

Robert McNally, Director,
Biopesticides and Pollution Prevention Division

Date:

9/26/13

EPA Form 8570-6

IR9804

Soil Treatment Pesticide for Formulating Purposes Only

ACTIVE INGREDIENT :
Allyl isothiocyanate (CAS No. 57-06-7)* 99.8%
OTHER INGREDIENTS : 0.2%
TOTAL: 100.0%
*This product contains 8.5 lbs. active ingredient per gallon.

ACCEPTED

SEP 26 2013

Under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, for the pesticide registered under EPA Reg. No. 89285-1

KEEP OUT OF REACH OF CHILDREN
DANGER — PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand the label find someone to explain it to you in detail.)

FIRST AID	
IF INHALED	· Move person to fresh air. · If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth, if possible. · Call a poison control center or doctor for further treatment advice.
IF IN EYES	· Hold eye open and rinse slowly and gently with water for 15 to 20 minutes. · Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. · Call a poison control center or doctor for treatment advice.
IF ON SKIN OR CLOTHING	· Take off contaminated clothing. · Rinse skin immediately with plenty of water for 15 to 20 minutes. · Call a poison control center or doctor for treatment advice.
IF SWALLOWED	· Call a poison control center or doctor immediately for treatment advice. · Have person sip a glass of water if able to swallow. · Do not induce vomiting unless told to do so by a poison control center or doctor. · Do not give anything by mouth to an unconscious person.
NOTE TO PHYSICIAN: Because rapid absorption may occur through lungs if product is aspirated and cause systemic effects, the decision to induce vomiting or not should be made by a physician.	
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. **For Chemical Emergency** **Spill Leak Fire Exposure or Accident** **Call CHEMTREC Day or Night** **Domestic North America 800-424-9300** **International 703-527-3883 (collect calls accepted)**	

EPA Registration No.: (pending as File Symbol 89285-R)
EPA Establishment No.: XXXXXX

ISAGRO USA

NET CONTENTS:

Isagro USA, Inc.
430 Davis Drive, Suite 240, Morrisville, NC 27560

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

DANGER – PELIGRO. May be fatal if swallowed, absorbed through skin, or inhaled. Do not get in eyes, on skin or on clothing. Do not breathe vapour. **Corrosive.** Causes irreversible eye damage and skin burns. Prolonged or frequently repeated skin contact may cause allergic reactions in some individuals. Wear protective clothing, chemical-resistant gloves, respiratory protection and protective eyewear. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum or using tobacco, or using the toilet. Remove and wash contaminated clothing before reuse.

ENVIRONMENTAL HAZARDS

Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying local sewage treatment plant authority. For guidance contact your local State Water Board or Regional Office of the EPA. Do not contaminate water when disposing of equipment washwaters or rinsate.

DIRECTION FOR USE

It is violation of Federal law to use this product in a manner inconsistent with its labelling. Read entire label. This product should be used only for formulation into a soil pesticide product for control of fungi, insects, nematodes and weeds.

This product may be used to formulate products for any additional use(s) not listed on the MP label if the formulator, user group, or grower has complied with U.S. EPA submission requirements regarding support of such use(s).

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

PESTICIDE STORAGE: Store unused product in original container only in cool, dry area out of reach of children and animals.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product must be disposed of on site or at an approved waste disposal facility.

CONTAINER DISPOSAL for non-refillable containers: Non-refillable container. Do not reuse or refill this container. Triple rinse (or equivalent) promptly after emptying. Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank. Fill the container ¼ full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Turn the container over onto its other end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Repeat this procedure two more times. Then offer for recycling or reconditioning, or puncture and dispose of in sanitary landfill, or incineration. Do not burn, unless allowed by state and local ordinances.

CONTAINER DISPOSAL for rigid, refillable containers: Refillable container. Refill this container with IRF135 pesticide only. Do not reuse this container for any other purpose. Cleaning the container before final disposal is the responsibility of the person disposing of the container. Cleaning before refilling is the responsibility of the refiller. To clean the container before final disposal, empty the remaining contents from this container into application equipment or mix tank. Fill the container about 10 percent full with water. Agitate vigorously or recirculate water with the pump for 2 minutes. Pour or pump rinsate into application equipment or rinsate collection system. Repeat this rinsing procedure two more times.

LIMITATION OF WARRANTY AND LIABILITY

Read the entire label before using this product, including this Limitation of Warranty and Liability. If the terms are not acceptable, return the product at once unopened for a refund of the purchase price. This Company warrants that this product conforms to the chemical description on the label and is reasonably fit for the purposes set forth in the Directions for Use when used in accordance with the Directions for Use under normal conditions. TO THE EXTENT CONSISTENT WITH APPLICABLE LAW, ISAGRO MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS OR MERCHANTABILITY OR ANY OTHER EXPRESS OR IMPLIED WARRANTY.

Safety Data Sheet dated 6April2015

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Identification of the substance

Trade name: IR9804, ALLYL ISOTHIOCYANTATE

Trade code: -

1.2. Relevant identified uses of the substance or mixture and uses advised against

Mixture used in agricultural trials

Other uses are not allowed

1.3. Details of the supplier of the safety data sheet

Company:

ISAGRO S.p.A. – Via Caldera, 21 . 20153 MILANO – Italy

Tel. 02 40901276

Competent person responsible for the safety data sheet:

msds@isagro.it

1.4. Emergency telephone number

Quality, Health, Safety and Environment Dept (office hours: 9.00-18.00): n.. 02 40901276

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

Directive criteria, 67/548/CE, 99/45/EC and following amendments thereof:

Properties / Symbols:

T+ Very toxic

T Toxic

Xn Harmful

C Corrosive

N Dangerous for the environment

R Phrases:

R10 Flammable.

R22 Harmful if swallowed.

R24 Toxic in contact with skin.

R26 Very toxic by inhalation.

R34 Causes burns.

R42/43 May cause sensitization by inhalation and skin contact.

R50/53 Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Warning, Flam. Liq. 3, Flammable liquid and vapour.

Danger, Acute Tox. 1, Fatal if inhaled.

Warning, Acute Tox. 4, Harmful if swallowed.

Danger, Acute Tox. 3, Toxic in contact with skin.

Danger, Skin Corr. 1C, Causes severe skin burns and eye damage.

Warning, Skin Sens. 1, May cause an allergic skin reaction.

Danger, Resp. Sens. 1, May cause allergy or asthma symptoms or breathing difficulties if inhaled.

Warning, Aquatic Chronic 1, Very toxic to aquatic life with long lasting effects.

Adverse physicochemical, human health and environmental effects:
No other hazards

2.2. Label elements

Symbols:

Danger

Hazard statements:

H226 Flammable liquid and vapour.
H330 Fatal if inhaled.
H302 Harmful if swallowed.
H311 Toxic in contact with skin.
H314 Causes severe skin burns and eye damage.
H317 May cause an allergic skin reaction.
H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled.
H410 Very toxic to aquatic life with long lasting effects.

Precautionary statements:

P210 Keep away from heat/sparks/open flames/hot surfaces. — No smoking.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P303+P361+P353 IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340 IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER or doctor/physician.
P370+P378 In case of fire: Use chemical foam/powder or carbon dioxide for extinction.
P403+P233 Store in a well-ventilated place. Keep container tightly closed.

Special Provisions:

None

2.3. Other hazards

It does not contain vPvB/PBT substances.

Other Hazards:

Vesicant, lachrymator
If heated to decomposition or on contact with acid or acid fumes, it emits highly toxic fumes; can react with oxidizing materials.
Risk of causing a spontaneous violent reaction (see Kemler number in section 14).

SECTION 3: Composition/information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Hazardous components within the meaning of EEC directive 67/548 and CLP regulation and related classification:

99.8% Allyl Isothiocyanate (AITC)

CAS: 57-06-7, EC: 200-309-2

T+,T,Xn,C,N; R42/43-10-26-24-22-34-50/53

2.6/3 Flam. Liq. 3 H226

3.1/1/Inhal Acute Tox. 1 H330

3.1/4/Oral Acute Tox. 4 H302

3.1/3/Dermal Acute Tox. 3 H311

3.2/1C Skin Corr. 1C H314

3.4.2/1 Skin Sens. 1 H317

3.4.1/1 Resp. Sens. 1 H334

4.1/C1 Aquatic Chronic 1 H410

SECTION 4: First aid measures

4.1. Description of first aid measures

In case of skin contact:

Immediately take off all contaminated clothing.

Areas of the body that have - or are only even suspected of having - come into contact with the product must be rinsed immediately with plenty of running water and possibly with soap.

WARNING! This product is toxic through skin contact. OBTAIN IMMEDIATE MEDICAL ATTENTION.

Wash thoroughly the body (shower or bath).

Remove contaminated clothing immediatley and dispose off safely.

In case of eyes contact:

After contact with the eyes, rinse with water with the eyelids open for a sufficient length of time, then consult an opthalmologist immediately.

Protect uninjured eye.

In case of Ingestion:

Do NOT induce vomiting.

Give nothing to eat or drink.

In case of Inhalation:

If breathing is irregular or stopped, administer artificial respiration.

In case of inhalation, consult a doctor immediately and show him packing or label.

After contact with skin, wash immediately with soap and plenty of water.

4.2. Most important symptoms and effects, both acute and delayed

May cause allergy or asthma symptoms or breathing difficulties if inhaled.

May cause an allergic skin reaction.

At high doses the substance is toxic to kidney, stomach and urinary bladder.

Very dangerous if swallowed, in contact with skin/eyes and if inhalated (see also R phrases/H statements in section 2).

Dangerous if in contact with skin and eye (corrosive, it facilitates permeation).

4.3. Indication of any immediate medical attention and special treatment needed

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

Treatment:

Treat symptomatically and supportively.

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media:

CO_2, chemical foam or dry chemical fire extinguisher.

Extinguishing media which must not be used for safety reasons:
None in particular.

5.2. Special hazards arising from the substance or mixture
Do not inhale explosion and combustion gases which, at high temperatures, may produce toxic substances such as COx, NOx, CS_2, HCN, COS.
Burning produces heavy smoke.

5.3. Advice for firefighters
Use suitable breathing apparatus .
Collect contaminated fire extinguishing water separately. This must not be discharged into drains.
Move undamaged containers from immediate hazard area if it can be done safely.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures
Wear personal protection equipment.
Remove all sources of ignition.
Wear breathing apparatus if exposed to vapours/dusts/aerosols.
Provide adequate ventilation.
Use appropriate respiratory protection.
See protective measures under point 7 and 8.

6.2. Environmental precautions
Do not allow to enter into soil/subsoil. Do not allow to enter into surface water or drains.
Retain contaminated washing water and dispose it.
In case of gas escape or of entry into waterways, soil or drains, inform the responsible authorities.
Suitable material for taking up: absorbing material, organic, sand

6.3. Methods and material for containment and cleaning up
Wash with plenty of water.

6.4. Reference to other sections
See also section 8 and 13

SECTION 7: Handling and storage

7.1. Precautions for safe handling
Avoid contact with skin and eyes, inhaltion of vapours and mists.
Use localized ventilation system.
Don't use empty container before they have been cleaned.
Before making transfer operations, assure that there aren't any incompatible material residuals in the containers.
Contamined clothing should be changed before entering eating areas.
Do not eat or drink while working.
See also section 8 for recomened protective equipment.

7.2. Conditions for safe storage, including any incompatibilities
Keep away from unguarded flame, sparks, and heat sources. Avoid direct exposure to sunlight. Store in a darkened place, cool (T < 20 °C) and dry.
Keep away from food, drink and feed.
Incompatible materials:
Strong oxidants and reducing agents, strong acids and bases, water, alcohol and amines.
See also section 10.
Instructions as regards storage premises:
If possible store in the dark and in any case protected by direct sun light. Store in a cool and adequately ventilated place.

7.3. Specific end use(s)
None in particular.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters
No occupational exposure limit available

8.2. Exposure controls

Eye protection:
Not needed for normal use. Anyway, operate according good working practices.
Protection for skin:
Use clothing that provides comprehensive protection to the skin, e.g. PVC, PTFE (poly tetrafluoro ethylene) or fluorinated rubber.
Protection for hands:
Use protective gloves that provides comprehensive protection, e.g. PVC, PTFE (poly tetrafluoro ethylene), fluorinated rubber or butilic rubber.
Respiratory protection:
Based on the conditions of use and where ventilation is not sufficient and/or for a long exposure, provide respiratory protection.
If needed use air purifying respirator with an organic-vapor removing cartridge (ABEK filter).
Thermal Hazards:
None
Environmental exposure controls:
None

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Appearance and colour:	Liquid
Odour:	Pungent
Odour threshold:	Non available
pH:	4-5 (1% suspension in water)
Melting point / freezing point:	- 80 °C (referred to *AITC*)
Initial boiling point and boiling range:	151 °C (referred to *AITC*)
Solid/gas flammability:	
Upper/lower flammability	Not available
or explosive limits:	Not available
Vapour density:	3,4 (air = 1) (referred to *AITC*)
Flash point:	46 °C (closed cup) (referred to *AITC*)
Evaporation rate:	
Vapour pressure:	1.33 kPa at 38.3 °C (referred to *AITC*)
Relative density:	1.013 kg/l (referred to *AITC*)
Solubility in water:	2 g/L at 20 °C (referred to *AITC*)
Solubility in oil:	Soluble in most common organic solvents
Partition coefficient n-octanol/water):	Log P = 2.11 (referred to *AITC*)
Auto-ignition temperature:	Not available
Decomposition temperature:	Not determined
Viscosity:	Not determined
Explosive properties:	Not classified as explosive
Oxidizing properties:	Not oxidizing

9.2. Other information

Miscibility:	Not available
Fat Solubility:	Not available
Conductivity:	Not available
Substance Groups relevant Properties	It can cause a spontaneous violent reaction

SECTION 10: Stability and reactivity

10.1. Reactivity
Stable under normal conditions
10.2. Chemical stability
Stable under normal conditions and if stored in original packaging (stabilized with inert gas).
10.3. Possibility of hazardous reactions

It may generate toxic gases on contact with strong oxidising agents, and strong reducing agents.
It may catch fire on contact with strong oxidising agents.
It may react vigorously with water at temperatures > 100 °C
It may react spontaneosly with violence
It may emit toxic fumes when on contact with strong oxidizing agents, strong reducing agents.

10.4. Conditions to avoid
Stable under normal conditions. Avoid T > 40 °C and keep away from ignition sources.

10.5. Incompatible materials
Avoid strong oxidizing/reducing substances, strong acids and bases, water, alcohols and amines.
Avoid contact with oxidizing materials, with acids and acid fumes. The product could catch fire.

10.6. Hazardous decomposition products
It doesn’t give decomposition in normal storage conditions and in original containers (stabilized product with inert gas).
At high temperatures it decomposes giving dimers, trimers and cyclization products.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Data referred to *AITC*:
Acute toxicity:
LD50 (oral):
425 mg/kg (rat, female) (internal study) (ref. method OPPTS 870.1100)

LC50 (4h) (dermal):
Between 200 mg/kg and 2000 mg/kg (rat, male and female) (method OPPTS 870.1200)

LC50 (4h) (inhalation):
Between 0.206 mg/L and 0.508 mg/L (rat, 4h) (internal study) (method OPPTS 870.1300)

Irritating power/Corrosivity:
It may cause severe skin burns and severe eye damage (rabbit, female) (H314) (internal study) (method OPPTS 870.2500)

Sensitization:
It may cause an allergic skin raction (H317) (mice, female) (internal study) (method OPPTS 870.2600)

It may cause allergy or asthma symptoms or breathing difficulties if inhaled (H334) (internal study) (method OPPTS 870.2600)

Subchronic toxicity:
The substance is toxic on kidney, stomach and urinary bladder.

Carcinogenic/teratogenic/mutagenic effects:
No carcinogenic/teratogenic/mutagenic effect

SECTION 12: Ecological information

12.1. Toxicity
Adopt good working practices, so that the product is not released into the environment.

Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

Data referred to *AITC*:
Fish-
LC50 (96h): < 0.1 mg/L (bibliographic source)

12.2. Persistence and degradability
Data referred to *AITC*:
Degradability (soil): t1/2=20-60 hours

12.3. Bioaccumulative potential
Not available

12.4. Mobility in soil
Not available

12.5. Results of PBT and vPvB assessment
Not requested

12.6. Other adverse effects
None

SECTION 13: Disposal considerations

13.1. Waste treatment methods
Recover, if possible. Send to authorised disposal plants or for incineration under controlled conditions. In so doing, comply with the local and national regulations currently in force.

SECTION 14: Transport information

14.1. UN number

ADR-UN number:	1545
IATA-Un number:	1545
IMDG-Un number:	1545

14.2. UN proper shipping name

ADR-Shipping Name:	ALLYL ISOTHIOCYANATE, STABILIZED solution
IMDG-Technical name:	ALLYL ISOTHIOCYANATE, STABILIZED solution

14.3. Transport hazard class(es)

ADR-Class:	6.1
ADR-Label:	6.1 + 3 + Marine Pollutant
ADR – Hazard identification number:	639
IATA-Class:	6.1
IMDG-Class:	6.1
IMDG-Label:	6.1 + 3 + Marine Pollutant

14.4. Packing group

ADR-Packing Group:	II
IMDG-Packing group:	II

14.5. Environmental hazards

Marine pollutant:	Marine pollutant

14.6. Special precautions for user

Kemler Code:	639 Toxic and flammable material (flash point ≤ 60 °C), which may cause a spontaneous violent reaction
Limited Quantity:	100 mL
IMDG-EMS:	F-E, S-D
Tunnel restriction code:	(D/E)

14.7. Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code
Environmental Pollutant:
Not applicable

SECTION 15: Regulatory information

15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture
Dir. 67/548/EEC (Classification, packaging and labelling of dangerous substances). Dir. 99/45/EEC (Classification, packaging and labelling of dangerous preparations). Dir. 98/24/EC (Risks related to chemical agents at work). Dir. 2000/39/EC (Occupational exposure limit values); Dir. 2006/8/CE. Regulation (CE) n. 1907/2006 (REACH), Regulation (CE) n. 1272/2008 (CLP), Regulation (CE) n. 790/2009 (1° ATP CLP), Regulation (EU) n. 453/2010 (Annex I).
Where applicable, refer to the following regulatory provisions :
Directive 82/501/EEC ('Activities linked to risks of serious accidents') and subsequent amendments.
Regulation (EC) nr 648/2004 (detergents).
1999/13/EC (VOC directive)

15.2. Chemical safety assessment
Not requested

SECTION 16: Other information

EPA Reg. Number: 89285-1

R-phrases in section 3:
R10 Flammable.
R22 Harmful if swallowed.
R24 Toxic in contact with skin.
R26 Very toxic by inhalation.
R34 Causes burns.
R42/43 May cause sensitization by inhalation and skin contact.
R50/53 Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.

H-statements in section 3:
H226 Flammable liquid and vapour.
H330 Fatal if inhaled.
H302 Harmful if swallowed.
H311 Toxic in contact with skin.
H314 Causes severe skin burns and eye damage.
H317 May cause an allergic skin reaction.
H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled.
H410 Very toxic to aquatic life with long lasting effects.

Paragraphs modified from the previous revision:
2. HAZARDS IDENTIFICATION
3. COMPOSITION/INFORMATION ON INGREDIENTS
4. FIRST AID MEASURES
5. FIREFIGHTING MEASURES
6. ACCIDENTAL RELEASE MEASURES
7. HANDLING AND STORAGE
8. EXPOSURE CONTROLS/PERSONEL PROTECTION
9. PHYSICAL AND CHEMICAL PROPERTIES
10. STABILITY AND REACTIVITY
11. TOXICOLOGICAL INFORMATION
12. ECOLOGICAL INFORMATION
14. TRANSPORT INFORMATION

This document was prepared by a competent person who has received appropriate training.
Main bibliographic sources:

ECDIN - Environmental Chemicals Data and Information Network - Joint Research Centre, Commission of the European Communities
SAX's DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS - Eight Edition - Van Nostrand Reinold
CCNL - Appendix 1
Insert further consulted bibliography

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality.
It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended.
This MSDS cancels and replaces any preceding release.

ADR:	European Agreement concerning the International Carriage of Dangerous Goods by Road.
CAS:	Chemical Abstracts Service (division of the American Chemical Society).
CLP:	Classification, Labeling, Packaging.
DNEL:	Derived No Effect Level.
EINECS:	European Inventory of Existing Commercial Chemical Substances.
GefStoffVO:	Ordinance on Hazardous Substances, Germany.
GHS:	Globally Harmonized System of Classification and Labeling of Chemicals.
IATA:	International Air Transport Association.
IATA-DGR:	Dangerous Goods Regulation by the "International Air Transport Association" (IATA).
ICAO:	International Civil Aviation Organization.
ICAO-TI:	Technical Instructions by the "International Civil Aviation Organization" (ICAO).
IMDG:	International Maritime Code for Dangerous Goods.
INCI:	International Nomenclature of Cosmetic Ingredients.
KSt:	Explosion coefficient.
LC50:	Lethal concentration, for 50 percent of test population.
LD50:	Lethal dose, for 50 percent of test population.
PNEC:	Predicted No Effect Concentration.
RID:	Regulation Concerning the International Transport of Dangerous Goods by Rail.
STEL:	Short Term Exposure limit.
STOT:	Specific Target Organ Toxicity.
TLV:	Threshold Limiting Value.
TWATLV:	Threshold Limit Value for the Time Weighted Average 8 hour day. (ACGIH Standard).
WGK:	German Water Hazard Class.

Identification and quantification of the N-acetylcysteine conjugate of allyl isothiocyanate in human urine after ingestion of mustard.

D Jiao, C T Ho, P Foiles, et al.

Cancer Epidemiol Biomarkers Prev 1994;3:487-492.

Identification and Quantification of the *N*-Acetylcysteine Conjugate of Allyl Isothiocyanate in Human Urine after Ingestion of Mustard[1]

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Division of Chemical Carcinogenesis, Naylor Dana Institute for Disease Prevention, American Health Foundation, Valhalla, New York 10595 [D. J., P. F., F-L. C.], and Department of Food Science, Cook College, Rutgers University, New Brunswick, New Jersey 08903 [C-T. H.]

Abstract

Allyl isothiocyanate (AITC) is a constituent of cruciferous vegetables. It occurs widely in the human diet as a natural ingredient or food additive. AITC possesses numerous biochemical and physiological activities. It is cytotoxic and tumorigenic at high doses and also is a modulator of enzymes involved in metabolism of xenobiotics, including carcinogens. It is plausible that the wide consumption of dietary AITC may have profound effects on human health. To facilitate investigations of the effects of dietary AITC in humans, a method of measuring its uptake is needed. In this study, a urinary marker was developed for quantifying AITC uptake in humans. Four adult volunteers were asked to eat a meal containing brown mustard as the source of AITC. The 48-h urine samples were collected from these individuals and analyzed by reverse phase high performance liquid chromatography. A major urinary metabolite was found, which was identified as *N*-acetyl-*S*-(*N*-allylthiocarbamoyl)-L-cysteine, the *N*-acetylcysteine conjugate of AITC, by comparing its retention time and UV, nuclear magnetic resonance, and mass spectra with those of the synthetic standard. After ingestion of mustard, the AITC conjugate was detected in urine collected from 0 to 12 h. No conjugate was found in urine samples collected after 12 h. The major portion of this metabolite was excreted within 8 h. The average total excretion of AITC conjugate was 5.4 ± 1.7 (SD) mg after consumption of 10 g of mustard and 12.8 ± 2.0 mg when 20 g of mustard was consumed. Thus, a dose-dependent excretion of this metabolite was demonstrated. The average conversion rate of AITC to its urinary *N*-acetylcysteine conjugate in humans was estimated to be 53.5 ± 8.1%. These results suggest that the urinary *N*-acetylcysteine conjugate of AITC may be a convenient and useful biomarker for quantifying human exposure to AITC.

Introduction

AITC[3] is widely present in cruciferous vegetables such as cabbage, broccoli, kale, cauliflower, and horseradish (1–3). It is also commonly used in the human diet as a flavor agent (4). Like other isothiocyanates, AITC inhibits microsomal enzyme activities (5). Previous studies have shown that liver microsomes, obtained from rats that were fed a diet containing AITC, metabolize nitrosamines to a lesser extent than those of the untreated rats (6). AITC and its glucosinolate precursor, sinigrin, given in the diet, also inhibit hepatic DNA methylation induced by the tobacco-specific nitrosamine 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone in rats (6–8). These results suggest the potential of AITC in modulating the carcinogenic activities of nitrosamines, since many arylalkyl isothiocyanates structurally related to AITC are known to be inhibitors of lung tumorigenesis induced by 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (9). It was shown recently that AITC inhibits the growth of human cancer cells *in vitro* (10). Furthermore, several authors have reported that AITC induces the Phase II detoxification enzyme glutathione *S*-transferases (11, 12). On the other hand, chronic treatment with high doses of AITC induces urinary bladder tumors in rats (13). The diverse biochemical and biological activities of AITC and its wide consumption suggest its potential effects on human health.

Human exposure to AITC is mainly through the consumption of mustard, in particular brown mustard, and cruciferous vegetables. Because information on the exact content of AITC in these foods usually is not available and sometimes is impossible to obtain due to different storage and cultivation conditions, it is difficult to estimate the uptake of AITC in humans (4). Therefore, a marker would be useful to quantitatively monitor human exposure to AITC through diet. This information will be used to evaluate in epidemiological investigations the possible effects of dietary AITC on human health. Previously, it has been shown that the *N*-acetylcysteine conjugate of AITC (Fig. 1) is a urinary metabolite in rodents treated with AITC (14, 15). The urinary metabolites of the structural analogues of AITC, BITC and PEITC, have been studied in humans (16, 17). In this study, we describe the identification and use of the *N*-acetylcysteine conjugate of AITC as a simple and con-

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[1] This work was supported by National Cancer Institute Grant CA 46535.
[2] To whom requests for reprints should be addressed, at American Health Foundation, Division of Chemical Carcinogenesis, 1 Dana Road, Valhalla, NY 10595.

[3] The abbreviations used are: AITC, allyl isothiocyanate; BITC, benzyl isothiocyanate; PEITC, phenethyl isothiocyanate; HPLC, high performance liquid chromatography; NMR, nuclear magnetic resonance; s, singlet; d, doublet; t, triplet; dd, doublet of doublets; ddd, doublet of doublets of doublets; ddt, doublet of doublets of triplets.

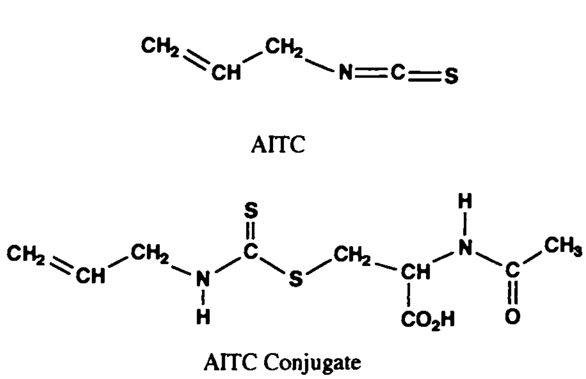

Fig. 1. Structures of AITC and its *N*-acetylcysteine conjugate.

venient urinary marker for the uptake of AITC after a mustard meal.

Materials and Methods

Instrumentation. NMR spectra were recorded on a Bruker AM 360 WB spectrometer using methanol-d_4 as solvent. Negative ion desorption chemical ionization mass spectra were obtained on a Hewlett-Packard 5988A mass spectrometer. A HPLC system (Waters Associates, MA) equipped with an automatic gradient controller, two Model 501 pumps, and a Waters 990 photodiode array detector in conjunction with reverse-phase C_{18} columns were used in the analyses and purification of the *N*-acetylcysteine conjugate of AITC. A Varian 3400 gas chromatograph equipped with a fused silica capillary column (60 m x 0.32 mm inside diameter, 1 µm thickness, DB-1; J & W, Inc.) and a flame ionization detector were used to analyze the concentration of AITC in the mustard paste.

Chemicals. AITC was purchased from Aldrich Chemical Co. (Milwaukee, WI) and *N*-acetylcysteine was purchased from Sigma Chemical Co. (St. Louis, MO). The *N*-acetylcysteine conjugate of AITC was prepared as described in the literature (18) and was characterized by ^{1}H, ^{13}C-NMR spectroscopy, and mass spectrometry. The measured chemical shifts (δ) and coupling constants (J) are given as: ^{1}H-NMR (360 MHz, in CD_3OD, δ in ppm referenced to tetramethylsilane, 2.00 (3H, s, CH_3), 3.55 (1H, dd, J: 14.1, 8.6 Hz, Cys-CH_2), 4.02 (1H, dd, J: 14.1, 4.7 Hz, Cys-CH_2), 4.28–4.40 (2H, ddd, J: 12.2, 5.6, 1.5 Hz, allyl-CH_2), 4.72 (1H, dd, J: 8.6, 4.7 Hz, Cys-CH), 5.18 (1H, ddd, J: 10.2, 1.5, 1.5 Hz, *cis*-vinyl-CH_2), 5.26 (1H, ddd, J: 17.2, 1.5, 1.5 Hz, *trans*-vinyl-CH_2), 5.94 (1H, ddt, 17.2, 10.3, 5.7 Hz, vinyl-CH); ^{13}C-NMR (92.52 MHz, in CD_3OD, δ in ppm referenced to tetramethylsilane), 199.2 ($\underline{C}$=S), 173.5, 173.2 (two $\underline{C}$=O), 133.7 ($\underline{C}$H=), 117.6 ($\underline{C}H_2$=), 53.8 (Cys-$\underline{C}$H), 50.4 (allyl-$\underline{C}H_2$), 38.3 (Cys-$\underline{C}H_2$), 22.8 (N-$\underline{C}H_3$); MS *(m/e)*, 261 (M-H), 244, 221, 162, 131 (base peak), 58. Grey Poupon Dijon mustard was purchased from a local grocery store and kept refrigerated after opening. Mustard was chosen as a source of AITC because it is frequently used in cooking and thus it is relatively convenient to use in human studies.

Quantitative Analysis of AITC in Grey Poupon Country Dijon Mustard. Grey Poupon Dijon Mustard paste (100 g), combined with *tert*-butyl isothiocyanate (14.36 mg) as an internal standard, was thoroughly mixed with 1000 ml of distilled water and 200 g of NaCl. The mixture was stirred with 200 ml of CH_2Cl_2 for 3 h and then filtered through Celite 545. After filtration, the CH_2Cl_2 phase was separated from the aqueous phase and subsequently dried over 20 g of anhydrous Na_2SO_4. After removing Na_2SO_4 by filtration, the CH_2Cl_2 extract was concentrated by a stream of N_2 gas. The concentrated extract was used in the gas chromatography analysis using the following conditions: injector temperature, 270°C, detector temperature, 300°C; helium carrier flow rate, 1 ml/min; temperature program, 40°C (5 min), 2°C/min, 260°C (20 min); split ratio, 50:1.

Human Studies. Two experiments using different amounts of mustard were performed. Each experiment involved four adult volunteers (two males and two females, age 20–45). In the first experiment, 10 g of mustard was ingested with bagel or bread at breakfast by each participant. All participants were advised to avoid cruciferous vegetables, mustard, and mustard flavored foods in the diet 2 days prior to and during the experiment. In the control experiment, all participants were asked to eat the same food as in the experimental diet with the only exception of mustard. In the second experiment, participant 1 in the first experiment was replaced by another volunteer of the same sex. The same protocol was used except that 20 g of mustard was consumed with turkey or chicken sandwiches in a lunch. In both experiments, urine samples were collected at intervals of 0–2, 2–4, 4–8, 8–12, 12–24, 24–36, and 36–48 h following breakfast or lunch. Urine samples were analyzed immediately or stored at −20°C overnight. After thawing, an aliquot (50 µl) of clear urine sample (the sample was centrifuged if not clear) was analyzed by a reverse phase HPLC system consisting of a Waters C_{18}-µBondapak column eluted isocratically with acetonitrile (10%) in 20 mM phosphate buffer (pH 3.0) at a flow rate of 1 ml/min.

Quantification. The HPLC peak of AITC conjugate detected at wavelength of 254 nm was used for integration. Standard solutions were prepared in 20 mM phosphate buffer (pH 3.0) with various concentrations of a synthetic *N*-acetylcysteine conjugate of AITC. The urinary metabolite was quantified with a calibration curve obtained using these standard solutions, which is linear over the concentration range examined (10^{-6} to 10^{-4} M). The urine samples were analyzed in the same fashion as the standards. Single and triple HPLC measurements were performed for samples obtained from experiments 1 and 2, respectively.

Isolation and Identification of the *N*-Acetylcysteine Conjugate of AITC in Human Urine. All crude urine samples collected in experiment 1 from 2–4 h following ingestion of mustard were combined (800 ml). Ammonium sulfate (160 g) was added and dissolved in the urine. The pH of the solution was adjusted to 3 with 12 N HCl. The acidic medium prevents possible decomposition of the conjugate during the work-up process. The solution was extracted with ethyl acetate (2 × 200 ml). The organic phase was washed twice with water (100 and 40 ml) and once with saturated NaCl solution (40 ml). After removing the solvent by a rotary evaporator under vacuum, the solid residue was dissolved in 5 ml of deionized water. Using a semipreparative reverse-phase C_{18} HPLC column (Whatman Partisil 10 ODS-3 column Magnum 9), a mobile phase of 20% acetonitrile in 20 mM aqueous phosphate buffer (pH 3.0), and an isocratic elution at a flow rate of 2.5 ml/min, the AITC conjugate eluted at 30 min was purified and obtained in sufficient quantity after repetitive runs. The collected fractions were combined and evaporated to dryness under vac-

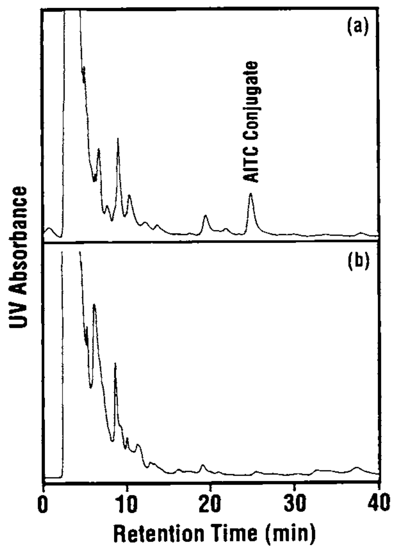

Fig. 2. Reverse phase HPLC chromatograms obtained from analysis of human urine after the mustard ingestion *(a)* and before the mustard ingestion *(b).*

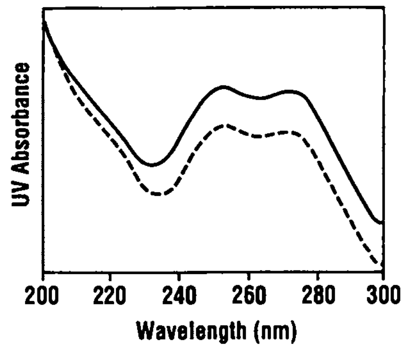

Fig. 3. Comparison of UV spectra of the synthetic AITC conjugate (——) and the urinary metabolite (- - - -).

uum. The residue was extracted with methanol. The extracts were combined and the solvent was removed in a vacuum to afford a solid. The compound was identified as the *N*-acetylcysteine conjugate of AITC by comparing its retention time, UV, ^{1}H-NMR, and mass spectra with those of the synthetic conjugate.

Results

Two separate experiments were performed to establish the uptake-dependent excretion of the AITC conjugate in humans. In each experiment, a major metabolite of AITC was identified in the urine collected after ingestion of mustard and the metabolite was not present in the urine after consuming the control diet (Fig. 2). The peak at 25.2 min coelutes with the synthetic standard of the *N*-acetylcysteine conjugate. This compound was isolated and purified from crude urine samples as described in "Materials and Methods." It has the same characteristic UV absorptions as the synthetic standard (Fig. 3). Its identity was further confirmed to be *N*-acetyl-*S*-(*N*-allylthiocarbamoyl)-L-cysteine by comparing its ^{1}H-NMR and mass spectra with those of the synthetic standard (Fig. 4).

In both experiments, the *N*-acetylcysteine conjugate of AITC was detected in all urine samples collected within 12 h after ingestion of mustard. The detection limit using this method is in the 1–10 ng range. No metabolite was detected in the urine after 12 h by using the direct measurement described here or by using organic solvent extraction procedures reported previously (16). The cumulative amounts of the AITC conjugate in the urine collected at different time intervals are shown in Table 1. Normally, the amount of excreted AITC conjugate reaches the maximum between 2 and 8 h. The amount of excretion depends on both the concentration of AITC conjugate in urine and the volume of urine collected in a given time interval. The maximum concentration of AITC conjugate excreted in urine was observed at 2–4 h following ingestion of mustard, as shown in Fig. 5. The majority of the conjugate was excreted within 8 h. The total average excretion is proportional to the amount of mustard consumed, *i.e.,* 5.4 ± 1.7 (SD) mg (3.6–7.6 mg) and 12.8 ± 2.0 mg (10.5–15.2 mg) are excreted corresponding to 10 and 20 g of mustard consumed. These results showed an uptake-dependent excretion of the AITC metabolite after mustard meals.

Consistent with the literature report (18), we have found that the *N*-acetylcysteine conjugate of AITC is in equilibrium with its free form. In our study, the equilibrium was evident by the presence of a small peak eluting after the conjugate which coeluted with AITC under the HPLC conditions used. A significant percentage of the *N*-acetylcysteine conjugate of AITC decomposed during an extended period of storage in a neutral medium, even at −20°C. Because of its instability, caution should be taken in quantifying the levels of this conjugate in the urine. Previously, we have found that PEITC is stabilized in acidic medium (16); it is likely that the AITC conjugate would be considerably more stable at acidic pH.

Although brown mustard is known to be rich in AITC (4), the exact content of AITC in the commercial products was not available. We have used gas chromatography to quantitatively analyze AITC in the mustard paste used in the human experiments. The result showed that the AITC content of the mustard is 453 ppm, or 0.453 mg of AITC/g of mustard. Using this information, we were able to calculate the conversion rate of AITC to its *N*-acetylcysteine conjugate in humans, as shown in Table 2. The average of the individual conversion rates is 53.5 ± 8.1%, which is consistent with the previous studies on the metabolism of BITC and PEITC in humans (16, 17). Those studies have shown that the conversion rates of these two isothiocyanates to their corresponding urinary *N*-acetylcysteine conjugates are 53.7 ± 5.9% and 47 ± 16%, respectively. Assuming that the average conversion rate of AITC obtained here is applicable to a larger population and is independent of the source of AITC, one may estimate the amount of AITC to which humans were recently exposed through the consumption of various foods and vegetables by simply measuring their urinary excretions of the *N*-acetylcysteine conjugate of AITC.

Discussion

The *in vivo* metabolism of several natural isothiocyanates has been studied in rodents and humans. For instance, the *N*-acetylcysteine conjugates of AITC and PEITC are excreted in the urine of mice (14, 19), although the major

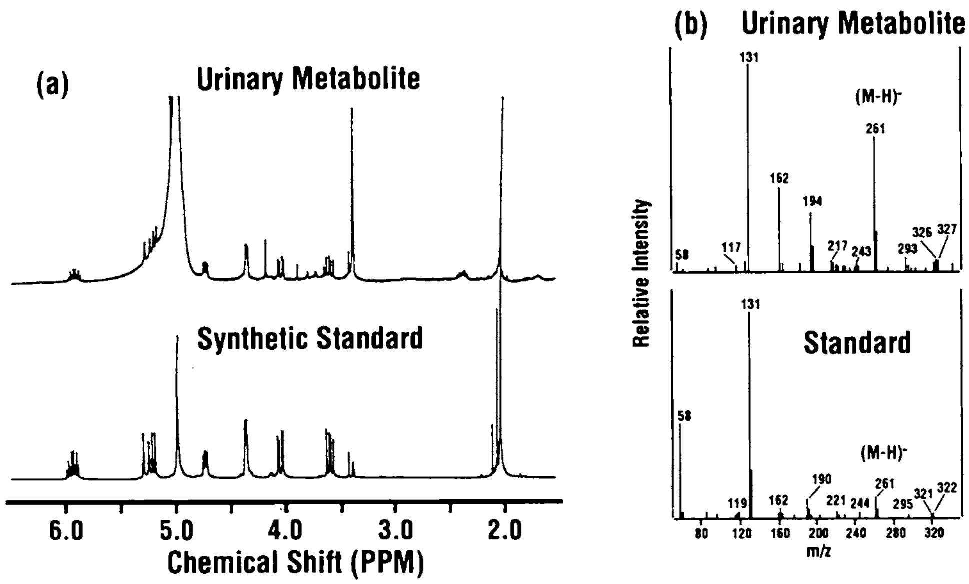

Fig. 4. *(a)* Comparison of the 360 MHz ^{1}H-NMR of the synthetic standard of the *N*-acetylcysteine conjugate of AITC and the metabolite isolated from human urine samples after ingestion of mustard. Note that differences for solvent peak intensities at 3.35 and 4.97 ppm are due to the different concentrations of the two samples. The resonances for the AITC conjugate are identical in two spectra. *(b)* Comparison of their mass spectra. The major fragments $C_4H_5NS_2$ (131 *m/e*) and C_2H_4NO (58 *m/e*) for the AITC conjugate negative ion (261 *m/e*) were observed in both spectra.

Table 1 Cumulative amounts of the *N*-acetylcysteine conjugate of AITC in human urine 12 h after ingestion of mustard

Subject	Time interval (h)	Experiment 1		Experiment 2	
		AITC conjugate[a] (mg)	Total excretion (mg)	AITC conjugate[b] (mg)	Total excretion (mg)
1[c]	0–2	0.7		2.8 ± 0.1	
	2–4	2.6		4.0 ± 0.2	
	4–8	2.4		3.2 ± 0.1	
	8–12	1.6	7.6	0.5 ± 0.1	10.5
2	0–2	2.6		4.7 ± 0.1	
	2–4	1.1		[d]	
	4–8	ND[e]		5.0 ± 0.1	
	8–12	ND[e]	3.6	3.6 ± 0.1	13.3
3	0–2	3.6		2.8 ± 0.1	
	2–4	[d]		6.1 ± 0.5	
	4–8	1.2		2.9 ± 0.2	
	8–12	0.4	5.3	0.5 ± 0.0	12.3
4	0–2	1.1		1.9 ± 0.2	
	2–4	1.2		5.4 ± 0.1	
	4–8	2.2		6.2 ± 0.6	
	8–12	0.4	4.9	1.7 ± 0.2	15.2

[a] Based on one measurement for each sample.
[b] Mean ± SD of three separate determinations.
[c] Subject 1 participated in experiment 1 but was replaced by another individual of the same sex in experiment 2.
[d] No urine was excreted during this period.
[e] ND, not determined due to peak overlap.

metabolite of PEITC in mice is a cyclic mercaptopyruvic conjugate (19). However, the *N*-acetylcysteine conjugates are the major urinary metabolites in rats treated with AITC and BITC (15, 20). In humans, the *N*-acetylcysteine conjugates of BITC and PEITC appear to be the only urinary metabolites following ingestion of BITC, gardencress, and watercress (16, 17). However, to the best of our knowledge, the metabolism of AITC in humans has not been reported before.

Conjugations of isothiocyanates with glutathione appear to be the major metabolic pathway in humans, since most of their urinary metabolites are mercapturic acids or other derivatives from glutathione conjugates (14–19). Although the Phase II enzyme glutathione *S*-transferase-catalyzed conjugation of isothiocyanates is considered to be a natural detoxification process (16, 17), it has been postulated that this pathway may also be involved in the cyto-

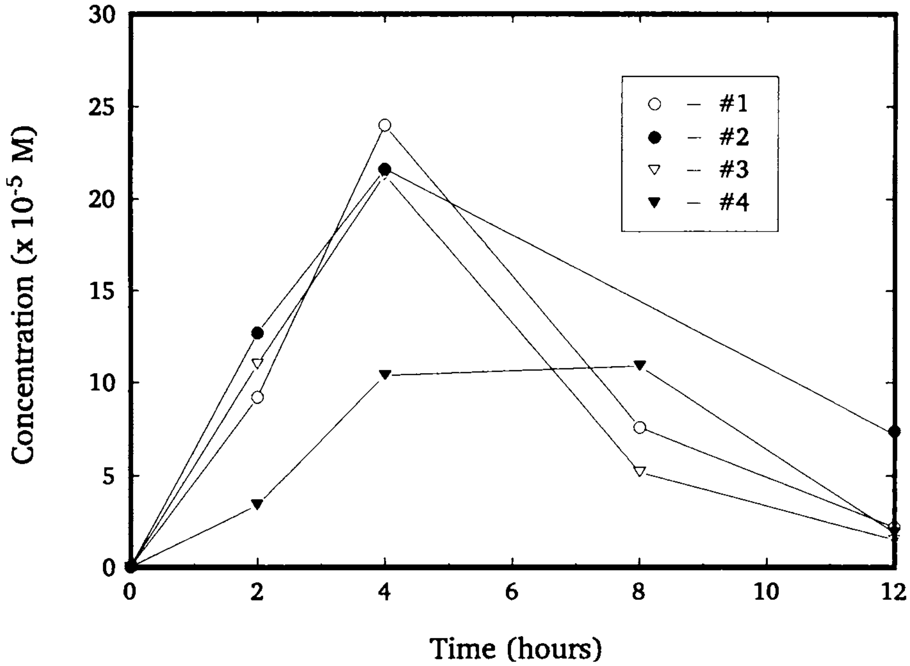

Fig. 5. The concentration of the *N*-acetylcysteine conjugate of AITC in urine collected from four volunteers *versus* time (hours) following the ingestion of mustard in experiment 2.

Table 2 Estimated percentage of conversion of allyl isothiocyanate to the *N*-acetylcysteine conjugate of AITC in human after a mustard meal[a]

Subject	Total conjugate excreted (mg)	AITC equivalent (mg)	Conversion (%)
1	10.5	4.0	44.2
2	13.3	5.0	55.2
3	12.3	4.6	50.8
4	15.2	5.7	63.4

[a] Based on 0.453 mg/g weight of AITC in Grey Poupon mustard consumed in experiment 2.

toxicity of isothiocyanates (18). The glutathione conjugates of isothiocyanates are usually subject to further degradation to give final metabolites, the *N*-acetylcysteine conjugates of isothiocyanates, by enzymes such as γ-glutamyltranspeptidase, cysteinylglycinase, and *N*-acetyltransferase (20). Recently, the activities of the detoxification enzyme glutathione *S*-transferase have been associated with the risk of certain human cancers (21, 22). A survey of smokers demonstrated that individuals lacking glutathione *S*-transferase μ had a significantly higher incidence of lung cancer than those who display glutathione *S*-transferase μ activity (23). A discrepancy between phenotyping and genotyping the isozymes of glutathione *S*-transferase in relation to the risk of lung cancer in smokers was also reported (24, 25). The levels of excretion of the AITC conjugate in the urine following mustard consumption may be used to phenotype an individual for the activity of these enzymes. Therefore, it would be important to identify the specific glutathione transferase isozymes responsible for the conjugation of AITC.

It has been well documented that compounds in cruciferous vegetables induce Phase II detoxification enzymes, such as quinone reductase and glutathione *S*-transferase (11, 26). An isothiocyanate isolated from broccoli, (−)-1-isothiocyanato-(4R)-(methylsulfinyl)butane (CH_3-SO-$(CH_2)_4$-NCS, sulforaphane), was shown to be a strong Phase II enzyme inducer (27). Knowing that consumption of vegetables reduces the risk of cancer (28, 29), it is noteworthy that these isothiocyanates isolated from natural sources, including AITC, PEITC, and sulforaphane, may function as either Phase I enzyme inhibitors (5, 30, 31), which prevent the activation of carcinogens, and/or as Phase II enzyme inducers (11, 27). Much work is needed to further establish the detailed mechanism regarding how these naturally occurring compounds may work in humans to reduce the risk of cancer. The results presented here should provide a useful tool in the epidemiological investigations of the biological role of AITC in humans.

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Allyl isothiocyanate as a cancer chemopreventive phytochemical

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Abstract

Allyl isothiocyanate (AITC), which occurs in many common cruciferous vegetables, is widely and often frequently consumed by humans. Besides antimicrobial activity against a wide spectrum of pathogens, it showed anticancer activity in both cultured cancer cells and animal models, although the underlining mechanisms remain largely undefined. Bioavailability of AITC is extremely high, as nearly 90% of orally administered AITC is absorbed. AITC absorbed in vivo is metabolized mainly through the mercapturic acid pathway and excreted in urine. Available data suggest that urinary concentrations of AITC equivalent are at least 10 times higher than in the plasma, and tissue levels of AITC equivalent in the urinary bladder were 14-79 times higher than in other organs after oral AITC administration to rats. These findings suggest that AITC may be most effective in the bladder as a cancer chemopreventive compound. AITC at high dose levels also exhibit a low degree of cytotoxicity and genotoxicity in animal studies, but such adverse effects are unlikely in humans exposed to dietary levels of AITC. Overall, AITC exhibits many desirable attributes of a cancer chemopreventive agent, and further studies are warranted in order to elucidate its mechanism of action and to assess its protective activity in humans.

Keywords

allyl isothiocyanate; chemoprevention; cruciferous vegetable; sinigrin

1 Introduction

Allyl isothiocyanate (AITC), also known as mustard oil, is one of the most common naturally occurring isothiocyanates (ITCs) [1,2]. ITCs occur primarily in cruciferous vegetables, many of which show significant cancer chemopreventive activities, and therefore are widely suspected to account in part for the cancer preventive activities of these vegetables in humans [3]. Sulforaphane is perhaps the most widely known crucifer-derived cancer chemopreventive ITC [4]. ITCs are synthesized and stored in cruciferous vegetables as glucosinolates (*β*-thioglucoside *N*-hydroxysulfate), which are believed to be chemically and biologically inert, and formed from the latter when plant tissues are damaged. The conversion is catalyzed by myrosinase (a thioglucoside glucohydrolase), first forming thiohydroximate-O-sulfonates, which rapidly and spontaneously rearrange to give rise to ITCs. Myrosinase coexists with but is physically separated from glucosinolates under normal conditions. Conversion (up to 40%) to ITCs of ingested glucosinolates that escape plant myrosinase may take place in vivo, as the intestinal microflora of both humans and animals also possess myrosinase activity [5-7].

AITC is derived from sinigrin, as shown in Fig. 1, which is the predominant glucosinolate in many commonly consumed cruciferous vegetables, such as Brussels sprouts, cabbage,

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cauliflower and kale [1,8], and are particularly abundant in mustard, horseradish and wasabi [9,10]. For example, each gram of fresh wasabi yields as much as 34 μmol sinigrin/AITC [10]. Conversion of sinigrin to AITC by human microflora myrosinase has been well documented [11,12]. However, the yield of AITC in certain vegetables such as cabbage may vary significantly, due to the presence of an epithiospecifier protein, which promotes formation of 1-cyano-2,3-epithiopropane, at the cost of AITC [8]. Interestingly, a recent study has found that 1-cyano-2,3-epithiopropane induces Phase 2 genes and affords cytoprotection [13]. AITC is a liquid at ambient temperature (melting point of -80°C) and has a very pungent taste, apparently due to its activation of the transient receptor potential A1 channel (TRPA1) in sensory neurons [14,15]. Indeed, AITC is responsible for the pungent taste of the above-mentioned vegetables, and synthetic AITC is sometimes deliberately added to some vegetable products such as a prepared horseradish meal to enhance the flavor. AITC appears to serve the plant as a defense against herbivores, as chewing the plant by the herbivores generates AITC that presumably repels them.

Human exposure to AITC is undoubtedly widespread and frequent, as many common cruciferous vegetables are a rich source of AITC, but the exposure levels have not been well documented. A large number of studies on the biological response to AITC have been published, many of which suggest that AITC is a highly attractive cancer chemopreventive agent. But a few other studies also raised the concern of potential toxicity. In this review, the evidence that argues for and against AITC as a cancer chemopreventive agent is presented and discussed: it is divided into five sections, including bioavailability and metabolic disposition of AITC, cellular uptake and tissue distribution of AITC, antimicrobial activity of AITC, anticancer activity of AITC, and dichotomy of cytoprotective activity and toxicity of AITC. To the best of my knowledge, a similar review on AITC has not been published. Hence, this article may be a useful reference on the biological response to AITC, as most if not all of the relevant data are cited and discussed herein.

2 Bioavailability and metabolic disposition of AITC

More than 90% of a single oral dose of [^{14}C]AITC (25 or 250 μmol/kg body weight) was absorbed in mice and rats, and in both instances nearly 80% of the administered doses was recovered in the urine [16,17]. These results indicate extremely high bioavailability of AITC and that absorbed AITC is primarily eliminated in the urine. Our recent study showed that urinary elimination of AITC was very rapid, as approximately 75% and 0.6% of a single oral dose of AITC were detected in the urine collected in the first and second 24-h periods after dosing [18]. No apparent sex-related differences were observed in the ability of these animals to absorb and dispose AITC. Human absorption and disposition of AITC appear to closely resemble that of animals, as studies showed that at least 42-54% of the dose was recovered in the urine as a metabolite (see the next paragraph for detail) within 10-12 h after each human volunteer was given 45-90 μmol of AITC supplied as either a horseradish paste or a mustard paste [5,19].

Although covalent modification of lysine residues (through the NH_2 group) of protein by AITC can take place in physiological conditions [20], it predominantly undergoes conjugation with cysteine residues (through the SH group). AITC is primarily metabolized through the mercapturic acid pathway in vivo (Fig. 2). An initial conjugation through its –N=C=S group with glutathione (GSH) gives rise to the corresponding conjugate, which then undergoes further enzymatic modifications to finally form NAC conjugate, which is excreted in the urine. In rats dosed orally with [^{14}C]AITC, approximately 80% of the ^{14}C in the urine was present as the NAC conjugate, with the majority of the remaining radioactivity detected as thiocyanate [16, 17]. It is not clear if thiocyanate was generated directly from AITC or its NAC conjugate, nor is it known to possess any cancer chemopreventive activity. In contrast, in mice dosed orally with [^{14}C]AITC, less than 20% of the urinary radioactivity was related to the NAC conjugate, and the level in female mice appeared to be only half of that in male mice, whereas the majority of the remaining radioactivity was associated with thiocyanate [16,17]. The NAC conjugate was also the major metabolite in humans, as 42-54% of the dose was recovered in the urine as NAC-AITC within 10-12 h in each volunteer who consumed AITC [5,19], although it is not known if AITC gives rise to thiocyanate in humans. Thus, the rat appears to resemble human more than mice in AITC metabolism.

3 Cellular uptake and tissue distribution of AITC

Studies in our laboratory have shown that AITC as well as other ITCs rapidly accumulate in cells. ITCs appear to enter cells by diffusion, but once in the cell, ITCs are rapidly conjugated with intracellular thiols [21-23]. GSH, which is the most abundant intracellular thiol, was found to be the major driving force for ITC accumulation [22], and cellular GSTs enhance ITC accumulation by promoting the conjugation reactions [24]. Not surprisingly, ITCs that are already conjugated with thiols, such as GSH, cysteine, and NAC, were unable to accumulate in cells [22]. Indeed, addition of excess GSH to culture medium was shown to completely block the cytotoxicity of AITC and benzyl ITC [25]. The peak intracellular ITC accumulation was achieved within 0.5-3 h of exposure, reaching 100-200-fold over the extracellular ITC concentration, and the total intracellular ITC accumulation can reach millimolar levels [21, 22].

However, intracellularly accumulated GSH conjugates of ITCs, perhaps other thiol conjugates as well, were exported out of cells rapidly. For example, the half-time stay of the accumulated sulforaphane equivalent in human prostate cancer LNCaP cells was only about 1 h [26]. The export of ITC conjugates appears to be mediated, at least partly, by membrane drug transporters, e.g., multidrug resistance associated protein-1 (MRP-1) [26,27]. Thus, continuous intracellular accumulation may only be possible when ITCs persist in the extracellular space at a level that allows cellular uptake of ITC to offset the rapid export of the accumulated conjugates. Total intracellular accumulation levels of ITC (area under time-concentration curve) may be critical for their biological activity, as we previously showed that the total intracellular accumulation levels of ITCs determined their activity to induce Phase 2 cytoprotective enzymes [21,28].

Bollard et al reported that the peak levels of AITC equivalents in the blood of mice and rats, following a single oral dose of [^{14}C]AITC at 25 and 250 μmol/kg, were approximately 0.04 mM and 0.5 mM, respectively [17]. Our recent study showed that the average 24-h urinary concentrations of AITC equivalent were 0.36 and 4.2 mM, respectively, following a single oral dose of AITC at 25 and 250 μmol/kg [18]. These results show that the average urinary concentrations of AITC equivalent are nearly 10 times higher than the peak levels of AITC equivalent in the blood, following AITC consumption. In fact, the difference may be much greater, because the blood levels of AITC equivalent were determined based on an all-inclusive radioactivity measurement, whereas the urinary levels of AITC equivalent were measured using the cyclocondensation assay which detects only free AITC and AITC metabolites formed in the mercapturic acid pathway [18], excluding other metabolites such as thiocyanate. Consistent with this analysis, urinary concentrations of ITC equivalent were 2-3 orders of magnitude higher than that in the plasma of rats fed orally with ITCs contained in broccoli sprout extracts (mainly sulforaphane), where all samples were measured by the cyclocondensation assay [29]. Not surprisingly, Bollard et al found that tissue levels of radioactivity in the bladder were 14-79 times higher than in other organs after a single oral dose of [^{14}C]AITC at 250 μmol/kg (Table 1) [17]. Thus, urinary bladder is by far the most exposed organ in vivo to orally ingested ITCs, including AITC, apparently resulting from selective urinary disposition of its metabolites, mainly the NAC conjugate. The NAC conjugates of ITCs as well as other ITC metabolites formed in the mercapturic acid pathway serve as carriers of ITCs, as they are unstable and dissociate to the parent ITCs [25,30].

4 The antimicrobial activity of AITC

Whereas sinigrin itself is not known to possess anti-microbial properties, AITC displays bactericidal activity against a variety of pathogenic bacteria, including Helicobacter pylori, Escherichia coli, Salmonella typhimurium, Staphylococcus aureus, Streptococcus mutans, Penicillium notatum, Bacillus cereus, and *Vibrio parahaemolyticus*, with the minimum bactericidal concentrations of AITC (the lowest concentration needed for complete inhibition of growth) ranging from 3.8 μM to 16.7 mM [31-33]. It has not been clearly understood why the minimum bactericidal concentrations of AITC varied so widely, but it was reported that change in pH in the culture medium from 4.5 to 8.5 elevated the minimum bactericidal concentration against *Escherichia coli* by 20 fold [32]. The anti-microbial activity is a property shared by many ITCs, and the activity of AITC appears to be relatively weak compared with several other ITCs. For example, the bactericidal activities of phenethyl ITC against 3 strains of *Helicobacter pylori* were 7.8-20.5 times more potent than AITC [31]. The implication of the bactericidal activity of AITC in cancer and infection in humans is unclear, although *Helicobacter pylori* is known to cause gastritis, gastric ulcer and gastric cancer in humans.

AITC also showed fungicidal activity against a variety of fungi and yeasts, including Aspergillus flavus, Endomyces fibuliger, Penicillium commune, Penicillium corylophilum, Penicillium discolor, Penicillium palitans, Penicillium polonicum, Penicillium roqueforti, Penicillium solitum, and Pichia anomala [34], and the mustard oil, of which 99% was AITC, was one of the strongest antifungal substances among the various natural oils examined [35].

The mechanism by which AITC kills bacteria or fungi is largely unknown, but its action appears to resemble polymyxin B [36], which is known to bind to cell membrane and to increase its permeability. AITC was also shown to significantly inhibit both thioredoxin reductase and acetate kinase isolated from *Escherichia coli* at approximately 100 μM [32]. These enzymes play an important role in cell growth and proliferation. In addition, AITC was also shown to cause oxidative stress and DNA damage in *Escherichia coli* [37]. Furthermore, as described below, studies in mammalian cells have revealed other mechanisms by which AITC causes cell death, some of which may be relevant to its bactericidal activity. However, both glutathione and cysteine were shown to almost completely abolish the bactericidal effect of AITC [38], which likely resulted from inhibition of its cellular uptake, as these agents were shown to block ITC uptake by mammalian cells (see Section 3 for detail).

5 The anticancer activity of AITC

5.1 Inhibition of cell proliferation

Whereas sinigrin itself is not known to possess any antiproliferative activity, AITC inhibits proliferation of various types of human cancer cells, with the IC50 values at the low micromolar range, regardless of their tissue origins and p53 status, and even in drug resistant cells that over express drug transporter MRP-1 or Pgp-1 [39-43]. In fact, exposure of cells to AITC for only 3 h seems sufficient to achieve growth inhibition [39,42]. More interestingly, AITC appears to be significantly less toxic to normal cells. For example, 83% of normal human prostate epithelial cells were viable following a 24-h exposure to 40 μM AITC, whereas only 36-38% of human prostate cancer cells (LNCaP cells and PC-3 cells) survived under similar conditions of AITC treatment [40]. Detransformation of human colorectal cancer HT29 cells also rendered them more resistant to the cytotoxic effect of AITC, elevating the maximal concentration at which no cell is killed from 3.2 μM in HT29 cells to 7.4 μM in detransformed counterparts (24 h treatment) [41]. The IC50 value of AITC in normal human bladder epithelial cells is

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approximately 10 times higher than that in human bladder cancer cells (our unpublished observation).

5.2 Cell cycle arrest and induction of apoptosis

Inhibition of cell proliferation by AITC was associated with cell cycle arrest and/or induction of apoptosis. AITC at concentrations near its IC50 value caused significant arrest of cells (up to 80%) in either G1 phase or G2/M phase. For example, it arrested human leukemia HL60 cells in G1 phase [39], but caused G2/M arrest in bladder cancer UM-UC-3 cells [42], human cervical cancer HeLa cells [44], human colorectal cancer HT29 cells [45], and human prostate cancer cells (PC-3 and LNCaP) [40]. Smith et al subsequently showed that approximately 25% of AITC-treated HT29 cells were arrest in M phase. The reason as to why AITC causes G1 arrest in some cells but G2/M arrest or M arrest in other cells is not known. In LNCaP cells, however, where AITC causes G2/M arrest, AITC was shown to modulate a number of important G2/M regulators, including down regulation of cyclin B1, cdk1, cdc25B and cdc25C, and to cause the disruption of tubulin [40,45].

Treatment of HL60 cells with AITC at 10 μM for 24 h rendered nearly 30% cells apoptotic, which was associated with disruption of mitochondrial transmembrane potential, activation of several caspases (caspse-3, -8, -9 and -12), and activation of c-Jun N-terminal kinase (JNK) [39,46]. AITC also significantly induced apoptosis in PC-3 cells and LNCaP cells, which was associated with down regulation of anti-apoptotic Bcl-2 and Bcl-xl and activation of extracellular signal-regulated kinase and JNK [40,47]. However, AITC was a poor apoptosis inducer in other cell lines, such as HT29 cells and UM-UC-3 cells (no more than 5% cells became apoptotic after AITC treatment) [42,45]. Interestingly, it is of note that AITC induces c-Jun, a key component of activator protein 1 (AP-1), increased the transactivation activity and/or DNA binding activity of AP-1 in both HT29 cells and UM-UC-3 cells [48,49]. The pro-survival or apoptosis inhibitory function of AP-1 is well known.

5.3 Other anticancer activities

Matrix metalloproteinases (MMPs) play important roles in cancer metastasis. Both AITC and its NAC conjugate were reported to significantly inhibit the transcription of MMP-2/-9 in human hepatoma SK-Hep1 cells at 0.1-5 μM, which was associated with inhibition of cell adhesion, migration and invasion [50]. MMP-2 and MMP-9 degrade components of basement membrane and are strongly implicated in the invasion and metastasis of cancer cells [51,52]. The extent of histone acetylation also influences the growth of cancer cells and increasing histone acetylation is a recognized strategy for cancer prevention and therapy [53,54]. AITC at 20 μM was shown to stimulate histone acetylation in mouse erythroleukemia DS19 cells, but this does not appear to result from inhibition of histone deacetylase [55]. However, sulforaphane was shown to inhibit histone deacetylase in cancer cells [56]. AITC was also found to significantly inhibit the production of nitric oxide (NO) and the expression of inducible nitric oxide synthase (iNOS) in lipopolysaccharide-treated J774.1 macrophages at <10 μM [57], and to inhibit NF-κB activation in lipopolysaccharide-treated HT-29 cells at 25-100 μM [58]. NO, iNOS and NF-κB are important signaling molecules in inflammation and cancer.

5.4 Inhibition of tumor growth

Intraperitoneal injection of 10 μmole AITC (approximately 333 μmol/kg body weight) three times per week for three weeks, beginning the day of tumor cell inoculation, inhibited PC-3 human prostate cancer xenografts in athymic mice by approximately 45%, with no apparent toxicity [59]. In another study, male Wistar rats were given dimethylhydrazine (DMH) subcutaneously twice (separated by 5 days) to induce aberrant crypt foci in the colonic mucosa, and AITC or sinigrin was given to the rats in the diet for 5 weeks, starting the next day after the second dose of DMH. Both sinigrin and AITC reduced the number of DMH-induced aberrance crypt foci in the colonic mucosa by approximately 40% [60]. Interestingly, in this study, sinigrin was more potent than AITC, as sinigrin at 1 μmol/kg diet was as effective as AITC at 4 μmol/kg diet. Since sinigrin itself is not known to possess cancer preventive activity, its inhibition of DMH-induced colonic aberrant crypt foci formation most likely resulted from its myrosinase-catalyzed conversion to AITC in vivo. In another study where hepatocarcinogenesis in ACI/N rats was induced by adding diethylnitrosamine in drinking water for 5 week, dietary supplementation with sinigrin at 1200 ppm (3 μmol sinigrin/g diet) during the carcinogen treatment period also reduced tumor incidence by 50% and reduced tumor multiplicity by more than 90% [61]. However, in 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK)-induced lung tumorigenesis in A/J mice, where a single oral dose of AITC at 1 or 5 μmol/mouse was given to the animal 2 h prior to a single intraperitoneal injection of NNK and lung tumorigenesis assessed 16 weeks later, AITC was ineffective, while a number of synthetic ITCs, especially 1-dodecyl ITC and 1,2-diphenylelthyl ITC were highly effective under the same experimental conditions [62]. The last animal model differs from other three models in that it is designed to evaluate acute inhibition of carcinogen activation (inhibition of carcinogen-activating enzymes) by a test agent.

6 The dichotomy of cytoprotective activity and toxicity of AITC

6.1 Stimulation of cytoprotective mechanisms

AITC has been shown to induce several Phase 2 enzymes, including NAD[P]H:quinone oxidoreductase-1, glutathione S-transferase, glutamate cysteine ligase and/or heme oxygenase 1 in both cultured cells in vitro and animal tissues in vivo [18,21,28,42,63-65]. Induction of the Phase 2 proteins by AITC must have resulted at least in part from the activation of nuclear factor erythroid 2-related factor 2 (Nrf2), a key transcription activator of the above-mentioned Phase 2 genes and many other genes, as AITC at 25 μM rapidly and markedly elevated Nrf2 level and Nrf2 transactivation activity in human hepatoma HepG2 cells [28,63]. Nrf2 activates Phase 2 gene transcription by binding to the upstream regulatory element, namely the antioxidant response element (ARE). Indeed, McWalter et al showed that AITC was unable to stimulate the transcription of the downstream gene linked to a mutated ARE [65]. Given that Nrf2 is known to regulate a variety of Phase 2 genes and other genes [66], AITC probably stimulates many such genes. Because many Phase 2 proteins are major cellular antioxidant and carcinogen detoxification enzymes, it seems reasonable to assume that AITC would prevent oxidant- and carcinogen-induced damage. Indeed, AITC was found to significantly inhibit in a dose-dependent manner the formation of gastric lesions induced by ethanol, hydrochloric acid, ammonia, aspirin, and indomethacin in Sprague-Dawley rats at the oral dose levels of 1.25-10 mg/kg body weight (12.5-100 μmol/kg) [67].

However, to what extent stimulation of cytoprotective proteins by AITC contributes to its cancer chemopreventive activity is not clear. Nor is it clear whether activation of Nrf2 signaling attenuates its anticancer activities such as induction of cell cycle arrest and apoptosis of cancer cells.

6.2 Cytotoxicity and genotoxicity of AITC

Pretreatment of HepG2 cells with AITC at up to 6 μM for 24 h enhanced benzo(a)pyrene (BP)-induced DNA damage by almost 2 fold, as measured by the single cell gel electrophoresis assay [68]. The reason why AITC increased BP genotoxicity is not known, as its effect on Nrf2 and carcinogen-detoxifying enzymes was not measured in these cells. Treatment of HL60 cells with AITC at 2-5 μM for only 3 h was shown to cause DNA damage and the formation of 8-oxo-7,8-dihydro-2'-deoxyguanosine, which was thought to result from increased formation of reactive oxygen species [69]. Intracellular generation of reactive oxygen species and DNA damage were also detected in bacterial cells treated with AITC [70].

However, DNA damage by AITC in HepG2 cells (formation of micronucleus) was negligible in HeLa cells (unscheduled DNA synthesis), and its mutagenicity in bacterial cells (Ames test) occurred only at relatively high concentrations (>50 μM) [37,71]. Nor did AITC cause significant chromosome aberrations or sister chromatic exchanges in a SV40-transformed Indian muntjac cell line and a Chinese hamster ovary cell line even at highly cytotoxic doses [72,73]. Likewise, unscheduled DNA synthesis was not detected in the livers of Sprague-Dawley rats receiving a single oral dose of AITC up to 125 mg/kg body weight (1.25 mmol/kg) [74].

Rats receiving a single oral dose of AITC at approximately 13 mg/kg showed reduced uptake of iodine by the thyroid gland [75], suggesting a weak goitrogenic activity of AITC. However, another study showed that rats (Shoe: WIST) given AITC at oral doses up to 40 mg/kg 5 days/week for 4 weeks did not show any changes in thyroid weight, even though the highest AITC dose caused a significant decrease in body weight [76]. F344 rats and B6C3F1 mice given oral AITC at 50 mg/kg body weight (500 μmol/kg) 5 days per week for 2 weeks showed a thickened mucosal surface of the stomach in both rats and mice and a thickened urinary bladder wall in male mice, but no gross or microscopic lesions were detected in the animals given oral AITC at 25 mg/kg (250 μmol/kg) 5 days per week for 13 week [77]. In a further experiment where F344 rats and B6C3F1 mice of either sex were administered orally with 12 or 25 mg/kg (120 or 250 μmol/kg) AITC 5 times per week for 103 weeks [77], urinary bladder cancer was detected in 4% and 8% male rats treated with the low and high doses of AITC respectively, whereas no bladder tumor was detected in any other groups. Subcutaneous fibrosarcoma was detected in 6% of female rats receiving the high dose of AITC, but not in any other groups. Human relevance of these findings is likely to be very limited, if any, because average human consumption of AITC has been estimated to be less than 1 mg/day (approximately 10 μg/kg body weight) [78]. The sex-, species-, and organ-specific susceptibilities of tumorigenesis to AITC have not been well understood. A single instillation of AITC into the urinary bladder of female F344 rats at 2.8 mg/ml/kg body weight for 2 h via the urethra using a catheter caused acute toxic damage to the bladder, including hemorrhage, inflammatory cell infiltration, vacuolar degeneration and apoptosis/necrosis of the mucosal/submucosal tissues, and delayed increase in BrdU labeling index [79]. But interpretation of this data needs caution, because AITC was given at very high concentration (28 mM), and its NAC conjugate (the principal urinary metabolite) was not examined.

7 Concluding remarks

AITC, a common dietary phytochemical, presents many desirable attributes of a cancer chemopreventive agent, including extremely high bioavailability after oral administration, rapid uptake by cells, microbicidal activity against a wide spectrum of pathogens, significantly higher toxicity in malignant cell than in normal cells, its ability to rapidly induce cancer cell death regardless of its tissue origin or p53 status and even in drug resistant cells, activation of Nrf2 signaling, and inhibition of cancer development in vivo. However, the AITC dose levels used in the preclinical studies are far greater than what humans are normally exposed to, raising the question of whether the preclinical data are relevant to humans and whether dietary consumption of AITC significantly contributes to cancer prevention in humans. The observation that bladder is the tissue which is by far the most exposed to orally administered AITC, apparently resulting from its almost exclusive elimination through the urine, suggests that AITC may most be useful for bladder cancer prevention.

The molecular mechanisms by which AITC attacks bacteria, fungi, and cancer cells remain poorly defined, but the putative chemopreventive mechanisms are summarized in Fig. 3. Further studies are needed to verify and extend these findings. Chronic administration of AITC to rodents at high doses levels caused low incidence of urinary bladder transitional cell carcinoma and subcutaneous fibrosarcoma among other toxicities. But it is highly unlikely that such toxicities would occur in humans, because dietary consumption levels of AITC appear to be several orders of magnitude lower than the doses used in the animal studies.

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Abbreviations

AITC	allyl isothiocyanate
DMH	dimethylhydrazine
GSH	glutathione
ITC	isothiocyanate
NAC	*N*-acetylcysteine
Nrf2	nuclear factor erythroid 2-relarted factor 2

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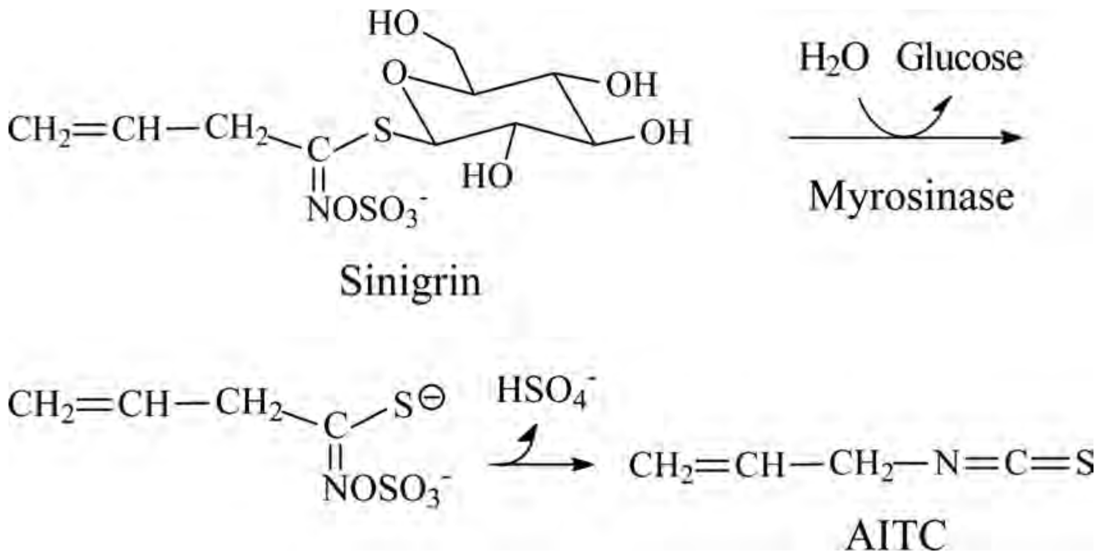

Figure 1.
Myrosinase-catalyzed conversion from sinigrin to AITC

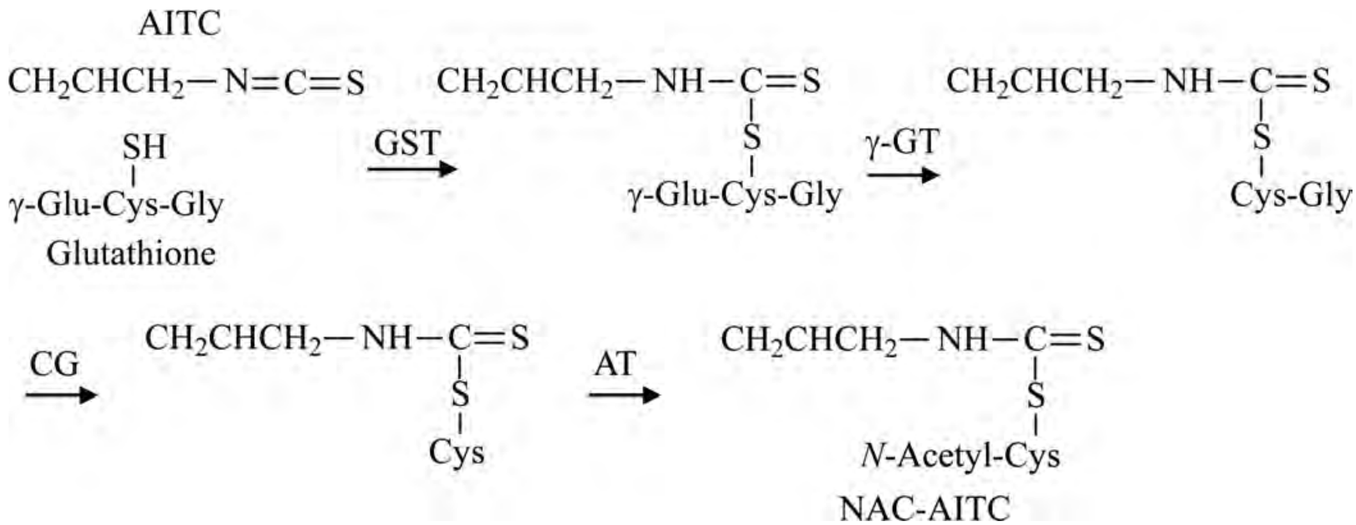

Figure 2.
AITC metabolism through the mercapturic acid pathway. GST, glutathione S-transferase; γ-GT, γ-glutamyltranspeptidase; CG, cysteinylglycinase; AT, *N*-acetyltransferase.

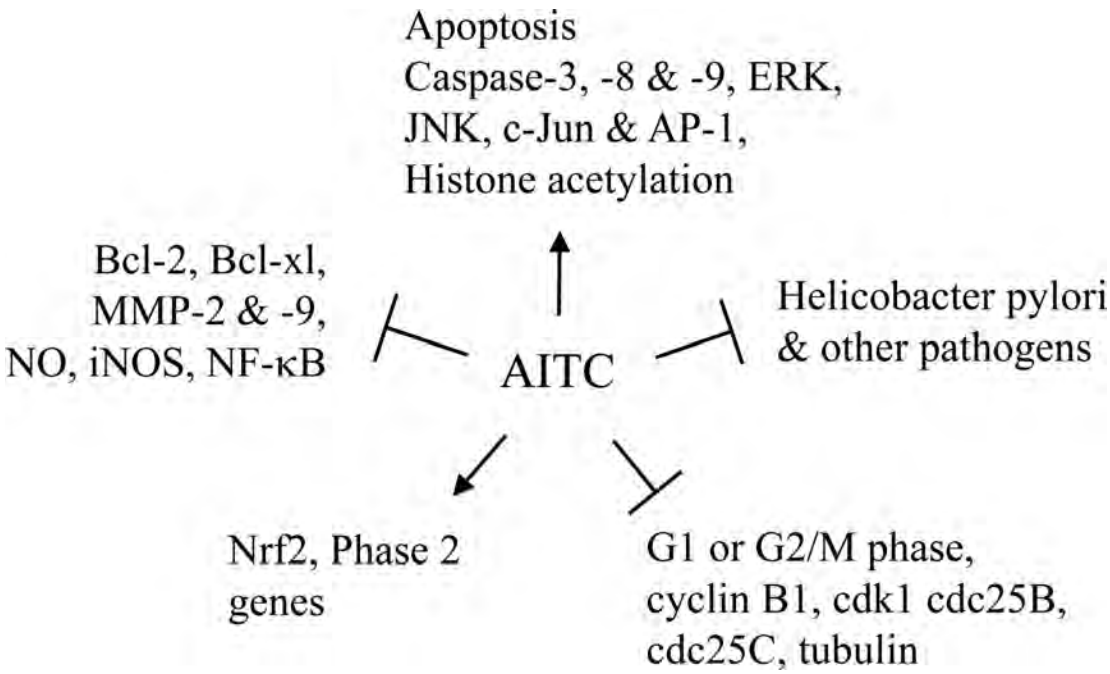

Figure 3.

Putative cancer chemopreventive mechanisms of AITC. The arrows indicate activation, and the Ts indicate inhibition. The information is compiled from a collection of published studies in different cell lines, which are discussed in this review. AP-1, activator protein 1; ERK, extracellular signal-regulated kinase; iNOS, inducible nitric oxide synthase; JNK, c-Jun N-terminal kinase; MMP-2 &-9;matrix metalloproteinase-2 & -9; NO, nitric oxide; Nrf2, nuclear factor erythroid 2-relarted factor 2.

Table 1

Amounts of radioactivity remaining within the organs of rats at various time intervals following oral administration of [^{14}C]AITC[a)]

Time after oral doing (h)	µg equivalent of [^{14}C]AITC/g wet tissue weight				
	Urinary bladder	**Brain**	**Kidney**	**Liver**	**Spleen**
0.33	235.3 ± 48.7	3.6 ± 3.0	18.1 ± 8.0	12.4 ± 1.7	10.5 ± 7.2
1	248.5 ± 27.4	2.8 ± 0.6	14.4 ± 3.6	14.5 ± 2.6	10.4 ± 3.7
2	248.3 ± 22.8	3.5 ± 1.6	19.3 ± 2.4	14.5 ± 3.6	9.6 ± 0.4
6	215.0 ± 39.9	3.0 ± 3.0	19.7 ± 6.7	16.0 ± 4.8	8.8± 3.7

[a)] A single oral dose of [^{14}C]AITC at 250 µmol/kg was administered to male F344 rats and the organs were then collected at the indicate time points and measured for radioactivity (ref 17). The results in female rat were similar.

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Mustard Cover Crops Are Ineffective in Suppressing Soilborne Disease or Improving Processing Tomato Yield

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Abstract. **Mustard (*Brassica* spp.) cover crop residue has been reported to have significant 'biofumigant' action when incorporated into soil, potentially providing disease suppression and yield improvement for the succeeding crop. The effects of growing over-winter mustard cover crops preceding processing tomato (*Lycopersicon escultentum* Mill.) production were investigated in six field trials in the Sacramento Valley of California from 2002–04. A selection of mustard cover crops were compared to a legume cover crop mix, a fallow-bed treatment (the current grower practice in the region), and in two of the six trials, fumigation treatments using metam sodium. Mustard cover crops removed 115 to 350 kg·ha^{-1} N from the soil profile, reducing NO_3-N leaching potential. Soil populations of *Verticillium dahliae* Kleb. and *Fusarium* spp. were unaffected by the cover crops, and there was no evidence of soilborne disease suppression on subsequent tomato crops. Mustard cover crops increased tomato yield in one field, and reduced yield in two fields. In one of two fields, metam sodium fumigation significantly increased tomato yield. We conclude that, while environmental benefits may be achieved, mustard cover cropping offers no immediate agronomic benefit for processing tomato production.**

Processing tomato is an important crop in the Sacramento Valley of California, and the sustainability of tomato production from both an economic and environmental perspective has been the subject of considerable research. Between the Sustainable Agriculture Farming Systems (SAFS) (Clark et al., 1999) and the Long-term Research on Agricultural Systems (LTRAS) (Denison et al., 2004) projects there have been nearly 20 site-years comparing organic, reduced input, and conventional production practices. One feature of organic and reduced input systems that might be useful in conventional production is the use of over-winter cover crops; currently nearly all commercial fields in the region are maintained in a fallow condition before tomato production. In both the SAFS and LTRAS projects over-winter cover cropping improved soil physical and biological properties (Clark et al., 1998; Colla et al., 2000; Martini et al., 2003; Poudel et al., 2001); unfortunately, the direct effects of cover cropping on tomato yield were unclear, since other management differences (fertilizer, weed control, direct seeding vs. transplanting, etc.) among production systems were confounding factors. Miyao and Robbins (2000) evaluated cover cropping in conventionally managed Sacramento Valley tomato fields across three production seasons (1998–2000). In all years cover cropping significantly reduced winter runoff and increased tomato yield up to 7% compared with a winter fallow treatment. Although the factors responsible for yield improvement were not identified, possible mechanisms included improved in-season irrigation water infiltration (Colla et al., 2000) or suppression of soilborne diseases (VanBruggen, 1995).

While cover crop evaluation in the SAFS and LTRAS projects centered on legumes due to their contribution to N fertility, the use of other types of cover crops may be more appropriate in conventional rotations where N availability is seldom a production constraint. Given their widely documented biofumigation effects (Brown and Morra, 1997; Fenwick et al., 1989), mustard cover crops (family *Brassicaceae*) present a potentially useful alternative. Mustards contain glucosinolates, compounds that upon hydrolysis release isothiocyanates (ITCs) and related compounds with broad biocidal activity. Among the soil pathogens reported to be effectively suppressed by the action of mustard residues are *Verticillium dahliae* (Olivier et al., 1999; Subbarao et al., 1999), *Sclerotinia minor* (Subbarao, 1998), and *Helminthosporium solani* (Vaughn et al., 1993). This study was conducted to evaluate the effects of over-winter mustard cover crops on soil pathogen populations, disease expression and fruit yield in conventionally managed processing tomato rotations.

Materials and Methods

Field trials were conducted at the University of California–Davis (UCD) and in commercial fields in Yolo County, Calif., from 2002–04. At UCD in 2002 processing tomatoes were grown in a Yolo silt loam soil. Production practices typical of the local commercial industry were used. Following harvest in early September, crop residue was incorporated into the raised, 1.5-m-wide beds, which were maintained so that the existing buried drip irrigation system could be reused the following season. The following cover crops were seeded on 22 Nov: 1) 'Humus' (rape, *Brassica napus* L.); 2) 'Pacific Gold' [indian mustard, *B. juncea* (L.) Czern.]; 3) 'Ida Gold' (white mustard, *Sinapis alba* L.); 4) 'ISCI 20' (*S. alba*); and 5) a mixture of 'Lana' woolypod vetch (*Vicia dasycarpa* Ten.), 'Magnus' pea (*Pisum sativum* L.), and 'Cayuse' oat (*Avena sativa* L.). The cover crops were sown and lightly incorporated on the top of the raised beds. A fallow bed control treatment was also included to represent the typical over-winter management practice. The experimental design was randomized complete block, with four replications; individual plots were one bed wide × 30 m long.

Cover crops were germinated by precipitation and were allowed to grow undisturbed until 28 Mar. 2003, when above-ground biomass was determined. One representative 0.5-m^2 section per plot was harvested, and cover crop fresh and dry biomass recorded. On 31 Mar. cover crops were flail-mowed and immediately incorporated to a depth of about 15 cm with two passes of a bed disk. The field was left undisturbed until mid-May when the soil beds were fertilized at 20 and 25 kg·ha^{-1} N and P, respectively. Tomato transplants ('Halley') were set in the field on 23 May. The crop was sprinkler-irrigated for establishment, then drip-irrigated for the remainder of the season. An additional 165 kg·ha^{-1} N was applied through the drip system over the growing season. A destructive fruit harvest was made on 17 Sept., with total fruit yield determined; marketable yield was determined after the removal of cull (green, sunburned and rotten) fruit. Soluble solids concentration of marketable fruit (°Brix, by refractometer) was measured, and the soluble solids yield (marketable yield × °Brix, a measure of overall productivity) was calculated.

In Fall 2003, a second experiment was initiated at UCD. A field of Yolo silt loam in which processing tomatoes had been grown that summer was prepared for cover crop planting. A randomized complete block design was used, with four replications of six treatments; individual plots were one 1.5-m bed wide × 30 m long. The following cover crops were seeded on 6 Nov.: 1) 'Pacific Gold'; 2) 'Caliente' (a commercial blend of two separate cultivars, one *B. juncea* and one *S. alba*); and 3) vetch–pea–oat mixture. Additional treatments were a winter fallow, winter fallow plus spring-applied metam sodium, and 'Pacific Gold' plus spring-applied metam sodium. The cover crops were sown on the bed tops and germinated by precipitation.

On 18 Mar. 2004, the cover crops were flail-mowed and immediately incorporated as described for the 2002–03 trial. The beds were then rolled and sprinkler-irrigated for 6 h to provide ideal conditions for hydrolysis of glucosinolates in the cover crop residue. Before incorporation, cover crop above-ground fresh and dry biomass was determined on a 0.6-m^2 section of each plot. Metam sodium (Soil Prep; Wilbur Ellis Co., San Francisco, Calif.) was applied to designated plots 1 week after cover

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crop incorporation, into soil near field capacity moisture content. The fumigant was applied through the buried drip irrigation system at 89 kg·ha^{-1} a.i. in 60 m^3·ha^{-1} of water. Preplant fertilizer was applied at 20 and 25 kg·ha^{-1} N and P, respectively. 'Heinz 9665' transplants were planted in single rows per bed on 6 May. Irrigation and additional N fertilization were as described for the previous season. A destructive fruit harvest was made on 31 Aug. Total and marketable fruit yield, and fruit soluble solids yield, were determined.

Four commercial field trials were initiated near Woodland, Calif., in Fall 2003; site characteristics and cultural details are given in Table 1. At one site (designated Woodland A) five overwintering treatments were compared: 1) 'Pacific Gold'; 2) 'Caliente'; 3) vetch–pea–bell bean (*Vicia faba* L. var. *equina*) mixture; 4) winter fallow; and 5) winter fallow + spring-applied metam sodium. The experimental design was randomized complete block with 6 replications; individual plots were three beds wide × 45 m long. Cover crops were seeded 6 Nov. and incorporated 16 Mar. 2004. Cover crop biomass was determined on 1-m^2 sections of the middle bed of each plot before incorporation; biomass of the *B. juncea* and *S. alba* components of the 'Caliente' blend were evaluated separately. Cover crops were flail-mowed and immediately incorporated with a bed disc. One week after incorporation metam sodium was applied at 107 kg·ha^{-1} a.i. in designated plots by a tractor-mounted applicator through four injection shanks per bed.

In the remaining fields (designated Woodland B, C, and D), fall-seeded 'Caliente' blend was compared to fallow bed management. At these sites the experimental design was randomized complete block, with 10, 8, and 5 replications, respectively; individual plots were 3 beds wide by 30 to 45 m long. Mustard biomass was determined as at Woodland A. Mustard plots were flail-mowed and incorporated by disking within 30 min. At commercial maturity, all Woodland field trials were machine harvested; total and marketable fruit yield and fruit soluble solids yield were determined.

Glucosinolate concentration of above-ground mustard biomass was determined for all 2003–04 trials except Woodland C. Immediately before soil incorporation, five to six representative whole plants were collected from each of three plots of each type of mustard cover crop; for the 'Caliente' blend, *B. juncea* and *S. alba* plants were collected and analyzed separately. The plants were freeze-dried and ground to pass through a 1-mm mesh screen. Concentrations of the primary glucosinolates (benzyl, 2-propenyl, 2-phenylethyl, 2-hydroxy-3-butenyl, and 4-hydroxybenzyl) were determined by gas chromatography using a modification of the procedure of Daun and McGregor (1991).

Net N mineralization rate from 2003–04 cover crop residues was evaluated in a laboratory incubation. Oven-dried cover crop samples were ground and analyzed for total N content by combustion (Carlo Erba 1500; Fisons Instruments, Beverly, Mass.). Soil from the UCD site was wetted to field capacity. Ground residue from each cover crop type from each site was blended into the moist soil at 0.5% by dry weight. Three replicate subsamples of moist, unamended soil, and of each residue/soil blend, were extracted in 2 N KCl and analyzed for mineral N concentration (NO_3-N + NH_4-N) using a flow injection analyzer (Lachat Instruments, Milwaukee, Wis.). The remainder of the unamended moist soil and the soil–residue blends were incubated in sealed containers at 20 °C; the containers were vented weekly to maintain aerobic conditions. After four weeks triplicate samples of unamended soil and of each soil–residue blend were extracted in 2 N KCl for determination of mineral N concentration. The change in mineral N, adjusted for the change in unamended soil, represented net N mineralization or immobilization by the residue.

The effect of cover crops on soilborne pathogens was evaluated at four of the 2003–04 trial sites. At UCD and Woodland A soil samples were collected in Fall 2003, before cover crop planting, and again in Spring 2004, before transplanting tomatoes. In each plot a composite sample of 12 soil cores (0 to 15 cm deep) was collected. After the sample was homogenized, a 3-g sample was added to 30 mL of 0.1% water agar. Following agitation for 5 min, two aliquots of 1 mL each were plated on selective media (pectate agar for *Verticillium dahliae* and Komada's medium for *Fusarium* spp.). Depending on the concentration of propagules in the soil, dilutions were adjusted to achieve a visually manageable number of colonies on the plates. Colonies of *V. dahliae* and *Fusarium* spp. were counted with the aid of a dissecting microscope. Soil pathogen data were analyzed by the ANCOVA procedure (SAS Institute, Cary, N.C.) using soil pathogen population preceding cover crop production as the covariate in the analysis of the spring populations.

During the 2004 tomato season significant foliar expression of plant infection by *V. dahliae* (Woodland A), fusarium foot rot (*Fusarium solani*) (Woodland B), and fusarium wilt (*F. oxysporum* f.sp. *lycopersici* W.C. Snyder & H.N. Hans.) (Woodland C) were observed. At each site the number of plants exhibiting disease symptoms was recorded 4 to 6 weeks before harvest. The identity of each pathogen was confirmed by plating symptomatic tissue on water agar or potato–dextrose agar.

Results

Mustard cover crops produced high biomass at UCD and the Woodland A and C sites, with much less biomass at Woodland B and D (Table 2). Where it was grown, the legume mix had substantially lower biomass than any mustard, undoubtedly due to the relatively early incorporation dates used. With the exception of the Woodland B site (following wheat), all 2003–04 mustard cover crops had high tissue N concentration. Above-ground biomass N ranged from 115 kg·ha^{-1} ('Caliente' at Woodland B) to 350 kg·ha^{-1} ('Pacific Gold' at Woodland A). Fertilization of the mustard cover crops was done only at Woodland B (60 kg·ha^{-1} N); elsewhere, mustard biomass N represented uptake of residual and mineralized soil N. The low-N 'Caliente' residue from Woodland B showed net N immobilization over 4 weeks of incubation, equivalent to about 6 kg·ha^{-1} N; in that field a seasonal total of 160 kg·ha^{-1} N was applied to the tomato crop, an amount sufficiently in excess of normal fertilizer requirement (Krusekopf et al., 2002) to overcome any adverse effect of cover crop immobilization. All other samples showed substantial net N mineralization, averaging about 20% of N content. The N concentration of cover crop residue was positively correlated with net N mineralization rate (r = 0.76).

Tissue glucosinolate concentration varied among sites and between mustard cultivars, averaging 16 mmol·kg^{-1} dry tissue (Table 2). *B. juncea* tissue contained mostly 2-propenyl glucosinolate, while the benzyl and 4-hydroxybenzyl forms were predominate in *S. alba* tissue. Total above-ground glucosinolate content of mustard residues ranged from 75 to 153 mol·ha^{-1}.

Cover crops had no significant suppressive effects on soil populations of *V. dahliae* or *Fusarium* spp. In Spring 2004, *Verticillium* populations varied from 4 to 14 colony forming units (cfu)/g at UCD and 11 to 24 cfu/gat Woodland A. *Fusarium* populations ranged from 4,000 to 5,700 cfu/g at UCD and 3,200 to 4,100 cfu/g at Woodland A. No significant foliar expression of soilborne disease was observed at UCD in 2004, or at Woodland D. At Woodland A the percent of plants showing foliar symptoms of *V. dahliae* infection was unaffected by cover crops; only the metam sodium treatment showed significant reduction in foliar symptoms (Table 3). At Woodland B *Fusarium* foot rot incidence was not significantly reduced by the cover crop. At Woodland C incorporation of 'Caliente' residue resulted in a significant increase in the percentage of plants showing foliar symptoms of *Fusarium* wilt; by harvest this disease had killed most plants in both the cover crop and fallow treatments, precluding fruit yield measurement.

At UCD cover crops had no significant effect on tomato fruit yield or soluble solids

Table 1. Site characteristics and cultural details of the 2003–04 commercial cover crop trials.

	Site			
	Woodland A	Woodland B	Woodland C	Woodland D
Soil texture	Silt loam	Fine sandy loam	Silty clay loam	Silt loam
2003 summer crop	Tomato	Wheat	Tomato	Tomato
Cover crop seeding date	6 Nov.	14 Nov.	19 Nov.	21 Nov.
Cover crop incorporation date	16 Mar.	14 Mar.	18 Mar.	23 March
Tomato cultivar	Heinz 9780	PS 347	Heinz 9780	HM 849
Transplanting date	16 Apr.	9 Apr.	21 May	11 May
Tomato harvest date	23 Aug.	30 Aug.	Crop loss	15 Sept.

Table 2. Above-ground cover crop biomass, nitrogen concentration, net nitrogen mineralization, and glucosinolate content; parentheses indicate standard errors.

Year	Site	Cover crop	Dry biomass (Mg·ha^{-1})	N (g·kg^{-1})	N mineralization (%)[z]	Total glucosinolates (mmol·kg^{-1})	Total glucosinolates (mol·ha^{-1})
2002–03	UCD	Humus	6.8 (0.1)				
	UCD	Pacific Gold	7.0 (0.5)				
	UCD	Ida Gold	8.3 (1.1)				
	UCD	ISCI 20	9.2 (0.9)				
	UCD	Legume mix	3.8 (0.6)				
2003–04	UCD	Pacific Gold	6.7 (0.6)	40	23 (4)	17 (4)	113 (29)
	UCD	Caliente[y]	8.2 (0.4)	33	13 (3)	16 (3)	129 (24)
	UCD	Legume mix	3.7 (0.2)	41	25 (4)		
	Woodland A	Pacific Gold	9.2 (0.5)	38	18 (2)	11 (2)	98 (14)
	Woodland A	Caliente	9.9 (0.3)	31	7 (1)	16 (1)	153 (2)
	Woodland A	Legume mix	5.2 (0.4)	37	25 (1)		
	Woodland B	Caliente	6.0 (0.2)	23	–5 (2)	13 (1)	75 (5)
	Woodland C	Caliente	8.1 (0.2)	41	9 (4)		
	Woodland D	Caliente	4.7 (0.2)	46	19 (1)	24 (3)	113 (12)

[z]Percent of biomass N mineralized in 4 weeks of soil incubation at 20 °C; negative number indicates net immobilization.
[y]*Brassica juncea* and *Sinapis alba* portions analyzed separately at all sites; data presented are weighted means.

Table 3. Incidence of foliar symptoms of soilborne disease, 2003–04 commercial trials.

Site	Over-winter field treatment	Disease	Foliar symptoms (% of plants)
Woodland A	Fallow	Verticillium wilt	41 a
	Fallow + metam sodium		19 b
	Pacific Gold		37 a
	Caliente		46 a
	Legume mix		42 a
Woodland B	Fallow	Fusarium foot rot	21
	Caliente		16
			NS
Woodland C	Fallow	Fusarium wilt	52 b
	Caliente		70 a

[z]Mean separation by Duncan's mean separation test at $p < 0.05$.
[NS]Nonsignificant at $p < 0.05$.

Table 4. Effect of over-winter field treatment and spring-applied metam sodium on yield of tomato fruit, and fruit soluble solids.

Site	Over-winter field treatment	Fruit yield (Mg·ha^{-1}) Total	Marketable	Fruit solids[z] (Mg·ha^{-1})
UCD 2002–03	Fallow	113	102	5.25
	Pacific Gold	106	95	5.02
	Ida Gold	105	94	5.08
	ISCI 20	107	95	5.14
	Humus	106	96	5.01
	Legume mix	111	100	5.16
		NS	NS	NS
UCD 2003-04	Fallow	122	110	5.27
	Fallow + metam sodium	126	117	5.67
	Pacific Gold	110	101	5.09
	Pacific Gold + metam sodium	117	108	5.29
	Caliente	110	104	5.09
	Legume mixture	122	110	5.24
		NS	NS	NS
Woodland A	Fallow	144 b[y]	121 b	5.58 ab
	Fallow + metam sodium	153 a	131 a	5.69 a
	Pacific Gold	134 c	109 cd	5.12 cd
	Caliente	129 c	106 d	5.00 d
	Legume mix	136 c	114 c	5.35 bc
Woodland B	Fallow	137 a	117	5.42
	Caliente	124 b	108	5.24
			NS	NS
Woodland D	Fallow	143	116 b	4.90
	Caliente	153	123 a	5.21
		NS		NS

[z]Marketable yield × soluble solids concentration (°Brix)
[y]Mean separation within sites by Duncan's mean separation test at $p < 0.05$.
[NS]Nonsignificant at $p < 0.05$.

yield in either year (Table 4). In 2004, metam sodium, alone or in combination with 'Pacific Gold', was similarly ineffective at UCD. However, at Woodland A, metam sodium significantly increased both total and marketable yield compared to the winter fallow treatment, which in turn had higher yield than any cover crop treatment. Both mustard cover crops had lower soluble solids yield than either the fallow or metam sodium treatments. Yield reduction with cover crops may have been due in part to damaging populations of darkling ground beetles (*Blapstinus* spp.), which were concentrated primarily in cover crop plots; chemical treatment and limited replacement of damaged transplants in those plots was necessary. Also, the grower established the transplants with irrigation through a buried drip irrigation system. At transplanting, soil moisture in cover crop plots was lower than in fallow plots, the result of cover crop transpiration during spring growth; differences in early season water availability may have affected tomato growth in cover crop plots.

Total fruit yield at Woodland B was significantly lower in 'Caliente' plots compared to the fallow treatment. The opposite result was observed at Woodland D, where 'Caliente' production resulted in increased marketable tomato yield. No fruit yield was obtained at Woodland C, where *Fusarium* wilt resulted in a complete crop loss.

Discussion:

In six field trials the use of over-wintering mustard cover crops had no consistent effects on soilborne disease suppression or tomato fruit productivity. The lack of effective disease suppression may have been attributable to several factors: insufficient glucosinolate content in the residue, incomplete conversion of glucosinolates to ITCs, or inefficient field management practices that reduced biofumigation effectiveness. While tissue glucosinolate concentrations were similar to those reported elsewhere (Lazzeri et al., 2003; Morra and Kirkegaard, 2002), and the amount of mustard biomass achieved at most of the sites was substantial, total glucosinolate content of the mustard residues was very low in comparison to typical application rates of synthetic fumigants like metam sodium. The metam sodium treatments used at UCD and Woodland A contained 690 and 830 mol·ha^{-1} of ITC-forming compounds, respectively, or 5 to 11 times the molar equivalent glucosinolate content of mustard residues at those sites. Since the toxicity of different ITCs varies widely (Sarwar et al., 1998) a direct molar comparison is simplistic; however, the relatively small amount of glucosinolate contained in mustard residues suggested a practical limitation to their effectiveness in disease suppression. Given the wide genotypic variation in glucosinolate concentration among mustard cultivars (Kirkegaard and Sarwar, 1998), further selection and breeding may significantly increase glucosinolate content of field-grown mustard cover crops.

Perhaps more important than total glucosinolate content of mustard residues are the factors governing release, distribution and retention of ITCs in the soil following residue incorporation. ITC release from mustard tissues requires hydrolysis of glucosinolates by myrosinase (Brown and Morra, 1997); since myrosinase and glucosinolates are separated in intact mustard tissues, the degree of tissue maceration during cover crop incorporation can greatly affect ITC formation. Morra and Kirkegaard (2002) reported that no more than 1% of ITC predicted from tissue glucosinolate concentration was measured in soil amended with mustard leaf tissue; cellular disruption by freezing and thawing increased ITC release efficiency, but to no more than 26%. Once mustard tissue is macerated, ITC release is rapid. Brown et al. (1991) reported that ITC concentration reached a maximum only 2 h after soil incorporation, and declined by >90% within 24 h. Lazzeri et al. (2004) found that 40% or more of initial glucosinolate content was lost if tissue was allowed to dry.

These factors suggest that grower management of mustard residues could greatly affect biofumigation effectiveness. For maximum effect, mustard residues need to be thoroughly shredded and immediately incorporated into moist soil. To the extent practical, those practices were followed in these field trials; in all fields the cover crops were flail-mowed and incorporated within <1 h. To prevent soil compaction the growers were forced to schedule these operations when the soil was drier than field capacity moisture content, potentially allowing some tissue desiccation. At UCD in 2004 sprinkler irrigation was applied immediately after incorporation to minimize this problem. Yet even with these efforts to optimize practices, no significant biofumigation effects were observed in any field.

Other researchers have reported that field-grown *Brassica* crops effectively suppressed soilborne disease in succeeding crops, increasing crop productivity. Examples include take-all (*Gaeumannomyces graminis*) on wheat (Kirkegaard et al, 2000), sclerotinia drop (*Sclerotinia minor*) on lettuce (Hao and Subbarao, 2003), and verticillium wilt (*Verticillium dahliae*) on cauliflower (Subbarao et al., 1999). In each of these studies, however, it was unclear whether ITC release from *Brassica* tissue was the primary mechanism of disease suppression, or whether more complex biological interactions were responsible.

Disease suppression is not the only potential benefit of cover crop production. Improved soil structure and water infiltration, and reduced winter runoff and associated erosion and nutrient loss, have been documented (Colla et al., 2000; Dabney et al., 2001; Joyce et al., 2002; Miyao and Robbins, 2000). In the present study large quantities of N were removed from the soil profile, decreasing NO_3-N leaching potential. We conclude that mustard cover crops may provide environmental benefits but are unlikely to suppress soilborne pathogens or increase processing tomato productivity under representative field conditions in the Sacramento Valley.

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Allyl Isothiocyanate and Carbon Dioxide Produced during Degradation of *Brassica juncea* Tissue in Different Soil Conditions

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Abstract. **A study was conducted to quantify volatiles generated from Indian mustard (*Brassica juncea* L. Czerniak) tissue incorporated into soils under controlled conditions. Mustard residues were incorporated into noncovered and covered soils that varied by texture, temperature, moisture, pH, or sterility (autoclaved or nonautoclaved). Sandy loam soil had 38% more allyl isothiocyanate (AITC) than clay loam soil. AITC concentration in 45 °C soil was 81% higher than in soil at 15 °C, and 56% higher in covered compared to noncovered treatments. The microbial catabolism of AITC was suggested by the result that AITC concentration in autoclaved soils was over three times that measured in nonautoclaved soils. The highest AITC level detected (1.71 μmol·L^{-1}) occurred in the autoclaved covered soil. Several factors also influenced CO_2 evolution. At 30 or 45 °C, CO_2 concentration was at least 64% higher than at 15°C. The covered soil had over twice the CO_2 found in the noncovered soil, and the nonautoclaved soil treatment yielded twice the CO_2 measured in the autoclaved soil. There were no main effect differences among soil moisture, soil pH, and soil texture treatments for CO_2 concentrations. This information could be helpful in defining ideal soil conditions for field scale experiments. Additionally, this study demonstrates a sampling technique for testing fumigation potential of biofumigation and solarization systems that may have the potential to replace methyl bromide.**

Soil fumigation is widely used in nursery stock, strawberry, tobacco, tomato, and other commodity crop production systems to control nematodes, pathogens, and weeds. Methyl bromide, a broad spectrum soil fumigant, has been one of the main pesticides used for soil fumigation. Methyl bromide was listed in the 1993 Montreal Protocol as an ozone-depleting compound and is banned for use in crop production in the U.S. in 2005 (USDA, 1999). Suitable replacements for methyl bromide are urgently needed.

Biofumigation and solarization are possible solutions to control nematodes, pathogens, and weeds. Biofumigation is the suppression of soil-borne pests via toxic compounds released from soil- incorporated *Brassica* tissue (Angus et al., 1994; Sams et al., 1997). Soil solarization is a technique in which a clear polyethylene tarp is used to trap solar energy during periods of high radiation, thereby raising soil temperatures to levels lethal to pathogens (Pullman et al., 1981).

Plants from the Brassicaceae family contain glucosinolates (GLs). Degradation products such as alcohols, aldehydes, isothiocyanates (ITCs), and nitriles are produced upon enzymatic hydrolysis of GLs by myrosinase (thioglucoside glucohydrolase, EC 3.2.3.1) (Morra and Kirkegaard, 2002). Residues from *Brassica* crops have been shown to have biotoxic activity against many soilborne pathogens and pests. ITCs, mainly allyl isothiocyanate (AITC), contribute to the majority of toxic effects observed in decomposing *Brassica* tissues (Chew, 1988; Peterson et al., 2001). In closed jars, volatiles from macerated Indian mustard completely suppressed *Pythium ultimum* (Trow) and reduced *Rhizoctonia solani* (Kühn) growth by 72.6% (Charron and Sams, 1999). Soil-incorporated white mustard tissue (*Brassica hirta biennis* L.) has been shown to significantly reduce *Aphanomyces euteiches* (Drechs.) root rot in peas (*Pisum sativum* L.) (Muelichen et al., 1997). Glucosinolate-derived ITCs inhibited pear pathogens such as *Botrytis cinerea* (Pers.: Fr.), *Monilinia laxa* (Aderhold & Ruhland), and *Mucor piriformis* (E. Fisch.) (Mari et al., 1996). Broccoli [*B. olereacea* L. (Botrytis Group)] residues reduced the population of *Verticillium dahliae* (Kleb) microsclerotia in soil (Subbarao and Hubbard, 1996). Indian mustard seed meal suppressed soilborne cereal pathogens when used as an in-furrow treatment for wheat (Kirkegaard et al., 1996). Indian mustard was also shown to suppress masked chaffer beetle larvae (Noble et al., 1998). Turnip-rape (*Brassica napas* L.) can suppress scentless mayweed (*Matricaria inodora* L.) and spiny sowthistle [*Sonchus asper* (L.) Hill] (Peterson et al., 2001). White mustard can reduce emergence of shepherd's purse [*Capsella bursa-pastoris* (L.) Medik], kochia [*Kochia scoparia* (L.) Schrad], and green foxtail [*Setaria viridis* (L.) Beauv.] (Al-Khatib et al., 1997).

Solarization has been shown to reduce populations of bacteria, fungi, insects, nematodes, and weeds (Pullman et al., 1981; Stapleton and DeVay, 1986). In an experiment in Alabama, the maximum temperatures attained during soil solarization ranged from 48 °C at the soil surface to 34 °C 20 cm deep (Himelrick and Dozier, 1991). Experiments conducted during two years of strawberry production in California showed that solarization increased strawberry yield 12% over the yield of nonsolarized plots (Hartz et al., 1993). Hartz et al. (1993) reported that soil temperatures exceeded 50 °C at the soil surface and 35 °C 10 cm below the surface. In Greece, soil solarization has been commercially adapted to control bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis* E.F. Smith) in greenhouse-grown tomato (Antoniou et al., 1995). In northern Florida, soil solarization decreased densities of *Phytophthora nicotianae* (Breda de Haan) and *P. solanacearum* to depths of 25 and 15 cm, respectively (Chellemi and Olson, 1994). Chellemi and Olson reported maximum temperatures in bare soil of 43.8, 38.9, and 36.5 °C and in solarized soil 49.5, 46.0, and 41.5 °C at depths of 5, 15, and 25 cm, respectively. Egley (1983) reported that solarization for one week reduced the numbers of viable prickly sida (*Sida spinosa* L.), common cocklebur (*Xanthium strumarium* Wallr.), velvetleaf (*Abutilon theophrasti* Medic.), and spurred anoda (*Anoda cristata* L.) seeds. Maximum temperature in this experiment at 1.3 cm soil depth reached 69 °C for 3 to 4 h in the mid-afternoon. This temperature did not eliminate dormant weed seed from the germination zone, but the treatment killed germinated seed which reduced the number of weed seedlings that otherwise would have emerged.

Biofumigation and solarization may be combined to improve efficacy. Qualitative and quantitative differences were found in volatiles released from cabbage (*Brassica oleracea* L.) incorporated into soil at temperatures typical of solarized soil (Gamliel and Stapleton, 1993). Also, this cabbage residue reduced propagules from *Pythium ultimum* and *Sclerotium rolfsii* by 95% when soil was heated, but no more than 25% without heat application. Heated soil amended with cabbage was found to contain alcohols, aldehydes, and ITCs in the soil air. Nonheated treatments contained methanethiol, ethanol, and occasionally acetic acid and methanol. In combination with biofumigation, solarization would increase the vapor pressure of compounds resulting in greater volatile release into the soil. Due to elevated volatile release, combining *Brassica* amendments with soil solarization can enhance the control of pathogens through the combination of thermal killing and the enhanced generation of toxic volatile compounds (Gamliel and Stapleton, 1997).

However, information about the influence of soil conditions (moisture, temperature, pH, texture) and microbes on ITC production from *Brassica* tissue is somewhat limited. AITC was found to be the predominant product formed by sinigrin (allyl GL) decomposition in soil or in ammonium acetate extracts from soils regard-

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less of soil characteristics (Borek et al.,1994). Morra and Kirkegaard (2002) reported that ITC release was greater in waterlogged fine sandy loam soil than in soil at –32 kPa .

The main objective of this research was to determine effects of soil texture, temperature, moisture, and pH on volatiles produced from the degradation of Indian mustard during simulated biofumigation. A second objective was to determine if the presence of soil microbes affected the volatiles released. Finally, the trapping effect of solarization was evaluated. No published research shows the relationship between the variables listed above in a comprehensive study that combines multiple environmental variables and uses one detection method. This information could be helpful in developing field sampling techniques as well as defining ideal field conditions for testing biofumigation and solarization systems for soil fumigation efficacy.

Materials and Methods

Experimental design. The experimental design was a balanced incomplete block with three replications with fractional factorial treatment assignments and repeated measures. The treatments were soil texture (clay loam and sandy loam), soil cover (covered with a teflon lid to simulate plastic mulch used in solarization, and noncovered), soil temperature (15, 30, and 45 °C), soil moisture (permanent wilting point, 60% field capacity, and field capacity), soil pH (soil adjusted to a pH of 7.0 and field pH), and soil sterilization (autoclaved and nonautoclaved soil). Repeated measures were taken at 0.25, 4, 8, and 24 h. Treatment combinations were obtained from the Optex procedure (SAS Institute, 1996). The experiment was conducted in 500-mL glass jars in darkness within incubation chambers that provided consistent environmental conditions. Relative humidity was maintained at 50% ± 10%.

Soils. Two soils were used, a Waynesboro clay loam (Fine, kaolinitic, thermic Typic Paleudults) and a Sequatchie fine sandy loam (Fine-loamy, siliceous, semiactive, thermic Humic Hapludults), both collected from the University of Tennessee Plant Science farm, Knoxville, Tenn. (Roberts et al., 1955). The soils were air dried at room temperature for approximately 40 h and sieved through a #20 mesh sieve. The soil textures were determined by a particle size analysis method using Stoke's law as described by Day (1965). A glass electrode pH meter was used to measure both deionized aqueous pH and $CaCl_2$ pH. Lime requirements for both soils were determined by the Adams and Evans (1962) method to determine the amount of lime required for the pH 7.0 treatment. Water retention curves were created for each soil using the pressure plate method by Klute (1986) to indicate the amount of water needed to attain field capacity, 60% field capacity, and permanent wilting point. Field capacity was assumed to be -33 kPa and permanent wilting point –1500 kPa. Soil moisture was maintained by adding water as jar weight decreased. Autoclaved soils were sterilized using the method described by Wolf and Skipper (1994). A sample of 350 ± 1 g of soil was placed in each 500-mL glass jar.

Plant material. Indian mustard plant introduction accession 458934 was acquired from the USDA–ARS Regional Plant Introduction Station, Ames, Iowa. Mustard used in this study was grown in the field at the University of Tennessee Plant Science Farm and harvested at the six- to eight-leaf growth stage.

Plant sample preparation. A consistent method for mustard tissue preparation was needed to ensure homogeneous mustard tissue introduction into the jar-soil system across replications and treatments. A method that involved freeze drying mustard tissue was determined to be the procedure that consistently yielded isothiocyanates in their respective ratios as compared to fresh materials (unpublished data). However, other volatiles such as alcohols and aldehydes were lost in this process. A similar method was used by Warton et al. (2001b) when preparing *Brassica* tissue for GL determination and ITC production following hydrolysis. Plant tissue was freeze dried (Labconco, Kansas City, Mo.) and homogenized manually, thereby ensuring that the same proportion of root, stem, and leaf tissue was added to each jar. To simulate tissue fresh weight of 3.15 g, 0.31 ± 0.01 g of freeze dried material was combined with 2.84 ± 0.01 mL of deionized water and mixed for 30 s. This amount of mustard was chosen based on an estimated total plant material that could be present per hectare if grown in the field (Duke, 1997). The mustard mixture was then thoroughly mixed with the soil in a plastic container for 30 s before being mixed into the soil within the jar.

Volatile sampling. Volatile samples were collected for 45 s by solid phase microextraction consisting of a fiber with a 100 μm polydimethylsiloxane (PDMS) coating (SPME; Supelco Bellefonte, Pa.). This coating functions by noncompetitive absorption and has a larger linear range than fibers that use competitive adsorption. A preliminary experiment indicated that this fiber was not saturated by AITC or CO_2 at detectable concentrations in this experiment. A Teflon tube (length 14.5cm., I.D. 6mm) was inserted through the soil to the bottom of every jar. Thirty-two 2-mm holes were drilled in each tube so that when inserted into the soil in the jar, the holes were 2.5 cm below the soil line, allowing volatiles in the soil air to diffuse into the tube. A septum through which the SPME sampler was inserted was placed into the top of each tube. For the cover treatments, a Teflon lid was installed and sealed with a threaded metal ring.

Chromatography. A Hewlett-Packard (HP) gas chromatograph (model 5890A Series II; Hewlett-Packard Co., Palo Alto, Calif.) using a fused silica EC-WAX capillary column (0.25 μm film thickness, 30 m × 0.25 mm ID; Alltech, Deerfield, Ill.) was connected to a HP 5972 mass selective detector (GC–MS). The chromatograph oven temperature was initially set to 60 °C, ramped 5 °C·min^{-1} to 150 °C, with the injector temperature at 200 °C. Allyl ITC, sec-butyl ITC, and 3-butenyl ITC were identified by comparing their mass spectra with published mass spectra (Ohashi et al., 1963). Carbon dioxide and AITC were identified by comparing their mass spectra to those of authentic standards.

The concentrations of AITC in the jars were calculated based on chromatographic peak areas in relation to standard curves. To generate the AITC standard curve, ethanol was added to 0.15 mL AITC (adjusted for 95% purity) for a 1 mL total volume. One microliter of the ethanol-AITC mixture was injected into a 500-mL jar to yield a concentration of 3.3 μmol·L^{-1} and sampled. The initial AITC mixture was then diluted for a total of five different concentrations. Concentrations of CO_2 were calculated based

Table 1. Least square means and standard errors for AITC concentrations for time, soil texture, soil temperature, soil cover and soil sterilization (autoclaved and nonautoclaved), aqueous soil pH, and soil moisture main treatment effects.[z]

Treatment	AITC concn (μmol·L^{-1}) Mean	SE
Time (h)		
0.25	0.80 a	0.07
4	0.88 a	0.07
8	0.67 b	0.07
24	0.41 c	0.07
Texture		
Clay	0.58 b	0.07
Sandy	0.80 a	0.07
Temperature (°C)		
15	0.48 b	0.09
30	0.71 ab	0.09
45	0.87 a	0.09
Soil cover		
Yes	1.05 a	0.09
No	0.32 b	0.09
Soil autoclaved		
Yes	1.06 a	0.07
No	0.32 b	0.07
Aqueous soil pH		
5.7	0.67 a	0.07
7.0	0.71 a	0.07
Soil moisture		
Field capacity	0.58 a	0.09
60% Field capacity	0.71 a	0.09
Permanent wilting point	0.78 a	0.09

[z]Means within a treatment with no common letter differ by LSD ($P \leq 0.05$).

on a standard curve made with 1%, 3%, and 5% standards. Jars with soil and Indian mustard were spiked with AITC and compared with standards in empty jars to determine recovery rates for both soils.

Statistical analysis. Analysis of variance was performed on all data for volatile analysis. The fractional factorial allowed all main and two-way interaction treatment effects to be tested. Lack of independence due to repeated measures was addressed with an autoregressive correlation structure. LSD mean separations ($P \leq 0.05$), converted to letter groups by the PDMIX612 macro (Saxton, 1998), were used for interpretation of significant fixed effects as determined by the Mixed procedure (SAS Institute, 1996).

Results

Soil analysis. The clay loam textured soil contained 25% sand, 47% silt, and 28% clay. The sandy loam textured soil contained 68% sand, 23% silt, and 9% clay. The clay loam soil had an aqueous pH of 5.6 and a $CaCl_2$ pH of 5.1 while the sandy loam soil had an aqueous pH of 5.7 and a $CaCl_2$ pH of 5.6. Field capacity and permanent wilting point was 22% and 8.5% gravimetric water content, respectively, for the clay loam soil. The sandy loam soil had field capacity and permanent wilting point moistures of 14% and 4.5% gravimetric water content, respectively.

Volatile analysis. Volatile compounds detected by GC–MS included AITC, carbon dioxide (CO_2), sec-butyl ITC, and 3-butenyl ITC. All treatments and two-way interactions were analyzed. The only three-way and higher interactions analyzed were those involving time, due to limitations of the statistical model. No three-way interactions were significant at $P \leq 0.05$. Main treatment effects and two-way interactions for AITC and CO_2 are discussed. Significant factors for sec-butyl ITC and 3-butenyl ITC are not discussed; however, most of the trends for AITC were repeated in the sec-butyl ITC and 3-butenyl ITC results (data not shown).

Main treatment effects for AITC. The sampling time effect was significant for AITC concentration with 0.25 and 4 h treatments yielding at least 19% more AITC than the 8 h treatment, and 95% more than the 24 h treatment (Table 1). AITC concentration at 24 h was 48% lower than the mean concentration of all earlier sampling times. The sandy loam soil produced 38% higher AITC concentration than the clay loam soil. Temperature had a significant influence, resulting in an AITC concentration in 45°C soil that was 81% higher than in 15°C soil. The 15 and 30°C soil treatments were not significantly different, nor were the 30°C and the 45°C soil treatments. On a percentage basis, covering or autoclaving soil had the greatest influence on AITC concentration; covered soil had over three times the concentration of AITC that was measured in noncovered soil, and similarly, AITC concentration in autoclaved soil was over three times that measured in nonautoclaved soil. There were no main effect differences among soil moisture and pH treatments.

Treatment interactions for AITC. Time × temperature, soil sterilization (autoclaved or nonautoclaved) × cover, time × soil sterilization, temperature × soil sterilization, and time × cover were significant for AITC concentration at $P \leq 0.01$ (Tables 2 and 3). The time × temperature interaction data showed that the AITC concentration in the 15°C treatment was 0.44 $\mu mol \cdot L^{-1}$ at 0.25 h, and did not significantly change over time. The AITC concentration in the 30°C treatment was 0.85 $\mu mol \cdot L^{-1}$ at 0.25 h and did not change significantly until at 24 h, it decreased to 0.43 $\mu mol \cdot L^{-1}$. The initial AITC concentration at 0.25 h (1.11 $\mu mol \cdot L^{-1}$) in the 45°C treatment did not change significantly at

Table 2. Least square means and standard errors for AITC concentrations for time × temperature, time × pH, and soil sterilization (autoclaved and nonautoclaved) × cover treatment interactions.[z]

Treatment		AITC concn ($\mu mol \cdot L^{-1}$) Mean	SE
Time (h)	Temperature (°C)		
0.25	15	0.44 fgh	0.11
0.25	30	0.85 bcd	0.11
0.25	45	1.11 ab	0.11
4	15	0.55 efg	0.11
4	30	0.91 abc	0.11
4	45	1.17 a	0.11
8	15	0.57 defg	0.11
8	30	0.67 def	0.11
8	45	0.76 cde	0.11
24	15	0.35 h	0.11
24	30	0.43 gh	0.11
24	45	0.45 fgh	0.11
Time	pH		
0.25	Limed	0.94 a	0.09
0.25	Field	0.66 cd	0.09
4	Limed	0.85 ac	0.09
4	Field	0.90 ab	0.09
8	Limed	0.67 bde	0.09
8	Field	0.66 cd	0.09
24	Limed	0.36 f	0.09
24	Field	0.46 ef	0.09
Soil autoclaved	Cover		
Yes	No	0.40 b	0.10
No	No	0.25 b	0.10
Yes	Yes	1.71 a	0.10
No	Yes	0.40 b	0.10

[z]Means within an interaction with no common letter differ by LSD ($P \leq 0.05$).

Table 3. Least square means and standard errors for AITC concentrations for time × soil sterilization (autoclaved and nonautoclaved), temperature × soil sterilization, and time × cover treatment interactions[z].

Treatment		AITC concn ($\mu mol \cdot L^{-1}$) Mean	SE
Time (h)	Autoclaved		
0.25	Yes	0.93 c	0.09
0.25	No	0.67 d	0.09
4	Yes	1.39 a	0.09
4	No	0.36 e	0.09
8	Yes	1.13 b	0.09
8	No	0.20 ef	0.09
24	Yes	0.76 d	0.09
24	No	0.05 f	0.09
Temperature (°C)	Autoclaved		
15	Yes	0.63 b	0.12
15	No	0.32 bc	0.12
30	Yes	1.16 a	0.12
30	No	0.27 c	0.12
45	Yes	1.37 a	0.12
45	No	0.37 bc	0.12
Time (h)	Cover		
0.25	No	0.70 c	0.09
0.25	Yes	0.90 c	0.09
4	No	0.36 d	0.09
4	Yes	1.39 a	0.09
8	No	0.18 e	0.09
8	Yes	1.15 b	0.09
24	No	0.05 e	0.09
24	Yes	0.77 c	0.09

[z]Means within a treatment with no common letter differ by LSD ($P \leq 0.05$).

4 h, but decreased to 0.76 μmol·L^{-1} at 8 h and decreased again to 0.45 μmol·L^{-1} at 24 h.

The soil sterilization × cover interaction data showed that the autoclaved covered treatment had a higher concentration of AITC (1.71 μmol·L^{-1}) than the autoclaved noncovered, nonautoclaved covered, and the nonautoclaved noncovered soil treatments (0.40, 0.25, and 0.40 μmol·L^{-1}, respectively). The autoclaved soil treatment had a concentration of 0.93 μmol·L^{-1} at 0.25 h, which increased to 1.39 μmol·L^{-1} at 4 h, decreased to 1.13 μmol·L^{-1} at 8 h, and decreased again to 0.76 μmol·L^{-1} at 24 h. The nonautoclaved treatment had an AITC concentration of 0.67 μmol·L^{-1} at 0.25 h, which decreased to 0.36 μmol·L^{-1} at 4 h and reached its lowest level of 0.05 μmol·L^{-1} at 24 h. The autoclaved soil treatments had higher AITC concentrations as temperature increased, rising from 0.63 to 1.37 μmol·L^{-1} as temperature increased from 15 to 45 °C. There were no significant differences between the nonautoclaved treatments at different soil temperatures.

The time × cover interaction data showed that the noncovered treatment had an AITC concentration of 0.70 μmol·L^{-1} at 0.25 h, which decreased to 0.36 μmol·L^{-1} at 4 h, then decreased again to 0.18 μmol·L^{-1} at 8 h. In the covered treatment, AITC concentration increased from 0.90 μmol·L^{-1} at 0.25 h to 1.39 μmol·L^{-1} at 4 h, then decreased to 1.15 μmol·L^{-1} at 8 h and 0.77 μmol·L^{-1} at 24 h.

Table 4. Least square means and standard errors of CO_2 (%) for time, temperature, and soil sterilization (autoclaved and nonautoclaved) treatment effects.[z]

Treatment	CO_2 concn (%) Mean	SE
Time (h)		
0.25	1.74 c	0.30
4	2.27 bc	0.30
8	2.58 b	0.30
24	3.62 a	0.30
Temperature (°C)		
15	1.84 b	0.31
30	3.02 a	0.31
45	2.80 a	0.31
Soil autoclaved		
Yes	1.72 b	0.28
No	3.39 a	0.28
Soil covered		
Yes	3.53 a	0.28
No	1.57 b	0.28
Soil moisture		
Field capacity	2.51 a	0.31
60% Field capacity	2.82 a	0.31
Permanent wilting point	2.33 a	0.31
Aqueous soil pH		
5.7	2.53 a	0.28
7.0	2.58 a	0.28

[z]Means within a treatment with no common letter differ by LSD ($P \leq 0.05$).

Table 5. Least square means and standard errors for CO_2 (%) for soil sterilization (autoclaved and nonautoclaved) × cover, time × soil sterilization, and temperature × soil sterilization treatment interactions.[z]

Treatment		CO_2 concn (%) Mean	SE
Soil autoclaved	Cover		
Yes	No	1.62 b	0.33
No	No	1.53 b	0.33
Yes	Yes	1.81 b	0.33
No	Yes	5.25 a	0.33
Time (h)	Autoclaved		
0.25	Yes	1.74 c	0.37
0.25	No	1.75 c	0.37
4	Yes	1.59 c	0.37
4	No	2.95 b	0.37
8	Yes	1.58 c	0.37
8	No	3.57 b	0.37
24	Yes	1.95 c	0.37
24	No	5.28 a	0.37
Temperature (°C)	Autoclaved		
15	Yes	1.79 b	0.39
15	No	1.90 b	0.39
30	Yes	1.65 b	0.39
30	No	4.38 a	0.39
45	Yes	1.71 b	0.39
45	No	3.90 a	0.39

[z]Means within an interaction with no common letter differ by LSD ($P \leq 0.05$).

Main treatment effects for CO_2. The sampling time effect was significant for CO_2 concentration. The 4, 8, and 24 h treatments had at least 30% more CO_2 than the 0.25 h treatment (Table 4). The CO_2 concentrations were similar at 4 and 8 h (2.27% and 2.58%, respectively) as well as 8 and 24 h (2.58% and 3.62%, respectively). The soil temperature effect was significant with the 30 and 45 °C treatments yielding at least 52% more CO_2 than the 15 °C soil treatment. Covered soil had more than twice the CO_2 measured in noncovered soil. Nonautoclaved soil produced 97% more CO_2 than autoclaved soil. There were no main effect differences for soil moisture, soil pH, and soil texture treatments.

Treatment interactions for CO_2. Soil sterilization × cover, time × soil sterilization, temperature × soil sterilization, and time × cover were significant for CO_2 production at $P \leq 0.01$ (Tables 5 and 6). The soil sterilization × cover data showed that the nonautoclaved covered soil treatment had about three times as much CO_2 as autoclaved covered, autoclaved noncovered, or nonautoclaved noncovered soil treatments. CO_2 concentrations in autoclaved treatments were stable across time, varying only from 1.6% to 2.0%. In the nonautoclaved treatments, however, CO_2 concentrations increased significantly from 1.8% at 0.25 h to 5.3% at 24 h. CO_2 concentrations did not vary with temperature in autoclaved soils, but in nonautoclaved soils, the CO_2 concentration at 15 °C was 1.9%, about half of that at 30°C (4.4%) and 45 °C (3.9%). In covered soil, CO_2 concentration increased with increasing sampling time, from 1.8% at 0.25 h to 5.5% at 24 h. In noncovered soil, CO_2 did not vary significantly with time and ranged from 1.5 to 1.7%.

Discussion

The AITC and 3-butenyl ITC detected by GC–MS are GL hydrolysis products similar to those detected by Vaughn and Boydston (1997). However, sec-butyl ITC, also detected within this experiment, was not detected by Vaughn and Boydston (1997) possibly due to differing sampling or tissue preparation techniques. Peterson et al. (2001) detected AITC, sec-butyl, and 3-butenyl ITC released from decomposing turnip rape (*Brassica napus* L.). In a study evaluating decomposition of *B. juncea* in soil, Bending and Lincoln (1999) detected AITC, but no other ITCs. Bending and Lincoln also detected methanethiol, dimethyl-sulphide, carbon-disulphide, and dimethyl-disulphide; methanethiol was the dominant headspace compound throughout their analyses, none of which we detected. Again, differences in volatiles detected are likely due to the tissue preparation method used in this experiment and/or differing sampling techniques. In addition, it is well documented that GL levels can vary within a species and between cultivars, which would lead to varying GL degradation products (Kirkegaard and Sarwar, 1998).

At the six-leaf stage, leaves and stems of Indian mustard PI 458934 had an allyl GL concentration of 31.8 μmol·g^{-1} and at flowering, 43.5 μmol·g^{-1} (data not shown). By adding 0.31 g of mustard, the maximum theoretical concentration

Table 6. Least square means and standard errors for CO_2 (%) for time × cover treatment interactions.[z]

Treatment		CO_2 concn (%)	
Time (h)	Cover	Mean	SE
0.25	No	1.66 c	0.37
0.25	Yes	1.83 c	0.37
4	No	1.46 c	0.37
4	Yes	3.09 b	0.37
8	No	1.49 c	0.37
8	Yes	3.68 b	0.37
24	No	1.71 c	0.37
24	Yes	5.53 a	0.37

[z]Means within an interaction with no common letter differ by LSD ($P \leq 0.05$).

of AITC in the 0.5-L jar would have been 23 $\mu mol \cdot L^{-1}$. The range of AITC recovery for most experiments was between 1.0% and 7.4% of this theoretical concentration. The recovery rate calculated by using AITC spiked soil samples yielded <0.1% of the theoretical AITC yield for both soils, perhaps since AITC standard does not undergo a hydrolysis process compared to AITC evolving from sinigrin in plant tissue. Warton et al. (2001b) found that the molar amount of ITC produced by hydrolysis is lower than the amount of corresponding GL present in plant tissue, possibly due to incomplete hydrolysis. Morra and Kirkegaard (2002) found that 1% or less of the ITC predicted from tissue GL concentration was measured in soil amended with rapeseed or mustard. The Indian mustard in this study was finely ground after freeze drying. Since GLs and myrosinase are stored in separate vacuoles within the plant cell, freeze drying and subsequent grinding could allow these reagents to react more efficiently than during normal plant tissue decay. Because this study used homogenized freeze dried tissue, we effectively reduced the inherent variability that would have been introduced using fresh tissue and were able to evaluate treatment effects that otherwise would have been nondetectable.

Our results revealed that AITC concentration generally decreased with increasing time. This result is similar to those found by Borek et al. (1994), Brown et al. (1991, 1994), Morra and Kirkegaard (2002), and Peterson et al. (2001) and supports the knowledge that activity of ITCs on soil organisms and seeds is very short in duration.

AITC concentration was also related to soil texture. AITC levels were higher in the sandy loam soil compared to the clay loam soil. Similarly, Bending and Lincoln (1999) found that gas phase AITC concentrations in a clay loam soil were lower than in a sandy loam soil. This result may be due to the higher organic carbon content of clay loam soil to which AITC could adsorb or react. Soil adsorption of methyl ITC (MITC), a similar compound to AITC, has been shown to increase with increasing organic matter (Matthiessen et al., 1996; Smelt and Leistra, 1974). Since adsorption of AITC to soil constituents decreases AITC gas phase concentration, biofumigation in soils with high clay content may be less effective compared to sandy textured soils. Also, diffusion may be slower in clay soil due to smaller pore space and increased tortuosity.

Soil temperature influences AITC concentration. The partitioning of ITCs into phases of the three-phase soil system (vapor, aqueous, and solid) is dependent on their solubility in water (Brown and Morra, 1997). For MITC, gas phase diffusion was the most important factor for the loss of methyl ITC from soil due to the strong partitioning into the gas phase (Frick et al., 1998; Van den Berg et al., 1999). However, soil temperature was shown not to influence soil sorption of MITC (Matthiessen et al., 1996). Because we found that soil temperature influenced AITC concentrations detected, the rate of partitioning of AITC between the vapor and aqueous phases was likely the most influential factor determining the rate of AITC volatilization. AITC escape from the aqueous phase may be enhanced by higher temperatures due to higher kinetic energies.

Also, higher concentrations of AITC were detected within covered treatments, probably due to reduced diffusion from the soil. Because solarization systems increase soil temperatures, both trapping and higher AITC vaporization effects would likely be realized.

AITC levels tended to be higher in autoclaved soil than nonautoclaved soil. Microbial degradation of AITC in the nonautoclaved soil probably accounted for lower levels of AITC. Although Borek et al. (1995) determined that autoclaved soil treatments did not change disappearance rates of AITC, Warton et al. (2001a) documented enhanced biodegradation by microbes of MITC in soils where metham sodium had been extensively used compared to soils with no metham sodium history. *Rhodococcus* spp. and *Bacillus* spp. were both implicated in the enhanced biodegradation of MITC. Warton et al. (2003) demonstrated that AITC degraded more rapidly in soil that also degraded MITC at higher rates than in nondegrading soil, perhaps as a consequence of the structural similarity of AITC and MITC.

Our results did not show differences in AITC concentrations among soil moisture treatments. Morra and Kirkegaard (2002) found that extractable ITC concentrations were greater in waterlogged fine sandy loam soil as compared to soil at –32 kPa. They cited increased water availability for glucosinolate hydrolysis as one reason for this result. Additionally, their technique of water-saturating the soil and tightly capping the tubes containing the soil prevented the partitioning of AITC into the gas phase, and therefore would have increased extractable ITCs compared to soil with free pore space. Our data indicates that gas phase ITC concentration does not vary significantly with soil moisture content at or less than field capacity. Our results concerning the effects of soil pH agreed with those of Borek et al. (1995) who found no correlation between AITC concentration and soil pH (ranging from 4.35 to 9.10) in six soils.

Because our sampling technique allowed us to measure CO_2, we were able to evaluate the influences of time, soil temperature, soil sterilization, and soil cover on CO_2 concentration. CO_2 concentration increased with increasing time. Similar results were reported by Reicosky et al. (1999) following soil disturbance. Because *Brassica* tissue used in this study was mixed thoroughly into the soil, it is not surprising that we observed a similar trend.

Relatively lower soil temperatures resulted in lower CO_2 concentrations in this study. This result may be attributed to lower respiration or organic carbon decomposition by soil microbes. Similar results were observed by Torbert et al. (2001) who showed that CO_2 emission was 32% higher in 30°C soil compared to 20 °C soil over a 30 d period and was 42% higher after 60 d.

The CO_2 concentration in covered soil was twice that obtained in noncovered soils, probably because CO_2 could not diffuse out of the covered jars. Covering soil immediately after incorporating *Brassica* tissue could be of particular importance because Reicosky et al. (1999) showed that soil disturbance greatly increases CO_2 emissions from soil due to enhanced biological activity. Enhanced soil biological activity was shown to be due to increases in soil temperature as well as oxygen available to soil microbes. Since biofumigation systems using *Brassica* tissue rely mainly on tillage to incorporate residue, covering the soil may reduce the amount of oxygen available to microbes that may use ITCs as a carbon source. However, the subsequent increase in soil temperature could enhance microbial activity which may in turn cause ITC concentrations to decrease. An alternative nontillage biofumigation method that uses a rotary tiller (Peterson et al., 2001) or rolling stalk chopper such as the types used by many Brazilian growers (Derpsch et al., 1991; Raper et al., 2003), or use of a membrane-disrupting herbicide such as paraquat to desiccate *Brassica* tissue before trapping with plastic, would reduce the amount of soil disturbance before planting and may prevent increased microbial activity.

The lower CO_2 concentrations measured in autoclaved compare to nonautoclaved soils indicate that at least half of CO_2 evolved was likely from microbial activity. Also, concentrations of AITC were much higher in autoclaved than in nonautoclaved soils. Lower AITC in nonautoclaved soils may be due to soil microorganisms using AITC as a carbon source.

Soil water content did not influence CO_2 concentration in this study. This result differs from that observed by Prior et al. (1997) who showed that CO_2 evolution initially increased under lower soil moisture potentials. Again, difference in results may be due to differing soil chemistry or microbiology. Lastly, in agreement with Torbert (1995), soil texture did not influence CO_2 concentration.

These data in summary suggest that higher concentrations of volatile AITC may be obtained in biofumigation at higher soil temperature.

Sandy loam textured soils may yield higher volatile AITC concentrations compared to clay loam soils. By covering biofumigated soils, maximum AITC concentrations would be maintained. This research also indicates that soil microbes play a role in the degradation of AITC. Solid phase microextraction is a viable method for detecting ITCs and likely for field work evaluating GL breakdown products.

Biofumigation and solarization may be environmentally sound and economically feasible alternatives for methyl bromide. One difficulty in replacing such a widely used pesticide with a biofumigation system is that insufficient field research has been conducted to quantify the effects of *Brassica* amendments on crop yield and the soil microbial community. The results in this experiment could help in the development of field scale experiments and methods for volatile monitoring, and subsequently, field plans for growers to use biofumigation as part of a program to control soilborne pathogens.

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Phytopathology
REVIEW

Q:1

Development and Deployment of Systems-Based Approaches for the Management of Soilborne Plant Pathogens

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ABSTRACT

Chellemi, D. O., Gamliel, A., Katan, J., and Subbarao, K. V. 2016. Development and deployment of systems-based approaches for the management of soilborne plant pathogens. Phytopathology 106:1-10.

Biological suppression of soilborne diseases with minimal use of outside interventive actions has been difficult to achieve in high input conventional crop production systems due to the inherent risk of pest resurgence. This review examines previous approaches to the management of soilborne disease as precursors to the evolution of a systems-based approach, in which plant disease suppression through natural biological feedback mechanisms in soil is incorporated into the design and operation of cropping systems. Two case studies are provided as examples in which a systems-based approach is being developed and deployed in the production of high value crops: lettuce/strawberry production in the coastal valleys of central California (United States) and sweet basil and other herb crop production in Israel. Considerations for developing and deploying system-based approaches are discussed and operational frameworks and metrics to guide their development are presented with the goal of offering a credible alternative to conventional approaches to soilborne disease management.

Additional keywords: agroecology, crop rotation, microbial diversity, organic amendments, soil fumigation.

Post World War II production of high value crops including fresh herbs and soft fruits gravitated toward a singular approach of maximizing enterprise profitability through increased production (yield). Improved technology, access to irrigation, transportation, storage, and pesticides contributed to the creation of highly efficient crop production systems. Escalating input costs were offset by gains from economies of scale. Synthetic fertilizers replaced organic amendments as the principal source of plant nutrients, and routine pesticide applications were relied upon to control soilborne diseases, particularly to disinfest important and hard to eradicate soilborne pathogens. Extended monocultures of genetically uniform cultivars selected for increased yield and extended shelf life further intensified selection for soilborne pathogens. In recent years, mounting public concern regarding environmental degradation and human health risks associated with pesticides, escalating crop production costs, competition for diminishing natural resources, and the continued crop losses from disease outbreaks despite increased pesticide use have created an impetus to examine alternative approaches to pest management.

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Integrated pest management (IPM) was developed as an alternative pest management approach incorporating ecosystem knowledge to balance the economic, environmental, and social consequences of remedial interventions. IPM is the coordinated use of multiple tactics to maintain damage from specific pests below an economic threshold, while conserving beneficial organisms and maintaining sustainability (Stern et al. 1959) and strives to manage pests by ecological principles of natural pest mortality factors, predator-prey relationships, genetic resistance, and cultural practices. Andrews (1983) indicated that integrated control should include three essential facets: (i) diversified controls coordinated to achieve an additive or, preferably, synergistic effect; (ii) economic (including aesthetic) analysis to the extent that action thresholds are developed to distinguish biological damage from economic damage (i.e., the amount of injury justifying a given increment of control); and (iii) ecological and environmental assessment to quantify, and subsequently minimize, a detrimental effect on nontarget organisms. By 2002, 66 additional definitions of IPM had been proposed (Bajwa and Kogan 2002). Entomologists pioneered the IPM concept that was later adopted by plant pathologists initially for foliar diseases followed by its adaptation to the management of soilborne pathogens.

In the case of IPM, the practice was not always consistent with the theory of IPM (Hardy 1996). For example, as IPM was applied to the management of arthropod pests, its application in many instances became limited to pest scouting and precision application of insecticides. Ecological processes at the landscape level, which can be used to understand and promote the inherent ability of ecosystems to limit pest outbreaks, were often deemphasized. Although IPM has made vast strides in the reduction of insecticides for control of arthropod pests, its adaptation to the management of soilborne pests has proven to be more difficult. Soil disinfestation must occur before the crop is planted, requiring assessment of economic injury and action thresholds well in advance of the current season. A paucity of systemic therapeutic interventions and the technical difficulties associated with the delivery of biocontrol agents to active infection courts further hamper the implementation of IPM for soilborne pests. Despite the many challenges of IPM for soilborne pests, its application to high value crops has been embraced following the mandated methyl bromide withdrawal from agriculture. The following IPM principles are suggested for the soilborne pathogens (Katan et al. 2012).

1. Accurate identification of the pathogens or other pests involved and consideration of the crop and soil pest history in the choice of management options.
2. Because IPM is a holistic approach, consideration to all sources of inoculum at all sites during the whole season, before, at and after planting should be given. The management tools for different pests need to be compatible with the relevant agricultural practices.
3. Combining management tools to improve the diversity and efficacy of pest control.
4. The impact of disease management on the soil and crop health, the agricultural and nonagricultural environments, natural resources, and human health should also be integral considerations.
5. Decision support systems enable the improvement in control effectiveness and curtail the dose and frequency of the applied measures. The relationships between pathogen inoculum density in soil and disease intensity, and between disease intensity and yield loss are integral to the success of these systems. These parallel the monitoring of pest population dynamics and thresholds developed by entomologists.
6. Issues such as economic, social, public, legislative, political, and local and international agreements and regulations should again be fundamental to the IPM program.
7. Since the soilborne pathogens survive in the soil, the long-term effects of the management options and soil reinfestation by pathogens should be considered.
8. Since IPM is an integrated approach, and has to be adapted for a variety of potential uses, technology transfer systems should be developed for each specific IPM program.

Even if the techniques for disease suppression are only partially effective and can only be used under specific conditions, they may still be effective when combined with other methods. This is particularly relevant for soilborne pathogens given that the management options are limited. If these options retain or improve the natural suppressiveness in a given soil, they have the potential to improve the overall system sustainability. This can be achieved by minimizing drastic measures or by reducing the frequency of applying these measures. Whenever possible, enriching the soil organic matter should remain a disease management goal.

As a matter of fundamental principle, the application of external corrective actions into a system can be effective in the short term. A more sustainable, robust solution with direct application to the management of soilborne pests is to redesign crop production systems to mitigate pest outbreaks through natural processes that promote ecosystem stability while minimizing the need for therapeutic intervention. Systems-based approaches to pest management evolved from the IPM concept to emphasize incorporation of agricultural practices into the design and operation of cropping systems that promote pest and disease suppression through natural biological feedback mechanisms (Lewis et al. 1997). A systems-based approach to the management of soilborne plant disease consists of four pillars: (i) prevent the introduction and spread of pathogens into the cropping system; (ii) reduce high pathogen populations to levels where they can be managed through natural biological feedback mechanisms; (iii) incorporate activities into the cropping system design to promote disease suppressive soil microbial communities; and (iv) minimize the impact of disruptive actions (pesticides, bio-pesticides, and other agents) through the use of an integrated approach for pest control which optimizes their use at relevant crop stages to interfere with the different stages of the pathogen life cycle. Implicit in this last item is the development of application technologies to assure maximum impact on the target pathogen, and to reduce populations to levels where they can again be regulated naturally. This review will explore the potential of systems-based approaches for management of soilborne diseases using two examples where this approach is being evaluated.

SYSTEMS-BASED APPROACH FOR SOILBORNE DISEASE MANAGEMENT

The concept of self-organizing ecosystems is pivotal to the development and deployment of systems-based disease management approaches. In agroecosystems, fluctuations in the density and composition of soil biological communities are the norm, particularly where natural or anthropogenic disturbances are key features. The degree of oscillation is governed by complex interactions involving soil edaphic factors, plant hosts, competing macro- and microbiological communities, and anthropogenic disturbances. Resilience (the capacity to self-organize into desirable steady states) and homeostasis (the maintenance of desirable steady states) are achieved through a series of continuous negative biological feedback loops. While far too complex to be measured in any precise way (Cabell and Oelofs 2012; Darnhofer et al. 2010), agroecosystems share a key similarity to other systems; they consist of networks nesting within other networks, all interacting within themselves and among themselves (Robinson 2007). Recognition of simultaneous interactions at multiple trophic levels is fundamental to the design and implementation of systems-based approaches to pest management (Levins 1986; Lewis et al. 1997). The reader is directed to Ashby (2001), Camazine et al. (2001), and Robinson (2007) for additional information on self-organizing agroecosystems.

Naturally occurring disease suppressive soils exemplify self-organization within agroecosystems. As defined by Baker and Cook (1974), disease suppressive soils are "soils in which the pathogen does not establish or persist, establishes but causes little or no damage, or establishes and causes disease for a while but thereafter the disease is less important, although the pathogen may persist in the soil." Natural suppression of plant pathogens and phytoparasitic nematodes in soil is well documented (Hornby 1983) and largely attributable to the composition of resident soil microbial communities they interact with (Mendes et al. 2011; Weller et al. 2002). Some well-known examples of naturally suppressive soils are listed in Table 1. Other than the examples of specific disease suppression (Weller et al. 2002), the mechanisms by which resident microbial communities suppress pathogens and nematodes is not well understood and suppression most likely results from combinations of specific and general disease suppression mechanisms. What is evident is the resilience of soil microbial communities and negative feedback loops they employ to suppress disease. For general disease and nematode suppression, beneficial shifts in microbial community composition can occur despite prior soil fumigation when organic production practices including crop rotations, organic amendments, and soil solarization are implemented (Chellemi et al. 2012, 2013). For specific disease Q:2 suppression, reductions in soilborne disease may also occur after repeated monoculture (Lucas et al. 1993; Rovira and Wildermuth 1981). Cultivation of the same plant host year after year is often considered the bane of sustainable crop production due to associations with increased outbreaks of plant pests and diseases, because of augmented pest or pathogen populations. For example, regional monoculture of cotton increased arthropod pest pressure in 13 of 15 published studies (Andow 1983) and was also attributable to increases in soilborne diseases of cotton (Shipton 1977). Yet, wheat monocultures are commonly associated with reductions in soilborne disease and also reduced arthropod pest populations in 7 out of 10 published studies (Andow 1983). The conflicting outcomes point to a need to further define the operational mechanisms of self-organizing ecosystems.

CASE STUDIES

Verticillium wilt in the coastal valleys of central California (United States). *The cropping system.* Strawberry and leafy greens are the dominant agricultural commodities in the coastal valleys of central California. Approximately 65,000 ha of lettuce and other leafy greens generate over U.S. $1.2 billion in farm gate value (USDA-NASS 1998 to 2012, 2014). Iceberg (crisphead) was the dominant lettuce type prior to the 1990s, but a significant proportion of the acreage has been replaced in recent years by Romaine and leaf lettuce, and to a lesser extent leafy greens including endive (*Cichorium endivia* L.), radicchio (*Cichorium intybus* L.), arugula (*Eruca vesicaria* L.), spinach (*Spinacia oleracea* L.), beet tops, red Swiss chard (*Beta vulgaris* L.), mache (*Valerianella locusta* (L.) Laterr.), mizuna, and tatsoi (*Brassica rapa* L.). Strawberry (*Fragaria* × *ananassa* Duchesne) contributes 88% of the fresh market and 94% of the processed strawberries produced in the United States (USDA-NASS 2014). Approximately 15,819 ha generated $2.6 billion in harvested revenue. Of those hectares, 1,239 ha were certified organic (California Strawberry Commission 2014 Acreage Survey) (2014). Strawberry production employs raised bed-plastic mulch systems, using mostly bare root seedlings from plants harvested from high elevation nurseries and transplanted into fumigated soil. The lettuce/strawberry rotation has dominated agricultural land use in the Salinas and Pajaro Valleys of the California central coast for decades and continues to be the backbone of the economic stability of the region.

Vulnerability to soilborne pathogens. A recent shift in lettuce production practices impacted existing lettuce diseases (Wu et al. 2011) and compromised lettuce to Verticillium wilt caused by *Verticillium dahliae* (Atallah et al. 2011; Subbarao et al. 1997), a disease to which lettuce was previously considered immune. Affected lettuce fields have suffered near-total losses (Atallah et al. 2011; Subbarao et al. 1997) and in strawberry, losses of up to 75% have been recorded in absence of soil fumigation (Wilhelm and Paulus 1980). Soil fumigation with methyl bromide and chloropicrin was developed in the late 1950s specifically to control Verticillium wilt of strawberry (Wilhelm et al. 1961) and was the industry standard for decades. In recent years, soil fumigation with mixtures of chloropicrin and 1,3-dichloropropene have replaced methyl bromide. This shift in soil fumigants has been associated with increased incidence of Fusarium wilt caused by *Fusarium oxysporum* f. sp. *fragariae* and charcoal rot caused by *Macrophomina phaseolina* (Koike et al. 2013). Commercially acceptable lettuce cultivars with resistance to Verticillium wilt are not yet available, and strawberry varieties exhibit limited levels of tolerance to the disease in the field, limiting the use of host resistance as an effective disease management tool.

Lettuce growers with Verticillium wilt-affected fields prefer to rotate with strawberry, where preplant fumigation with methyl bromide and chloropicrin until this year was a routine practice but other fumigants are registered and continue to be available. This allows growers to recover the cost of fumigation through a strawberry crop, and piggy-back on the residual fumigation effects when rotating back to lettuce production. The benefits of the residual fumigation effects, however, are short-lived as Verticillium wilt typically returns with greater severity following the second consecutive lettuce crop (Fig. 1) (Atallah et al. 2011; Short et al. 2015a). Q:3

Sources of inoculum. V. dahliae survives in soil in absence of a host for at least 14 years (Wilhelm 1955) owing to microsclerotia, which are clusters of specialized, thick-walled and highly melanized fungal cells (Fig. 2). Inoculum dispersal is facilitated by tillage practices, particularly involving infected crop residues at the end of the harvest season (Fig. 2). Plant infection is initiated when microsclerotia germinate and produce one to several hyphae that extend toward host roots (Fitzell et al. 1980). The pathogen is also capable of multiplying on several monocot plant species and dicot weed species common to both lettuce and strawberry production systems, including *Capsella bursapastoris* L., *Solanum sarrachoides* Sendtner, *Sonchus oleraceus* L., and *Senecio vulgaris* L. (Vallad et al. 2005) and those that serve as asymptomatic hosts (Krikun and Bernier 1987; Mathre 1989; Vallad et al. 2005). Seed transmission of *V. dahliae* occurs in lettuce (Vallad et al. 2005) and spinach (du Toit et al. 2005; Snyder and Wilhem 1962). Crop rotations with several *Brassica* species including broccoli and Brussels sprouts have been shown to reduce *V. dahliae* microsclerotia populations in soil and the subsequent incidence of Verticillium wilt (Fig. 3) (Subbarao et al. 2007).

Components of the systems-based approach. The systems-based approach is predicated on creating a soil environment supportive of biological regulation of pathogen populations through natural negative feedback mechanisms. To accomplish this, pathogen

TABLE 1
Examples of the suppression of plant pathogens and nematodes by indigenous populations of soil microorganisms

Plant pathogen/nematode	Host plant	Reference
Aphanomcyes euteiches	*Pisum sativum*	Persson et al. 1999
Criconemella xenoplax	*Prunus persica*	Kluepfel et al. 1993
Fusarium oxysporum f. sp. *lanatus* and f. sp. *lycopersici*	*Citrullus lanatus, Solanum lycopersici*	Alabouvette 1990; Larkin et al. 1996
Gaeumannomyces graminis var. *tritici*	*Triticum aestivum*	Rovira and Wildermuth 1981
Heterodera schachtii	*Beta vulgaris*	Westphal and Becker 1999
Q:13 *Meloidogyne incognita, M. javanica*	Multiple plant hosts	Weibelzahl et al. 1996
Thielaviopsis basicola	*Nicotiana tabacum*	Stutz et al. 1986
Phytophthora cinnamomi	Multiple plant hosts	Ko and Shiroma 1989
Rhizoctonia solani	*Triticum aestivum*	Lucas et al. 1993

populations must be present in levels that do not undermine the biological capacity of soils to regulate disease. There are five primary components.

1. Prevent the introduction of pathogens, in particular *Verticillium* species, into fields. The use of clean seed and transplants is recommended. While the lettuce, spinach, and strawberry industries have taken great strides to clean up infested seed through improved pathogen indexing programs, introduction of Verticillium species through infected spinach seed lots continues to be problematic (du Toit et al. 2005; Short et al. 2014, 2015a). This is because of the long-term survival of *V. dahliae* microsclerotia in soil once introduced.
2. When pathogens are present in numbers high enough to cause significant disease losses, soil disinfestation using chemical fumigants or other means is recommended.
3. Integrate beneficial crop rotations into long-term land management plans.
4. Make the most of the combined use of organic amendments and crop rotations to create beneficial shifts in soil microbial community composition associated with suppression of Verticillium wilt.
5. Mitigate inoculum build-up and dissemination, including microsclerotia, resulting from tillage of infected plants after harvest. This is accomplished by crop termination treatments immediately after harvest using a material that prevents both additional inoculum formation on infected plants and reduces viable pathogen propagules residing in the rooting zone.

Q:4

A schematic diagram is presented in Figure 4 to serve as a template for implementing a systems-based approach. Over the 3-year cropping cycle, one strawberry crop and two lettuce crops are

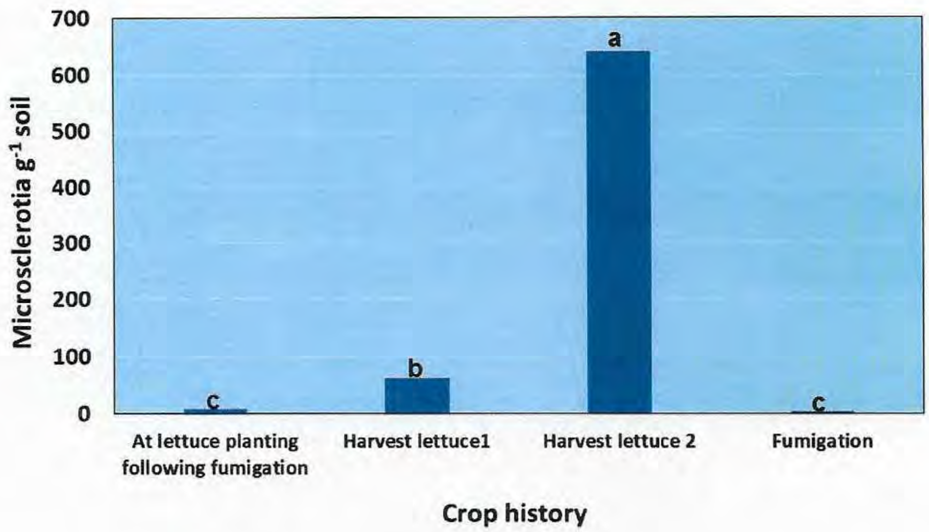


FIGURE 1

Fluctuation in number of microsclerotia of *Verticillium dahliae* per gram of soil detected in soil samples from an infested lettuce field in coastal California over two successive crops within a year, and requiring fumigation at the end of the second lettuce crop. Reproduced, with permission, from Atallah et al. (2011).

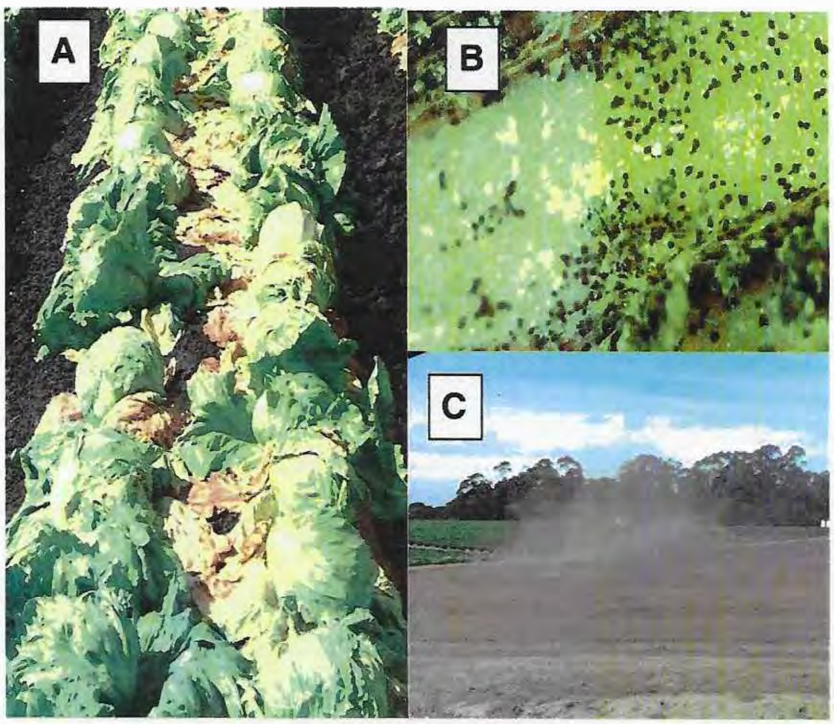


FIGURE 2

A, Verticillium wilt of crisp head lettuce. **B,** *Verticillium dahliae* microsclerotia on infected lettuce. **C,** Aerosol dispersal of soil infested with *V. dahliae* during tillage of infected lettuce crop. Neighboring field is susceptible strawberry.

cultivated. Soil sampling for *V. dahliae* populations and soil fertility following each crop is essential to gauge the progress of the disease management approach. Adjustments to the system should be made accordingly. For example, cropping cycles can be extended if pathogen populations do not decline sufficiently. Alternatively, crop termination applications and/or organic amendments can be omitted if pathogen populations decline below detectable thresholds. Versions of this systems-based approach are being evaluated on commercial farms in the Salinas Valley.

Record of success. An example is provided from a farm with a history of strawberry/lettuce rotations, soil fumigation, and recurrent epidemics of Verticillium wilt. Prior to initiating a systems-based approach, the incidence of Verticillium wilt ranged from 11 to 35% on the strawberry crop. Termination of the infected strawberry crop was accomplished using allyl-isothiocyanate (AITC, Dominus, ISAGRO USA, Morrisville, NC) applied at 155 kg ha^{-1} through the drip system (Fig. 5). Use of AITC-derived products has an added benefit as it occurs naturally in broccoli and Brussels sprouts, two crops common to the coastal valleys of central California and associated with suppression of Verticillium wilt (Harborne and Baxter 1993; Njoroge et al. 2011). Endemic soil microbial communities have been exposed to AITC for decades from the decomposing crops and have had ample time to adapt it as a carbon source. Successive broccoli crops, augmented with chitin-rich crab/feather meal (RootGuard, Agricultural Solutions, Plant City, FL) at 1.1 t ha^{-1} incorporated to a 12 cm depth, were compared with an adjacent area subjected to the broccoli rotations but not receiving the AITC crop termination treatment or chitin-based organic amendments. Crisphead lettuce was grown following the broccoli rotations and the soil density of *V. dahliae* microsclerotia monitored by collecting multiple samples along two transects and determining the number of microsclerotia per gram of soil using the technique described by Subbarao et al. (2007). Figure 6 depicts the initial decline of *V. dahliae* microsclerotia populations following the AITC application and subsequent oscillations in microsclerotia densities during the broccoli rotations. The oscillations are attributed to the redistribution of microsclerotia in the soil profile resulting from tillage practices. Resumption of crisphead lettuce led to an increase in microsclerotia density from <1.0 to >8.06 g^{-1} of soil in the section subjected to the broccoli rotation only (Fig. 6). In the section receiving the AITC crop termination treatment and applications of crab/feather meal in addition to the broccoli rotation, microsclerotia remained below 1.0 g^{-1} of soil. Thus, carefully designed cropping

FIGURE 3

Microsclerotia of *Verticillium dahliae* present in the soil at Watsonville during vegetable-strawberry rotation system from 1997 to 2000. V = vegetable rotation seasons, S = strawberry production seasons, BRL = broccoli rotation plots, and BSP = Brussels sprouts rotation plots. Adapted with modifications, by permission, from Subbarao et al. (2007).

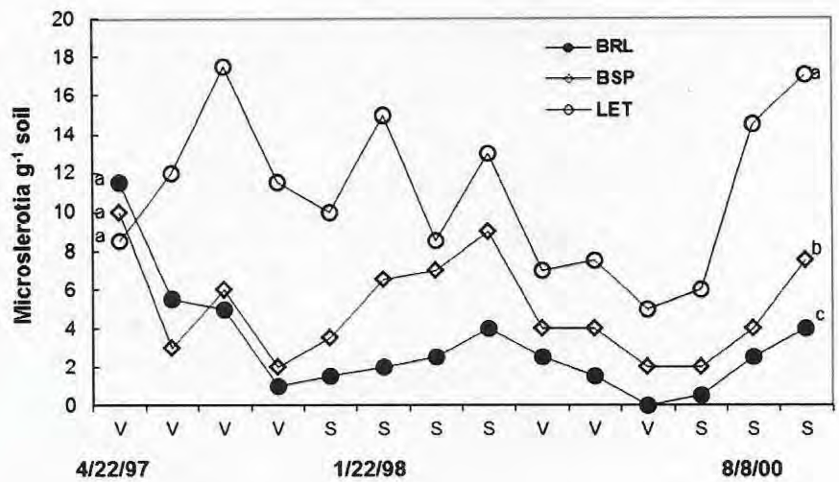
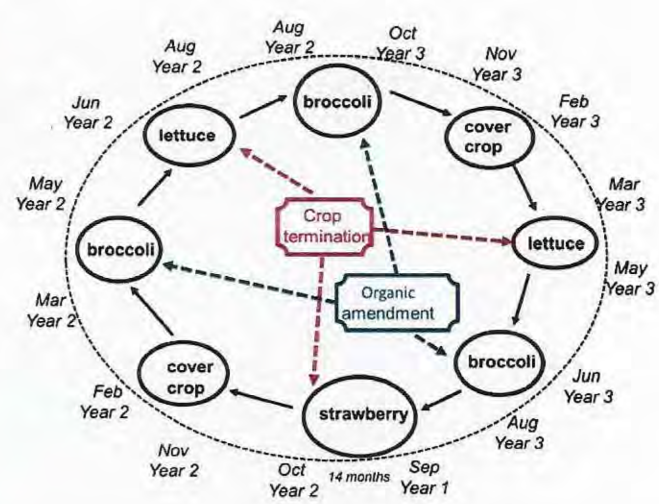


FIGURE 4

Framework for systems-based management of Verticillium wilt in the coastal valleys of central California.



patterns as part of the systems-based approaches in each region or field can be a very successful strategy of soilborne disease management.

Sweet basil and other herb crops in Israel. *The cropping system.* Herb crops are grown commercially in Israel for export of fresh produce. Many species and cultivars are grown both in open field and greenhouses that meet the demand for high quality produce year round. The main crops include sweet basil, chive, tarragon, sage, thyme, rosemary, and others. To maintain a steady supply of herbs, production has expanded to areas with diverse climatic conditions, soils, and artificial substrates. The increase in herb production has caused the inevitable increase in the occurrence of new and existing pathogens on these crops (Gamliel and Yarden 1997). These include diseases caused by nematodes and parasitic weeds, which have wide host ranges and their inoculum augmented by previous susceptible crops. Additionally, new pests and pathogens have been introduced (e.g., Fusarium wilt of basil, downy mildew of basil; Gamliel et al. 1996). Apart from the expansion and intensification of herb crop production, the changes in cultural and harvesting practices are likely contributors to the increase in disease incidence. These changes have had devastating effects on herb production.

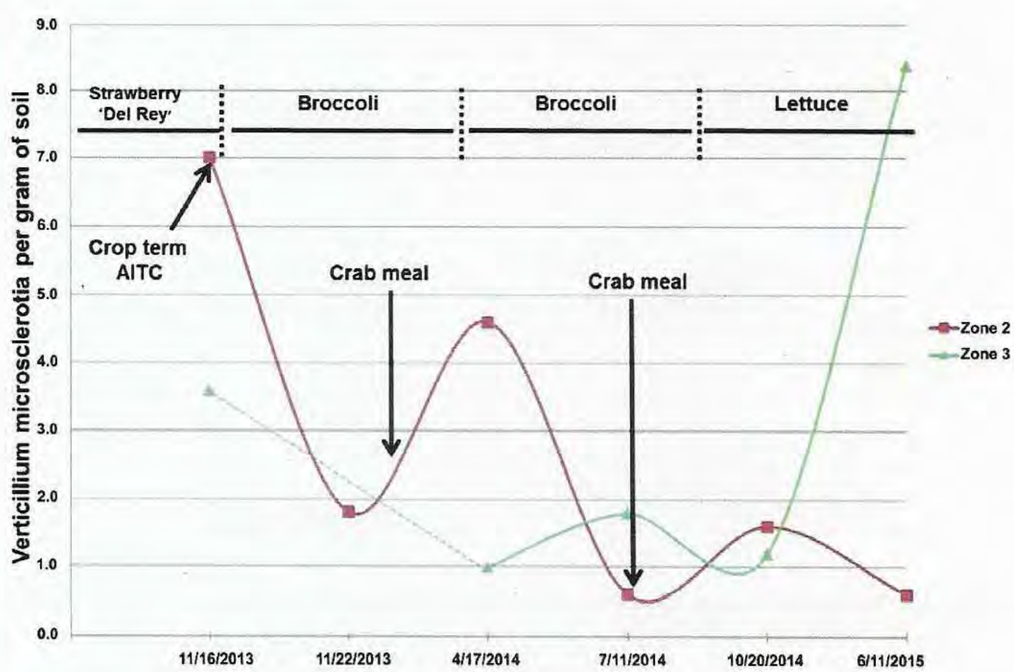
Vulnerability to soilborne pathogens. Many of the herb crops which are grown commercially in Israel are vulnerable to polyphagous soilborne pathogens. A majority of the crops are attacked by root knot nematodes and damping-off pathogens. In addition, the parasitic weed broomrape (*Phelibanchae egypitiaca*) is widespread in both open field and closed production systems. *Sclerotinia sclerotiorum* is

FIGURE 5

Strawberry field in the Salinas Valley with Verticillium wilt where allyl isothiocyanate applied through the drip irrigation was used to terminate the crop and mitigate production and redistribution of microsclerotia during tillage.

FIGURE 6

Comparison of temporal fluctuations in *Verticillium dahliae* microsclerotia populations in adjacent Salinas Valley fields. Zone 2 included an addition application of allyl isothiocyanate through the drip irrigation system to terminate the strawberry crop and two applications of crab/feather meal incorporated prior to transplanting broccoli at 1.1 t ha^{-1}. Zone 3 subjected to a strawberry-broccoli-broccoli-lettuce rotation only.



the most devastating disease causing both root and canopy rot. Its damage is evident during the cool seasons at peak herb production and marketing. Additionally, new pathogens have also emerged in specific crops. *Phyrenochaeta terrestris* is a known pathogen causing pink root in onions. Chive (*Allium schoenoprasum*) is also susceptible to this pathogen with similar symptoms and damage. Fusarium wilt and root rot of sweet basil (*F. oxysporum* f. sp. *basilicii*) were introduced during the early 1990s. This pathogen is characterized by soilborne and airborne inoculum and can also be disseminated by infected seeds. The ability of various pathogens to infect other crops indicates that a systems-based approach must target all the crops grown in a field since infection on one crop serves as the source of the inoculum for the following herb crop.

Sources of inoculum. The sources of inoculum for the above pathogens are diverse. Polyphagous soilborne pathogens (e.g., *S. sclerotiorum*, *Rhizoctonia solani*, *P. terrestris*, and *Meloidogyne* spp.) and others (*F. oxysporum* f. sp. *basilicii*, seeds of broomrape) survive on the debris from different crops and form resting structures in soil. Ascospores of *S. sclerotiorum* from germinating sclerotia in adjacent fields, dumping sites, and other sources are spread by wind and infect indoor and open field crops. Similarly, *F. oxysporum* f. sp. *basilicii* produces spores, which can be spread by air, infect adjacent crops, and survive in the soil. It also remains in the greenhouse structure and becomes a source of the inoculum (Gamliel et al. 1996). Infested organic manure can harbor *R. solani* and *Meloidogyne*
Q:5 *javanica*. *F. oxysporum* f. sp. *basilicii* and sclerotia of *S. sclerotiorum*. *F. oxysporum* f. sp. *basilicii* is also transmitted by seeds. This diversity of inoculum sources dictates that a system-based approach address all sources to minimize transmission of the pathogens from their sources of inoculum into crop production fields.

Available management tools and the components of the systems-based approach. Herb crops can serve as a good model for a systems-based approach for a number of reasons. Herb farms combine different types of crops, which can be rotated to prevent the establishment of host-specific pathogens. Furthermore, some of the herb crops, e.g., wild rocket, can be incorporated at the end of the season to serve as organic amendments to control existing soilborne pathogens in the soil (Klein et al. 2011). Such organic amendments may also increase soil suppressiveness and prevent or delay reestablishment of a pathogen. Many herb crops are grown in closed structures, which enables effective soil disinfestation treatments such as the combination of solarization with reduced dosage of fumigants, combination of solarization with organic amendments, and also solarization of the structure to eliminate airborne propagules and propagules which survive on the structural components of the closed system. The following is an example of a system-based approach for the management of *F. oxysporum* f. sp. *basilicii* in basil crop. It consists of the following pillars.

1. During the first season, a crop that can serve also as organic amendment is grown in the field. The spectrum of the available crops is wide and includes wild rocket, rosemary, sage thyme, oregano, and others. These crops are grown commercially and produce marketable products.
2. At the end of the season, the crop provides significant biomass that is chopped and incorporated into the soil with a rototiller to serve as an organic amendment. The field is then mulched with transparent polyethylene to provide the conditions for solarization combined with organic amendments. This procedure is accompanied by structural solarization to eliminate the inoculum on the structure.
3. During the second season, sweet basil is planted by using pathogen-free seeds of cultivars that are resistant to *F. oxysporum* f. sp. *basilicii*.
4. During sweet basil production, monitoring to locate diseased plants and their removal is done to prevent aerial spore spread.
5. At the end of the crop, all the crop debris are removed from the greenhouse and destroyed in a compost site. The soil and the greenhouse structure are solarized.
6. A different crop that can serve for organic amendment purposes is planted during the third season.

Records of success (area, seasons, and crops). This approach is now adopted by most but not all herb growers for all the cropping systems and has proven successful for the following reasons.

1. Crop rotation does not involve change in practice or introduction of new crops. It also does not need changes in technology.
2. The organic amendments are already available on site and are easy to use.
3. The approach is cost effective as it does not require additional inputs, and obviates the need for fumigation.
4. It applies to many other herb crops in addition to sweet basil.
5. Soil suppressiveness to plant disease is frequently improved and contributes to the overall system sustainability.

Challenges and difficulties.

1. This approach is not fully adopted by farmers that grow a limited range of crops or is less flexible in rotating limited number of crops in a limited area of production fields.
2. Using solarization has its own limitations, such as scheduling the crop and treatments.
3. Solarization of soil and structure is less effective in net houses, which comprise an important part of herb production. In such structures, intensity of solar radiation inside the structure is low and thus the efficacy is also low.

KEY CONSIDERATIONS FOR SYSTEMS-BASED APPROACHES

Systems-based approaches for managing soilborne diseases will continue to evolve as new scientific and technical advances become available. Regional cropping systems will change as markets, economics, and availability of natural resources fluctuate, necessitating changes to the systems approach. New disease and pest outbreaks will emerge, requiring further changes to the system and reprioritization of goals and objectives. It is naïve to assume that all assumptions pertaining to ecosystem and anthropogenic effects on plant pathosystems will be met or are correct in the design of the present system. Thus, it is imperative to guide development and deployment of systems-based approaches using a framework and associated metrics to assess progress.

Grower practices often contribute to the incidence and severity of soilborne diseases but are difficult to address from a management perspective. Grower decisions are determined by factors affecting enterprise profitability. Excluding instances where recent epidemics resulted in direct economic loss, soilborne pathogens are not an immediate concern and their consideration is often secondary. For example, manipulation of planting schedules to coincide with harvest periods generating increased profits often take precedence over timing of planting schedule to mitigate disease outbreak. Extending the growing season to gain additional returns through delayed harvests can lead to increased inoculum reservoirs in soil as the pathogen continues to reproduce on infected host plants. Finally, lack of revenue associated with cover crops, increased land values and higher nonharvest costs limit the adoption of crop rotations and promote the continuation of monocultures.

Effective management of the key economic soilborne plant pathogens responsible for yield and quality reduction is the goal. However, entire pest complexes will set the course of action for decision-making as the impact of primary pathogens to plant health can be exacerbated through interactions with secondary pathogens (i.e., root nibblers) and soil-inhabiting arthropods. The significant role of nematodes in the development of soilborne diseases is well documented (Back et al. 2002). The role of vesicular-arbuscular mycorrhizal fungi in soilborne disease is more complex, increasing the incidence of disease in some instances and decreasing in others (Dehne 1982). The role of mycorrhizal fungi on plant growth and elevated plant tolerance to stresses should be also considered (Gamliel et al. 2002).

Pathogen detection. Managing soilborne plant diseases within a systems-based approach requires a broad, multidisciplinary perspective. Soilborne pathogens are cryptic, limiting the economic and technical feasibility of soil sampling programs. To reliably ensure pathogen populations below the damaging thresholds, multiple samples must be collected and processed, escalating sampling costs and taxing the physical resources needed for their collection and assay. New polymerase chain reaction (PCR)-based detection methods offer potential to reduce costs and significantly shorten processing time. For example, for rapid detection of *V. dahliae* using real-time PCR based on the ribosomal DNA intergenic spacer reduced processing times from 6 to 8 weeks using traditional dry
Q:6 or wet sieving techniques to 2 to 3 days (Bilodeau et al. 2012;
Q:7 Termorshuizen et al. 1998). A practical, farm-based alternative is to survey disease in susceptible crops at season's end, when it is easier to detect pathogen presence and prior to redistributing infective propagules through the soil profile via tillage practices incorporating crop residue.

Risk mitigation. Systems-based ecological approaches to pest management operate under the premise that indigenous biological communities limit pest outbreaks through naturally occurring, self-regulating ecological feedback mechanisms. A defining feature of this approach is the de-emphasis of remedial interventions, whether biological, chemical, or physical (Levins 1986; Lewis et al. 1997). While attractive in theory, consistently achieving the desirable biological balance to mitigate outbreaks of a single pest species is difficult. Achieving the correct biological balance to simultaneously manage multiple pests at differing trophic levels is especially challenging, particularly on a regional scale. Multiple crops susceptible to the same pathogen complex can occur in proximity to each other. Neighboring farmers often have differing expectations of what constitutes acceptable levels of pest control. Risk mitigation drives the decision-making process for growers of high value crops because financial assistance is often required due to high, fixed and variable costs associated with crop production. From a risk perspective, application of broad-spectrum biocides including soil fumigants is an appealing option and often required as a prerequisite by the financial lending institution.

Financial costs. Despite extended time frames and increased costs associated with developing disease suppressive soils, the long-term benefits of minimizing pesticide use, improving soil fertility and reducing environmental impacts outweigh the costs and efforts. However, it is difficult to put a monetary value on those savings or amortize them over longer time frames as it also depends on the crop values over time. This precludes inclusion of systems-based approaches during the strategic planning process associated with future crop production. More attention to quantitative assessments of the financial costs and benefits associated with systems-based approaches is needed. While many organic farmers have embraced this concept, the majority of conventional growers are reluctant to integrate naturally occurring disease suppression mechanisms into crop production systems because the horticultural and pest management benefits do not outweigh the cost and time required to implement and manage them.

Spread of pathogens naturally and by other means. Plant pathogen populations in soil are dynamic. They are exposed to continuous spatial and temporal biotic, abiotic, and agricultural
Q:8 modifications (Short et al. 2015a). Their populations are supplemented by external sources arriving through infested seed, propagation material, contaminated equipment, and directly from field workers. The influx of newly described or exotic pathogens and hypervirulent strains of established pathogens further complicates the pathogen dynamics (Atallah et al. 2010; Short et al. 2014, 2015a). The issue of emerging and reemerging Q:9
pathogens presents a paradox as well (Subbarao et al. 2015). However, detection and management tools are continuously improving. Molecular techniques enable the detection of extremely low levels of pathogens with greater accuracy and reliability. In contrast, the globalization and the associated rapid and large scale movement of agricultural products for trade and travelers all over the world impede our attempts to prevent such invasions. New diseases are continuously reported from various parts of the world, e.g., *F. oxysporum* f. sp. *radicis-cucumerinum* (Vakalounakis 1996), Q:10
F. oxysporum f. sp. *lactucae* (Hubbard and Gerik 1993), *Verticillium* Q:11
dahliae (Subbarao et al. 1997), and others are such examples. Whatever is the source of the inoculum for these pathogens, they have a devastating potential (see case studies for further discussion on this issue).

Strategies and tactics for the management of soilborne pathogens. Pest control has come a long way from the primary goal of simply killing the pathogen. Thus, at last, "management" replaced "control" not only as a term but also as a concept. IPM assembles various measures under one roof. The special features of soilborne pathogens with regard to their biology, ecology, and survival in the soil present both difficulties and options for their management (Katan et al. 2012). The pathogen's existence in the soil makes the application of control measures very difficult, necessitating the use of drastic and soil penetrating measures, such as fumigants or heat, which while expensive also have adverse effects on beneficial organisms and the environment. On the plus side, the existence of pathogen inoculum in the soil prior to planting enables predicting the expected disease level and making decisions accordingly.

Many soilborne pathogens have multiple mechanisms of survival and dissemination, resulting in multiple sources of inoculum, all of which need to be identified and managed to ensure soil and crop health. The soil inoculum of soilborne pathogens is not the only source of infestation and paradoxically, in some cases is not even the major cause of infection. Aside from the soil in which the pathogens live, the various sources of inoculum include, infected propagation material, contaminated water, spreading of infested soil, insects and animals, inoculum adhering to the greenhouse structure or farm equipment and personnel, weeds and other hosts, as well as aerial propagules produced on the canopy of plants and spread through the air, as shown with various formae speciales of *F. oxysporum*. The above-ground aerial phase of the soilborne pathogens are usually overlooked, putting an additional burden on their management. Thus, the amount of inoculum left untreated will finally determine the degree of success or failure of the management actions. Therefore, the basic management strategies include physical, chemical, biological, cultural, physiological, and genetic approaches. These are reflected in tactics such as soil disinfestation (chemical, physical, solarization, and biological disinfestation), pesticides, breeding for resistance, grafting, induced resistance, sanitation, biological control, organic amendments, and others. Disease management in the greenhouse should also include the management of pathogens adhering to the structural components of the greenhouse (Gamliel et al. 2012) as well as the disinfestation of irrigation water.

CONCLUDING REMARKS

High input, conventional production systems have had a very successful reign in offering an efficient, secure, and stable food supply over many decades. Disease management under these systems has also relied on extensive inputs. Mounting public concerns regarding environmental degradation and human health risks associated with pesticides, escalating crop production costs, competition for diminishing natural resources, and the continued crop losses from disease outbreaks despite increased pesticide use have created an impetus to examine alternative approaches to soilborne disease management. While conventional approaches to manage diseases will continue to dominate in the near-future, over the long term, the systems-based approaches will undoubtedly offer a credible alternative. This paper has offered the necessary background for designing systems-based approaches to soilborne disease management and has illustrated such a system using two case studies.

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Q: 2_The in-text citation "Chellemi et al. 2013" is not in the reference list. Please correct the citation, add the reference to the list, or delete the citation.

Q: 3_Is this Short et al. 2015a or Short et al. 2015b?

Q: 4_Is this Short et al. 2015a or Short et al. 2015b?

Q: 5_Please correct the following sentences: "Infested organic manure can harbor *R. solani* and *Meloidogyne javanica*. *F. oxysporum* f. sp. *basilicii* and sclerotia of *S. sclerotiorum*."

Q: 6_Please make sure that this sentence is clear: For example, for rapid detection of *V. dahliae* using real-time PCR based on the ribosomal DNA intergenic spacer reduced processing times from 6 to 8 weeks using traditional dry or wet sieving techniques to 2 to 3 days

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AQUASAP 100% Seaweed Extract Powder - Technical Analysis

MICRO/MACRO NUTRIENTS	UNIT	ppm
Nitrogen (N)	g/100g	5400
Phosphorous (P)	g/100g	300
Potassium (K)	g/100g	357,800
Sodium (Na)	g/100g	74,300
Calcium (Ca)	g/100g	5,700
Silica (Si)	g/100g	2.,400
Magnesium (Mg)	g/100g	11,500
Iron (Fe)	g/100g	500
Sulphur (S)	g/100g	24,000
Boron as (B)	g/100g	1000
Copper (Cu)	mg/Kg	7.46
Zinc (Zn)	mg/Kg	47.82
Manganese (Mn)	mg/Kg	20.5
Cobalt	mg/Kg	0.5

AMINO ACIDS	UNIT	ppm
Threonine	g/100g	1,100
Cysteine	g/100g	traces
Valine	g/100g	1,100
Methionine	g/100g	1,100
Isoleucine	g/100g	1,200
Leucine	g/100g	1,200
Tyrosine	g/100g	1,100
Phenylalanine	g/100g	Traces
Histidine	g/100g	Traces
Lysine	g/100g	Traces
Arginine	g/100g	1,100
Tryptophan	g/100g	1,200
Proline	g/100g	1,100
Alanine	g/100g	1,200

AMINO ACIDS	UNIT	ppm
Aspartic Acid	g/100g	700
Glycine	g/100g	0500
Glutamine	g/100g	300
Serine	g/100g	400

PLANT GROWTH REGULATORS	UNIT	RESULTS
Indole 3-acetic acid	**ppm**	**6.67**
Zeatin	**ppm**	**1.37**
Giberrallins	**ppm**	**7.50**
Choline	**ppm**	**17.06**
Glycine Betain	**ppm**	**8.375**
Betain aldehyde	**-**	**Present**

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Histidine	g/100g	**Traces**
Lysine	g/100g	**Traces**
Arginine	g/100g	**1,100**
Tryptophan	g/100g	**1,200**
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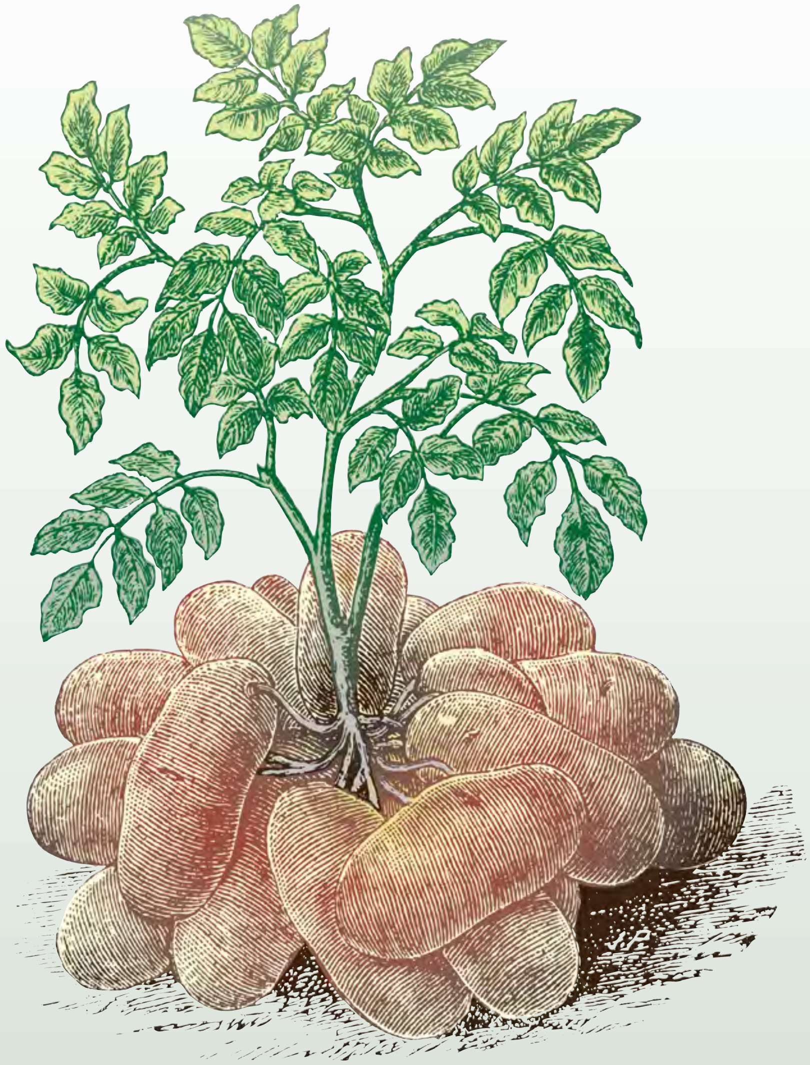
2015

Organic Production and IPM Guide for Potatoes



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Integrated Pest Management

New York State
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2015 Production Guide for
Organic Potato

Coordinating Editor

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**Pesticide Information and Regulatory Compliance*

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The information in this guide reflects the current authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this guide does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

Every effort has been made to provide correct, complete, and up-to-date pest management information for New York State at the time this publication was released for printing (June 2015). Changes in pesticide registrations and regulations, occurring after publication are available in county Cornell Cooperative Extension offices or from the Pesticide Management Education Program web site (*http://pmep.cce.cornell.edu*). Trade names used herein are for convenience only. No endorsement of products in intended, nor is criticism of unnamed products implied.

This guide is not a substitute for pesticide labeling. Always read the product label before applying any pesticide.

Updates and additions to this guide are available at http://www.nysipm.cornell.edu/organic_guide. Please submit comments or suggested changes for these guides to organicguides@gmail.com.

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Contents

INTRODUCTION

This guide for organic production of potatoes provides an outline of cultural and pest management practices and includes topics that have an impact on improving plant health and reducing pest problems. It is divided into sections, but the interrelated quality of organic cropping systems makes each section relevant to the others.

This guide attempts to compile the most current information available, but acknowledges that effective means of control are not available for some pests. More research on growing crops organically is needed, especially in the area of pest management. Future revisions will incorporate new information providing organic growers with a complete set of useful practices to help them achieve success.

This guide uses the term Integrated Pest Management (IPM), which like organic production, emphasizes cultural, biological, and mechanical practices to minimize pest outbreaks. With limited pest control products available for use in many organic production systems, an integrated approach to pest management is essential. IPM techniques such as identifying and assessing pest populations, keeping accurate pest history records, selecting the proper site, and preventing pest outbreaks through use of crop rotation, resistant varieties and biological controls are important to producing a high quality crop.

1. GENERAL ORGANIC MANAGEMENT PRACTICES

1.1 Organic Certification

To use a certified organic label, farming operations grossing more than $5,000 per year in organic products must be certified by a U.S. Department of Agriculture National Organic Program (NOP) accredited certifying agency. The choice of certifier may be dictated by the processor or by the target market. A list of accredited certifiers (Reference 10) operating in New York can be found on the New York State Department of Agriculture and Markets Organic Farming Development/Assistance web page (Reference 11). See more certification details under Section 4.1: *Field Selection: Certification Requirements* and Section 11: *Using Organic Pesticides.*

1.2 Organic Farm Plan

An organic farm plan is central to the certification process. The farm plan describes production, handling, and record-keeping systems, and demonstrates to certifiers an understanding of organic practices for a specific crop. The process of developing the plan can be very valuable in terms of anticipating potential issues and challenges, and fosters thinking of the farm as a whole system. Soil, nutrient, pest, and weed management are all interrelated on organic farms and must be managed in concert to be successful. Certifying organizations may be able to provide a template for the farm plan. The following description of the farm plan is from the NOP web site:

> "The Organic Food Production Act of 1990 (OFPA or Act) requires that all crop, wild crop, livestock, and handling operations requiring certification submit an organic system plan to their certifying agent and, where applicable, the State Organic Program (SOP). The organic system plan is a detailed description of how an operation will achieve, document, and sustain compliance with all applicable provisions in the OFPA and these regulations. The certifying agent must concur that the proposed organic system plan fulfills the requirements of subpart C, and any subsequent modification of the organic plan by the producer or handler must receive the approval of the certifying agent."

More details may be found at the Agricultural Marketing Service's National Organic Program website (Reference 12). The National Sustainable Agriculture Information Service, (formerly ATTRA), has produced a guide to organic certification that includes templates for developing an organic farm plan (Reference 13). The Rodale Institute has also developed resources for transitioning to organic and developing an organic farm plan (Reference 14).

1.3 Critical management strategies

While this guide contains many management strategies for organic potato production, Table 1.3.1, based on recommendations from a successful organic potato grower, summarizes those that are critically important.

Table 1.3.1 Critical management considerations

Challenge	Considerations
Planting date	Plant too early and potatoes rot or get frosted; plant too late and the risk of late blight and insufficient time to mature can severely affect yield. Take advantage of the good 3 week planting window that usually begins and ends in May. See Section 7: *Planting methods*.
Weed management	This is very important. Poor weed control can severely decrease yields, increase disease by preventing airflow, and interfere with harvest by clogging harvest equipment. Weeds impede hand harvesting as well. Multiple well-timed cultivations with hilling can be very effective even when previous cultural control was poor. Be ready to cultivate when the weather permits and crop and weed timing dictate. See Section 5: *Weed management.*
Insect control	The most troublesome insects are the Colorado potato beetle (CPB) and the potato leafhopper (PLH). For CPB, very effective results are achieved on a small scale by picking adults and on a larger scale with 1-2 sprays of Entrust Naturalyte Insect Control at the early larval stages (See Section 15.1). Damage inflicted by PLH is very variety-dependent. Select varieties that can withstand PLH damage because organically approved sprays may not work or be cost effective. See Section 6: *Varieties*.
Disease control	The disease of greatest concern is late blight. Always follow the recommended late blight cultural controls (Section 12.4: *Late blight*). In years where conditions are very favorable for late blight, organic growers will likely be affected and could suffer yield decreases of at least 50%. Factor this into the cost of growing the crop. Many growers experience late blight in 1 out of 5 years. Sprays labeled for late blight are available, but their effectiveness is not 100% and is very much dependent on the adequacy of spray equipment, frequency of spray, and timing of initial spray relative to development of the disease.

2. Soil Health

Healthy soil is the basis of organic farming. Regular additions of organic matter in the form of cover crops, compost, or manure create a soil that is biologically active, with good structure and capacity to hold nutrients and water (note that any raw manure applications must occur at least 120 days before harvest). Decomposing plant materials will activate a diverse pool of microbes, including those that break down organic matter into plant-available nutrients as well as others that compete with plant pathogens in the soil and on the root surface.

Rotating between crop families can help prevent the buildup of diseases and nematodes that overwinter in the soil. Rotation with a grain crop, or preferably a sod that will be in place for one or more seasons, deprives many, but not all, disease-causing organisms of a host, and also contributes to a healthy soil structure that promotes vigorous plant growth. The same practices are effective for preventing the buildup of root damaging nematodes in the soil, but keep in mind that certain grain crops are also hosts for some nematode species. Rotating between crops with late and early season planting dates can reduce the buildup of weed populations. Organic growers must attend to the connection between soil, nutrients, pests, and weeds to succeed. An excellent resource for additional information on soils and soil health is the online e-book, Building Soils for Better Crops (Reference 15). For more information, refer to the Cornell Soil Health website (Reference 16).

3. Cover Crops

Unlike cash crops, which are grown for immediate economic benefit, cover crops are grown for their valuable effect on soil properties and on subsequent cash crops. Cover crops help maintain soil organic matter, improve soil tilth, prevent erosion and assist in nutrient management. They can also contribute to weed management, increase water infiltration, maintain or increase populations of beneficial fungi, and may help control insects, diseases and nematodes. Beneficial fungi create a competitive environment in the soil, as they fight with plant pathogenic fungi for limited resources. To be effective, cover crops should be treated as any other valuable crop on the farm, carefully considering their cultural requirements, life span, mowing recommendations, incorporation methods, and susceptibility, tolerance, or antagonism to root pathogens and other pests. See Tables 3.1 and 3.2 for more information on specific cover crops and Section 8: *Crop and Soil Nutrient Management* for more information about how cover crops fit into nutrient management.

A certified organic farmer is required to plant certified organic cover crop seed. If, after contacting at least three suppliers, organic seed is not available, then the certifier may allow untreated conventional seed to be used. Suppliers should provide a purity test for cover crop seed. Always inspect the seed for contamination with weed seeds and return if it is not clean. Cover crop seed is a common route for introduction of new weed species onto farms.

3.1 Goals and Timing for Cover Crops

Adding cover crops regularly to the crop rotation plan can result in increased yields of the subsequent cash crop. Goals should be established for choosing a cover crop; for example, the cover crop can add nitrogen, smother weeds, or break a pest cycle. See the Cornell online decision tool to match goals, season, and cover crop (reference 17). The cover crop might best achieve some of these goals if it is in place for the entire growing season. If this is impractical, a compromise might be to grow the cover crop between summer cash crops. Allow two or more weeks between cover crop incorporation and cash crop seeding to permit decomposition of the cover crop, which will improve the seedbed and help avoid any unwanted allelopathic effects on the next cash crop. Another option is to overlap the cover crop and the cash crop life cycles by overseeding, interseeding or intercropping the cover crop between cash crop rows at final cultivation. An excellent resource for determining the best cover crop for your situation is Northeast Cover Crop Handbook by Marianne Sarrantonio (Reference 19).

Leaving cover crop residue on the soil surface might make it easier to fit into a crop rotation and will help to conserve soil moisture but some of the nitrogen contained in the residue will be lost to the atmosphere, and total organic matter added to the soil will be reduced. Turning under the cover crop will speed up the decomposition and nitrogen release from the residue. In wet years, the presence of cover crop residues may increase slug damage and infections by fungal pathogens such as *Pythium* and *Rhizoctonia,* often affecting stand establishment.

3.2 Legume Cover Crops

Legumes are the best choice for increasing available soil nitrogen for crops with a high nitrogen requirement like potatoes (see Table 4.2.1). Plant in advance of the potato crop to build the soil nitrogen, or after to replace the nitrogen used by the potato crop. Legumes have symbiotic bacteria in their roots called rhizobia, which convert atmospheric nitrogen gas in the soil pores to ammonium, a form of nitrogen that plant roots can use. When the cover crop is mowed, winter killed or incorporated into the soil, the nitrogen is released and available for the next crop. Because most of this nitrogen was taken from the air, there is a net nitrogen gain to the soil (See Table 3.1). Assume approximately 50 percent of the nitrogen fixed by the cover crop will be available for the cash crop in the first season, but this may vary depending on the maturity of the legume, environmental conditions during decomposition, the type of legume grown, and soil type.

It is common to inoculate legume seed with rhizobia prior to planting, but the inoculant must be approved for use in organic systems. Request written verification of organic approval from the supplier and confirm this with your organic farm certifier prior to inoculating seed.

Special Considerations for Potato

Monitor the incidence and severity of root diseases caused by fungal pathogens (Rhizoctonia, Pythium) and nematodes (lesion, root-knot), as legumes are good hosts and will increase these pathogens if present.

3.3 Non-legume Cover Crops

Non-leguminous cover crops are beneficial because they generate organic matter, compete with weeds and help prevent soil erosion. Planted after cash crops, when the soil is still warm and microbes are releasing nitrates, they capture nitrogen that otherwise might be leached from the soil. Some non-leguminous cover crops, such as winter rye, ryegrass, brassicas and buckwheat also have been shown to reduce soil-borne diseases when used in rotation with potatoes. Potatoes grown after ryegrass or buckwheat showed significant reductions in common scab in one multi-year study in Maine. Plant these cover crops by late August.

Sudangrass and brassicas will winter-kill in the Northeast, leaving a dead mulch for cover over the winter and facilitating early spring planting. Winter hardy cover crops must be incorporated before planting, and may deplete soil moisture in dry years. If incorporated, allow two weeks or more for decomposition prior to planting.

3.4 Combining Legumes and Non-legumes

Interseeding a legume with non-legume cover crop combines the benefits of both. A quick–growing rye grown in late summer with a nitrogen-producing vetch protects the soil from heavy harvest traffic in the fall, erosion in the winter, and supplies extensive organic matter and nitrogen when incorporated in the spring. Seed rye at 50-60 lbs/acre with hairy vetch at 30 lbs/acre. Growing these cover crops together reduces the over all nitrogen contribution but helps the vetch to survive harsh winters.

Special consideration for potato

Monitor the incidence and severity of root diseases caused by fungal pathogens (Rhizoctonia, Pythium) and nematodes (lesion, root-knot), as legumes are good hosts and will increase these pathogens if present.

3.5 Biofumigant Cover Crops

Certain cover crops, when tilled into the soil as green manures and degraded by microbes, release volatile chemicals that have been shown to inhibit weeds, pathogens, and nematodes. These biofumigant cover crops include Sudangrass, sorghum-sudangrass, and many in the brassica family. Degradation is quickest when soil is warm and moist. Lightly seal the soil surface using a culti-packer or 1/2 inch of irrigation or rainwater to help trap the volatiles and prolong their persistence in the soil. Wait at least two weeks before planting a subsequent crop to reduce the potential for the breakdown product to harm the crop (phytotoxicity). This biofumigant effect is not predictable or consistent. The levels of the active compounds and ability to suppress disease can vary by season, cover crop variety, maturity at incorporation, soil microbial diversity, and microbe population density.

One Maine study showed that 'Caliente 119', a high glucosinolate mustard blend, had the most consistent effect on reducing soil borne diseases (common scab, powdery scab, stem canker and black scurf) in the subsequent potato crop. Another Maine study showed higher potato yields on fields grown after 'Caliente 119', compared to potatoes grown after barely, however white mold incidence was also higher.

Reference

Cover Crops for Vegetable Growers: Decision Tool (Reference 17).
Northeast Cover Crops Handbook (Reference 18).
Cover Crops for Vegetable Production in the Northeast (Reference 19)
Crop Rotation on Organic Farms: A Planning Manual (Reference 21).

Table 3.1 Leguminous Cover Crops: Cultural Requirements, Nitrogen Contributions and Benefits.

Species	Planting Dates	Life Cycle	Cold Hardiness	Tolerances: Heat	Tolerances: Drought	Tolerances: Shade	pH Preference	Soil Type Preference	Seeding (lb/A)	Nitrogen Fixed (lb/A)[a]	Comments
Clovers											
Alsike	April-May	Biennial/ Perennial	4	5	5	6	6.3	Clay to silt	4-10	60-119	+Endures waterlogged soils & greater pH range than most clovers
Berseem	Early spring	Summer annual/ Winter annual[b]	7	6-7	7-8	5	6.5-7.5	Loam to silt	9-25	50-95	+Good full-season annual cover crop
Crimson	Spring	Summer annual/ Winter annual[b]	6	5	3	7	5.0-7.0	Most if well-drained	9-40	70-130	+Quick cover +Good choice for overseeding (shade tolerant) + Sometimes hardy to zone 5.
Red	Very early spring or late summer	Short-lived perennial	4	4	4	6	6.2-7.0	Loam to clay	7-18	100-110	+Strong taproot, good heavy soil conditioner +Good choice for overseeding (shade tolerant)
White	Very early spring or late summer	Long-lived perennial	4	6	7	8	6.2-7.0	Loam to clay	6-14	≤130	+Good low maintenance living cover +Low growing +Hardy under wide range of conditions
Sweet Clovers											
Annual White	Very early spring	Summer annual[b]	NFT	6-7	6-7	6	6.5-7.2	Most	15-30	70-90	+Good warm weather smother & catch crop +Rapid grower +High biomass producer
Biennial White and Yellow	Early spring-late summer	Biennial	4	6	7-8	4	6.5-7.5	Most	9-20	90-170	+Deep taproot breaks up compacted soils & recycles nutrients +Good catch crop +High biomass producer
Other Legumes											
Cowpeas	Late spring-late summer	Summer annual[b]	NFT	9	8	6	5.5-6.5	Sandy loam to loam	25-120	130	+Rapid hot weather growth
Fava Beans	April-May or July-August	Summer annual[b]	8	3	4	NI	5.5-7.3	Loam to silty clay	80-170 small seed 70-300 lg seed	71-220	+Strong taproot, good conditioner for compacted soils + Excellent cover & producer in cold soils +Efficient N-fixer
Hairy Vetch	Late August-early Sept.	Summer annual/ Winter annual	4	3	7	5	6.0-7.0	Most	20-40	80-250 (110 ave.)	+Prolific, viney growth +Most cold tolerant of available winter annual legumes
Field Peas	March-April OR late summer	Winter annual/ Summer annual[b]	7	3	5	4	6.5-7.5	Clay loam	70-220	172-190	+Rapid growth in chilly weather

NI=No Information, NFT=No Frost Tolerance. Drought, Heat, Shade Tolerance Ratings: 1-2=low, 3-5=moderate, 6-8=high, 9-10=very high. a Nitrogen fixed but not total available nitrogen. See Section 8 for more information. b Winter killed. Reprinted with permission from rodaleinstitute.org M. Sarrantonio. (1994) Northeast Cover Crop Handbook (Reference 19).

Table 3.2. Non-leguminous Cover Crops: Cultural Requirements and Crop Benefits

Species	Planting Dates	Life Cycle	Cold Hardiness Zone	Heat	Drought	Shade	pH Preference	Soil Type Preference	Seeding (Lb/A)	Comments
				--Tolerances--						
Brassicas e.g. mustards, rapeseed	April or late August-early Sept.	Annual / Biennial [b]	6-8	4	6	NI	5.3-6.8	Loam to clay	5-12	+Good dual purpose cover & forage +Establishes quickly in cool weather +Biofumigant properties
Buckwheat	Late spring-summer	Summer annual [b]	NFT	7-8	4	6	5.0-7.0	Most	35-134	+Rapid grower (warm season) +Good catch or smother crop +Good short-term soil improver for poor soils
Cereal Rye	August-early October	Winter annual	3	6	8	7	5.0-7.0	Sandy to clay loams	60-200	+Most cold-tolerant cover crop +Excellent allelopathic weed control +Good catch crop +Rapid germination & growth +Temporary N tie-up when turned under
Fine Fescues	Mid March-mid-May OR late Aug.-late Sept.	Long-lived perennial	4	3-5	7-9	7-8	5.3-7.5 (red) 5.0-6.0 (hard)	Most	16-100	+Very good low-maintenance permanent cover, especially in infertile, acid, droughty &/or shady sites
Oats	Mid-Sept-early October	Summer annual [b]	8	4	4	4	5.0-6.5	Silt & clay loams	110	+Rapid growth +Ideal quick cover and nurse crop
Ryegrasses	August-early Sept.	Winter annual (AR)/ Short-lived perennial (PR)	6 (AR) 4 (PR)	4	3	7 (AR) 5 (PR)	6.0-7.0	Most	14-35	+Temporary N tie-up when turned under +Rapid growth +Good catch crop +Heavy N & moisture users
Sorghum-Sudangrass	Late spring-summer	Summer Annual [b]	NFT	9	8	NI	Near neutral	NI	10-36	+Tremendous biomass producers in hot weather +Good catch or smother crop +Biofumigant properties

NI-No Information, NFT-No Frost Tolerance. AR=Annual Rye, PR=Perennial Rye.

Drought, Heat, Shade Tolerance Ratings: 1-2=low, 3-5=moderate, 6-8=high, 9-10=very high. b Winter killed. Reprinted with permission from Rodale Institute www.rodaleinstitute.org M. Sarrantonio. (1994) Northeast Cover Crop Handbook (Reference 19).

4. Field Selection

For organic production, give priority to fields with excellent soil tilth, high organic matter, and good drainage and airflow.

4.1 Certification Requirements

Certifying agencies have requirements that affect field selection. Fields cannot be treated with prohibited products for three years prior to the harvest of a certified organic crop. Adequate buffer zones must exist between certified organic and conventionally grown crops. The buffer zones must be a barrier such as a diversion ditch or dense hedgerow, or be a distance large enough to prevent drift of prohibited materials onto certified organic fields. Determining what buffer zone is needed will vary depending on equipment used on adjacent non-certified land. For example, use of high-pressure spray equipment or aerial pesticide applications in adjacent fields will increase the buffer zone size. Pollen from a genetically engineered plant can also be a contaminant. An organic crop should not be grown near an organic crop of the same species. Check with your certifier for specific buffer requirements.

These buffers commonly range between 20 to 250 feet depending on adjacent field practices.

4.2 Crop Rotation Plan

A careful crop rotation plan is the cornerstone of organic crop production because it allows the grower to improve soil quality and proactively manage pests. Although growing a wide range of crops complicates the crop rotation planning process, it ensures diversity in crop residues in the soil, and greater variety of beneficial soil organisms. Individual organic farms vary widely in the crops grown and their ultimate goals, but some general rules apply to all organic farms regarding crop rotation. Rotating individual fields away from crops within the same family is critical and can help minimize crop-specific disease and non-mobile insect pests that persist in the soil or overwinter in the field or field borders. Pests that are persistent in the soil, have a wide host range, or are wind-borne will be difficult to control through crop rotation. Conversely, the more host specific, non-mobile, and short-lived a pest is, the greater the ability to control it through crop rotation. The amount of time required for a crop rotation is based on the particular pest and its severity. Some particularly difficult pests may require a period of fallow. See specific recommendations in the disease and insect sections of this guide (Sections 12, 13, 15). Partitioning the farm into management units will help to organize crop rotations and ensure that all parts of the farm have sufficient breaks from each type of crop.

A well-planned crop rotation is key to weed management. Short season crops such as lettuce and spinach are harvested before many weeds go to seed, whereas vining cucurbits, with their limited cultivation time and long growing season, allow weeds to go to seed before harvest. Including short season crops in the rotation will help reduce weed populations provided the field is cleaned up promptly after harvest. Other weed reducing rotation strategies include growing mulched crops, competitive cash crops, short-lived cover crops, or crops that are intensively cultivated. Individual weed species emerge and mature at different times of the year, therefore alternating between spring, summer, and fall planted crops helps to interrupt weed life cycles.

Cash and cover crop sequences should also take into account the nutrient needs of different crops and the response of weeds to high nutrient levels. High soil phosphorus and potassium levels can exacerbate problem weed species. A cropping sequence that alternates crops with high and low nutrient requirements can help keep nutrients in balance. The crop with low nutrient requirements can help use up nutrients from a previous heavy feeder. A fall planting of a non-legume cover crop will help hold nitrogen not used by the previous crop. This nitrogen is then released when the cover crop is incorporated in the spring. See Section 3: *Cover Crops* and Section 5: *Weeds* for more information.

Rotating crops that produce abundant organic matter, such as hay and grain-legume cover crops, with ones that produce less, such as vegetables, will help to sustain organic matter levels and promote good soil tilth (see Section 2: *Soil Health* and Section 8: *Crop and Soil Nutrient Management*). Potatoes generally have a high nutrient requirement (Table 4.2.1). Growing a cover crop, preferably one that includes a legume, prior to or after potatoes will help to renew soil nitrogen, improve soil structure, and diversify soil organisms. Including short season crops in the rotation will help to reduce the overall weed population in the field.

Table 4.2.1 Crop Nutrient Requirements

	Nutrient Needs		
	Lower	**Medium**	**Higher**
Crop	Bean	Cucumber	Broccoli
	Beet	Eggplant	Cabbage
	Carrot	Brassica greens	Cauliflower
	Herbs	Pepper	Corn
	Pea	Pumpkin	Lettuce
	Radish	Spinach	Potato
		Chard	Tomato
		Squash	
		Winter squash	

From NRAES publication *Crop Rotation on Organic Farms: A Planning Manual.* Charles L. Mohler and Sue Ellen Johnson, editors (Reference 21).

Crop information specific to potatoes

Plan at least 2 years between potato crops and related crops, such as tomato and eggplant. See Cornell's minimum years to avoid specific diseases (Reference 54).

Phosphorous and potassium: Many fields with a long history of potato production have accumulated large amounts of these nutrients. Excessive levels of potash can depress specific gravity, an important factor in harvest quality. Moreover, high phosphorus and potassium levels can exacerbate problem weed species. For example, high phosphorus promotes common purslane and high potassium promotes dandelion. Removing alfalfa hay from the field for several years can reduce phosphorus and potassium levels.

Stem canker and black scurf *(Rhizoctonia solani):* Reduce canker and black scurf incidence by planting grass and cereal crops in rotation with potato or as green manure crops before potatoes. Tomato, strawberry, cabbage and Brussels sprout host canker and black scurf and will increase soil inoculum levels.

Common scab *(Streptomyces scabies)*: Use winter grain or forage grass as a green manure before potato or rotate with soybeans to reduce common scab. Avoid sweet clover as a green manure before potatoes. Rotate away from common scab hosts: beets, carrots, parsnip, radish, rutabaga and turnip.

White mold (*Sclerotinia sclerotiorum*): Beans, cabbage and Brussels sprouts host white mold and will increase soil inoculum levels.

Wireworms*:* Plant grains or grasses that are only in the field for part of the season because wireworm populations can build up in the soil if grasses are grown for an entire season or longer.

Soil structure: Root crops tend to reduce soil structure due to the additional soil disturbance during harvest; consequently, grow soil-building crops before and after a root crop.

Complementary crops: The timing of potato harvest and garlic planting are well suited for following potato with garlic.

See Table 4.2.2 for more crop rotation information specific for potatoes. For more details, see Crop Rotations on Organic Farms: A Planning Manual edited by Charles L. Mohler and Sue Ellen Johnson (Reference 21).

Table 4.2.2 Potential Interactions of Crops Grown in Rotation with Potatoes.

Crops in Rotation	Potential Effects from Rotation	Comments
Beans	White mold *increase*	Beans host white mold.
Beet, carrot, parsnip, radish, rutabaga, turnip	Common scab *increase*	These crops host common scab.
Cabbage, Brussels sprouts	Stem canker and black scurf and white mold *increase*	Cabbage and Brussels sprouts host these diseases.
Carrot, Celery	Root knot nematode *increase*	Any two-year sequence involving carrot, celery and potato should be avoided due to root-knot nematode.
Eggplant	Verticillium wilt, Colorado potato beetle and flea beetle (WT) *increase*	Eggplant hosts these pests.
Pepper	Verticillium wilt	Pepper hosts verticillium wilt.
Strawberries	Verticillium wilt, stem canker and black scurf *increase*	Strawberries host these diseases.
Tomato	Early blight, Verticillium wilt, black dot, stem canker and black scurf, Colorado potato beetle *increase*	Tomato hosts these pests.
Alfalfa	Fusarium wilt *reduction*	Alfalfa decreases Fusarium wilt.
Annual ryegrass, spring grain cover crop, Sorghum-sudangrass	Stem canker and black scurf *reduction*	Use of grasses in rotation with potato helps reduce stem canker and black scurf.
Oats, spring barley, rye, winter wheat, spelt	Stem canker and black scurf *reduction* Wireworm *increase*	One year of cereal grain in rotation with potato helps reduce stem canker and black scurf but can increase wireworm populations.
Soybean	Common scab *reduction*	Soybean before potato may reduce common scab.
Green Manures		
Winter grain cover crop as a green manure	Common scab, stem canker and black scurf *reduction*	Green manure of rye or other winter grain reduces common scab, stem canker and black scurf.
Grass and grass legume hay as a green manure	Common scab, stem canker and black scurf *reduction* Wireworm *increase*	Green manure of forage grass sod *reduces* common scab, stem canker and black scurf, but can increase wireworm populations.
Buckwheat green manure	Verticillium wilt *reduction* Soil tilth *improved*	Severity of Verticillium wilt was lower following buckwheat green manure than following canola or a fallow period; buckwheat leaves the soil in a good state of tilth for potato.
Sweet clover green manure	Common scab *increase*	Sweet clover green manure is more conducive to common scab development than alfalfa or rye.
Canola, rape and oilseed radish	General disease *reduction*	Plowed-down brassica cover crops act as a fumigant against potato diseases.

Excerpt from Appendix 2 of *Crop Rotation on Organic Farms: A Planning Manual*. Charles L. Mohler and Sue Ellen Johnson, editors (Reference 21).

4.3 Pest History

Knowledge about the pest history of each field is important for planning a successful cropping strategy. For example, avoid fields that contain heavy infestations of perennial weeds such as bindweed and quackgrass as these weeds are particularly difficult to control. One or more years focusing on weed population reduction using cultivated fallow and cover cropping may be needed before organic crops can be successfully grown in those fields. Susceptible crops should not be grown in fields with a history of Sclerotinia white mold without a rotation of several years with sweet corn or grain crops. Treat with Contans ™ to reduce fungal sclerotia in the soil immediately after an infected crop is harvested

Potatoes host both root-knot nematode, *Meloidogyne hapla*, and root-lesion nematode, *Pratylenchus penetrans*. Knowing whether these nematodes are present aids development of cropping sequences that prevent increase in uninfested or lightly infested fields and reduces populations in heavily infested fields. Refer to Section 13 for more information on nematodes.

Potatoes in close proximity to cornfields are at risk of infestation by the European corn borer. Potatoes will be especially vulnerable to egg laying if surrounding corn has not reached the mid-whorl stage during the spring flight period.

4.4 Soil and Air Drainage

Potatoes need well-drained soil to reduce the risk of pink rot and Pythium leak and powdery scab. Late blight will be less prevalent in fields with good soil and air drainage. Any practice that promotes leaf drying can slow development of foliar diseases because of the general need by pathogens for wet surfaces during infection. Fields with poor air movement such as those surrounded by hedgerows or woods are a poor choice for potatoes. Plant rows in an east-west direction and avoid overcrowding to promote drying of the soil and reduce moisture in the plant canopy.

5. WEED MANAGEMENT

Weed management can be one of the biggest challenges on organic farms, especially during the transition and the first several years of organic production. To be successful, use an integrated approach to weed management that includes crop rotation, cover cropping, cultivation, and planting design based on an understanding of the biology and ecology of dominant weed species. A multi-year approach that includes strategies for controlling problem species in a sequence of crops will generally be more successful than attempting to manage each year's weeds as they appear. Relying on cultivation alone to manage weeds in an organic system is a recipe for disaster.

Management plans should focus on the most challenging and potentially yield-limiting weed species in each field. Be sure, however, to emphasize options that do not increase other species that are present. Alternating between early and late-planted crops, and short and long season crops in the rotation can help minimize buildup of a particular weed or group of weeds with similar life cycles or growth habits, and will also provide windows for a variety of cover crops.

5.1 Record Keeping

Scout and develop a written inventory of weed species and severity for each field. Accurate identification of weeds is essential. Weed fact sheets provide a good color reference for common weed identification. See Cornell weed ecology and Rutgers weed gallery websites (References 24- 25)

5.2 Weed Management Methods

Planting and cultivation equipment should be set up on the same number of rows to minimize crop damage during cultivation. Specialized equipment may be needed to successfully control weeds in some crops. See resources at the end of this section to help fine-tune your weed management system.

For optimal weed management in potatoes, plan several seasons ahead. Do not plant potatoes in a field infested with quackgrass, which can damage tubers. Eliminate quackgrass and other perennial weeds and reduce the seed bank of annual weeds (1) by growing crops that require intensive cultivation, (2) by growing short season crops and cleaning up the field quickly after harvest, and (3) by using cultivated fallow periods.

Before planting potatoes, incorporate any growing weeds completely using a moldboard plow, spader or rotary tiller. When planting, ensure that the seed pieces are well covered. The surface after planting should be flat or have an inch or two of extra soil over the rows. If soil is mounded on top of seed pieces that are planted near the soil surface, tine weeding will probably uncover the seed. Placing extra soil over the rows with the planter ensures that the seed remains covered and guarantees aggressive action by the tine weeder as it knocks the extra soil into the shallow valleys

Tine weed every 5-7 days until potatoes emerge and again when the shoots are 4-6". At least one pre-emergence and one post-emergence tine weeding will be needed. An optimal tine weeder for potatoes will have stiff tines with a 45-degree bend. Tines should be set so that they do not hit the seed pieces. In particular, check to ensure that no seed pieces are flipped out of the ground by the weeder. Set the tines to run ½ to ¾" above the seed and move at 3-4 mph for optimal weed control.

If a tine weeder is used as recommended above, begin inter-row cultivation when plants are about 12-15" tall. At the first cultivation, heap 2"-3" of soil around base of plants in the row to bury small seedlings. Soil can be moved into the crop row either with disk hillers or with sweeps that have a relatively steep angle. The goal is to have the highest point of the soil in the line of the crop, rather than a dip in the middle where weeds remain uncovered. If potatoes are growing slowly, an additional cultivation might be needed. Most likely, the next operation will be hilling. If a tine weeder is not available, begin inter-row cultivation when the first flush of weeds has emerged, regardless of whether the potatoes are up yet. Throw sufficient soil into the row to completely cover weed seedlings. Repeat for each successive flush of weeds until the final hilling."

A standard hilling operation will usually cover any additional seedlings that have emerged. After hilling, the potato plants are usually too large to cultivate again, but sometimes an extra cultivation between the rows will be useful.

Between hilling and harvest, rogue out any large weeds that get established: In doing so, you will (1) prevent seed set that could pose problems for rotation crops (2) eliminate possible virus hosts and (3) avoid the development of very large weeds that can jam up the potato digger. Rogueing out large weeds may require less labor than cleaning out the digger when it becomes jammed.

Before harvest mow the vines. This will not only make digging the potatoes easier, but will also decrease the likelihood of weeds going to seed. Many weeds that have already flowered will continue to set seeds even if they have been completely uprooted and left on the soil surface. Some growers flame the residue after mowing to speed drying and kill fungal spores that might infect the tubers. This has the additional benefit of further reducing seed production, for example, by short weeds between the hills and by pieces of pigweed flowering stalks.

References

Crop Rotation on Organic Farms: A Planning Manual (Ref 21)
Steel in the Field e-book (Reference 23)
Cornell Weed Ecology website (Reference 24)
New Jersey Weed Gallery (Reference 25)
Principals of sustainable weed management for croplands (Ref 27)
New cultivation tools for mechanical weed control in vegetables
(Reference 28)
Weed 'Em and Reap videos (Reference 29)
Flame weeding for vegetable crops(Reference 30)
Vegetable farmers and their weed control machines (Reference 31).

6. RECOMMENDED VARIETIES

Variety selection is important both for the horticultural characteristics specified by the market and the pest resistance profile that will be the foundation of a pest management program. If disease pressures are known, Table 6.1.2 can help to determine which varieties will be more successful in reducing disease problems. Consider the market when choosing varieties, selecting those with some level of disease resistance if possible.

A certified organic farmer is required to plant certified organic seed. If, after contacting at least three suppliers, organic seed is not available for a particular variety, then the certifier may allow untreated conventional seed to be used.

Table 6.1.1 Cultural characteristics of potato varieties.

Variety	Skin color/ flesh color[2]	Maturity[3]	Tuber set [4]	Ave tuber weight [4]	Use[5]	Nitrogen required mineral soils	Nitrogen required muck soils	Organic Marketable Yield	Conventional marketable yield	Specific gravity[4]	External defects[4]	External defects[4]	Internal defects[4,10]	Internal defects[4,10]	Dormancy[11]
		Relative to Atlantic	#Tubers/ foot	Oz.		N lbs/A[6]	N lbs/A[6]	CWT/A	CWT/A	1.0xx[9]	%	Defects	%	Defects	
Adirondack Blue[1]	P/P	EM	6.7	4.3	T	125-150	80	160	205	73	12	knobs	2	VD	-4[b]
Adirondack Red[1]	R/R		9.2	3.4	T	125-150	80	180	216	67	5	green	3	VD	+10[b]
All Blue[1]	P/P	ML			T	100-125	80	120	210						+13[b]
Allegany	W/W	L			T	100-125	60	70	315						+48
Andover	W/W	EM	7.3	5.2	C,T	125-150	100	135	280	83	3	green	2	HH	+22[a]
Atlantic[7]	Bu/W	M	7.7	5.5	C	100-125	80	230	325	92	4	green	9	HH	0(std)
Austrian Crescent[1]	Bu/Y	L			T										
Bake-King		M			T										
Banana[1]	Y/Y	L			T										
Caribe[1]	RP/W	E			T										
Carola[1]	Y/Y	M	10	4.2	T	100-125	80	195	290	76	6	green	23	VD	+11
Chieftan[1]	R/W	M	8.8	6.2	T	100-125	80	270	335	71	4	green	6	VD	0(std)[b]
Elba[1]	Bu/W	VL			T	100-125	60	190	330						
Eva[1]	W/W	M	7.6	5.3	C,T	125-150	100	195	310	77	6	green	2	VD	+43
French Fingerlings[1]	R/Y				T										
Genesee	W/W	L	7.1	5.3	T	100-125	80	135	285	71	7	green	5	VD	-10
German Butterball[1]	Y/Y	L			T			70	250						
Green Mountain	W/W					100-125	80	220	185						
Kanona	W/W	ML			C	125-150	80		305						
Katahdin[1]	Bu/W	L	7.4	5.6	T	100-125	80	205	300	75	9	green	8	HH	+5

Table 6.1.1 Cultural characteristics of potato varieties.

Variety	Skin color/ flesh color[2]	Maturity[3]	Tuber set [4]	Ave tuber weight [4]	Use[5]	Nitrogen required mineral soils	Nitrogen required muck soils	Organic Marketable Yield	Conventional marketable yield	Specific gravity[4]	External defects[4]	External defects[4]	Internal defects[4,10]	Internal defects[4,10]	Dormancy[11]
		Relative to Atlantic	#Tubers/ foot	Oz.		N lbs/A[6]	N lbs/A[6]	CWT/A	CWT/A	1.0xx[9]	%	Defects	%	Defects	
Kennebec[1]	W/W	ML			C,T	100-125	80		265						+27
Keuka Gold[1, 8]	Y/Y	ML	9.9	5.1	T	100-125	80	225	400	76	4	green	8	VD	+7
King Harry	W/W				T	125-150	100	235	325						-5[a]
LaRatte[1]	Bu/Y	L			T										
Lehigh[1]	Bu/Y	ML	7.1	5.8	T	125-150	100	175	315	81	5	green	6	VD	+6
Marcy	Bu/W	L			C	80-100	60	120	385						+23
Monona	W/W	M			C,T	125-150[7]	100[7]		275						
Norland[1]	R/W	EM			T	125-150[7]	100[7]	160	265						-20[b]
Norwis	W/W	ML			C,T	100-125	80		370						
Ozette[1]					T										
Pike[8]	W/W	ML			C	100-125	80		310						
Purple Viking[1]	P/W	M			T										
Reba	W/W	M	7.4	5.6	C,T	100-125	80	140	325	76	4	green	4	HH	+20
Red Gold[1]	R/Y				T				175						
Red Norland	R/W		8.7	4.1	T	100-125	100	160	265	64	3	cracks	7	VD	-20[b]
Reddale[1]					T				270						
Redsen	R/W	E			T	125-150[7]	100[7]		220						
Rose Finn Apple[1]	R/Y				T										
Salem[1]	W/W	M	8.6	5.3	T	100-125	80	210	345	69	4	green	9	VD	+12
Snowden	Bu/W	VL			C,T	100-125	80								+3
Superior[1]	Bu/W	E	6.5	5.0	T	125-150[7]	100[7]	170	270	76	4	knobs	9	VD	0(std)[a]
Yellow Finn[1]	Y/Y	M			T			30							
Yukon Gold[1]	Y/Y	M		6.6	T	100-125	80	180	285						+4[a]

1. Varieties commonly grown by organic growers. **2**. W = white; Bu = buff white; R = red; Y = yellow; P = purple; B = blue, F= fingerlings**3**. Maturity relative to Atlantic: E = early; EM = early to medium; M = medium; ML = medium to late; L = late; VL = very late **4**. Adapted from Potato Cultural Guide table, John Mishanec, Don Halseth, Tom Zitter, Walter De Jong, Helen Griffiths and Ward Tingey.

5. Use: T = tablestock; C = chipstock. **6.** Nitrogen recommendations based on target yield for each variety. (mineral soil: H= 125-150 lb/ac., M= 100-125lb/ac, L= 80-100 lb/acre and muck soil: H= 100 lb/ac., M= 80 lbs/ac., L= 60 lbs/ac.) If you frequently get 300 cwt/a on a variety, increase the recommended rates in the table by 15%. **7.** If an early harvest is desired reduce N applied by 25 to 33 percent. **8.** May have internal necrosis in susceptible production areas. **9.** The numbers in this column are the last two digits (xx) of the specific gravity value. **10.** Internal Defects: Vd= vascular ring; HH=hollow heart; cracks= growth cracks. **11.** Dormancies are all compared in days (+ = longer, - = shorter) to Atlantic except for: a = Dormancy compared to Superior; b = Dormancy compared to Chieftain.

Table 6.1.2 Disease, nematode and insect resistance of potato varieties.

Variety[1]	Black dot	Early blight	Golden nematode race 01	Late blight[2]	Pink rot[3]	Scab[7]	Silver scurf[3]	Verticillium wilt	Leaf-hopper[6]	Colorado potato beetle[6]
Adirondack Blue[1]				S	S	MS	S		S	S
Adirondack Red[1]			S		S	MS	S		S	S
All Blue[1]									S	
All Red									MR	
Allegany		R	R		R^{Field} MS/S^{GH}	MR		R	S	S
Andover	MS/S	S	R	S	R/MR	MR			S	S
Atlantic[2]		MR	R	S	R/MR	MR		T	MS	MS
Austrian Crescent[1]					S					
Bake King						S			S	
Banana[1]	MS/S				R	R			S	
Butte					S				S	
Caribe[1]						M				
Carola[1]			S	M		T			S	MS
Chieftan[1]	MS	MR	S	S	MS	MR	MS		S	S
Elba[1]		R	R	R		R		R	MR	MR
Eva[1]	R/MR	M	R	S	R^{Field} S^{GH}	MR	MS		MS	MS
French Fingerlings[1]									S	
Genesee	MR	MR	R	S	S	MR		R	S	S
German Butterball[1]					S					
Green Mountain									MS	S
Kanona			R			VS			S	S
Katahdin[1]		MR	S	MS		S			MR	MS
Kennebec[1]			S	R		VS[4]			S	MS
Keuka Gold[1,5]	R/MR		R	S	R/MR	R			MS	S
King Harry					R				R	MR
LaRatte[1]										
Lehigh[1]	MR		R		S	VR			S	S
Marcy			R		MR	MR				

Table 6.1.2 Disease, nematode and insect resistance of potato varieties.

Variety[1]	Black dot	Early blight	Golden nematode race 01	Late blight[2]	Pink rot[3]	Scab[7]	Silver scurf[3]	Verticillium wilt	Leaf-hopper[6]	Colorado potato beetle[6]
Monona	MS/S		S		MS	MR			MS	S
Norland[1]	MR		S		MS/S	R				
Norwis (FL 657)	MR		S		MR[GH] S[Field]	VS			MS	S
Ozette[1]										
Pike[1,5]	MS/S		R		MR	R				
Prince Hairy										R
Purple Viking[1]										
Reba	MS/S	MR	R	S	MS/S	MR		MR	S	S
Red Gold[1]										
Red Norland	MR	VS	S	S	S[3]	T			S	S
Reddale[1]										
Redsen			S			MR			S	S
Rose Finn Apple[1]										
Salem[1]		MR	R	S		VR			S	MS
Snowden			S		MR	MS			MS	S
Superior[1]	MS	VS	S	S	R/MR[3]	R		VS	S	S
Yellow Finn[1]										
Yukon Gold[1]	MS	S	S	S	MS/S[Field3]	S	MS		MR	S

1. Varieties commonly grown by organic growers. **2.** All potato varieties should be considered susceptible to late blight. **3.** Adapted from: Potato Cultural Guide table John Mishanec, Don Halseth, Tom Zitter, Walter De Jong, Helen Griffiths and Ward Tingey. Reactions to pink rot will vary depending on whether rating is based on tuber infection in the field (Field) or on tubers recovered from plants infected in the greenhouse (GH). See Reference 45 for more information on pink rot susceptibility.

4. From: Pest Management Strategic Plan for Organic Potato Production in the West, Summary of workshops held on February 16, 2006 (Reference 5).

5. May have internal necrosis in susceptible production areas. 6. VR = very resistant; R = resistant; MR = moderately resistant; T = tolerant; MS = moderately susceptible; S = susceptible; or VS = very susceptible. **7.** No varieties should be considered immune to scab. In a very dry year, varieties can perform badly regardless of rating.

Table 6.1.3 Potato Variety Culinary Use Guide.

Variety	Distinct flavor	Texture	Baked	Boiled	Fried	Mashed	Potato salad	Turns gray after boiling	Firmness after boiling	Yield peeled	IPM friendly	Comments and remarks
Adirondack Blue[1]	Yes	Med	Moist	Loses color	No	Good	Good	No	Excellent	Low		Beautiful dark blue colored flesh, irregular shapes
Adirondack Red[1]		Med	Moist	Loses color	No	Good	Good	a little	Excellent	Good		Uniform shape, unique red colored flesh
Andover	Yes	Dry	Dry	Good	Yes	Fair	Fair	a little	Good	Mod	Yes	Dry fluffy baked, good for French fries, high starch
Atlantic		Dry	Dry	Poor	Yes	Poor	poor	a little	Poor	Good	Yes	Very dry baked potato, high starch
Carola[1]	Yes	Moist	Moist	Waxy	No	Excellent	Excellent	No	Excellent	Good		Bright yellow flesh, very moist, firm after boiling
Chieftan[1]		Moist	Moist	Excellent	No	Excellent	Excellent	No	Good	Mod		Good eating qualities, widely grown red
Eva[1]		Med	Inter-mediate	Good	Yes	Good	Good	a little	Good	High	Yes	Shallow eyes, smooth bright skin, uniform shape
Genesee		Med	Inter	Good	Ok	Good	Good	a little	Good	Good	Yes	Attractive round white, all purpose
Katahdin[1]		Med	Moist	Good	No	Excellent	Excellent	a little	Good	Mod	Yes	An old standard variety, round white
Keuka Gold[1]	Yes	Med	Inter	Good	Yes	Good	Good	a little	Good	Mod	Yes	Like Yukon Gold, from NY and very good eating qualities
Lehigh[1]		Med	Inter	Good	Yes	Good	Good	no	Good	Good	Yes	Round yellow flesh, firm after boiling, a new all purpose variety
Reba		Med	Inter	Good	Yes	Good	Good	a little	Good	Mod	Yes	Large, attractive bright white flesh, firm after boiling
Red Norland		Moist	Moist	Excellent	No	Excellent	Excellent	a little	Good	Mod		Darker in color than Chieftain, widely grown red, round
Salem[1]	Yes	Med	Inter	Good	Ok	Good	Good	a little	Good	Good		Round white, excellent flavor
Superior[1]		Med	Inter	Good	Yes	Superior	Excellent	a little	Good	Low		Very early, round white, irregular shapes

Adapted from Potato Variety Culinary Use Guide. John Mishanec, Don Halseth and Walter De Jong, Cornell University.

1. Varieties commonly grown by organic growers.

7. PLANTING METHODS

7.1 Seed Sources

A certified organic farmer is required to plant certified organic seed and is strongly advised to also plant only phytosanitary certified seed. If organic seed is not available in the preferred varieties, check with organic certifier to determine options.

While it may seem advantageous for organic growers to save their own seed, it is not recommended. Diseased seed not only affects the plants that grow from it but also puts the rest of the field and the whole farming operation at risk because cutters, planters, and other equipment can spread many diseases. In the case of late blight, diseased plants from affected seed tubers serve as the primary inoculum source from which other plants in the field can be infected as the inoculum is spread by wind, rain, and insect activity. This is the same risk posed by leaving cull piles exposed in the vicinity of production fields. A grower often cannot tell by looking at tubers whether they will be good for seed.

See the New York seed directory, Maine seed directory, and the Colorado seed directory.(References 32-34) for more information about the certification program, varieties and lists of phytosanitary certified seed suppliers. Carefully inspect seed at the time of receipt. If possible, evaluate the seed before it is shipped. For a guide to potato seed evaluation, see Reference 55.

7.2 Seed Preparation and Handling

When handling seed, growers should maintain lot identity and prevent contamination. Trucks, storage, and handling equipment must be clean and disinfected (see Table 10.3.1) between each lot of certified seed. Seed tubers should be stored at 38°F and high humidity to prevent premature sprouting and dehydration. Physiological disorders that result from lack of oxygen and excessively cold temperatures during storage or transit contribute to seed piece problems and poor stand establishment.

Optimum seed will have medium to young physiological age. Factors that contribute to aging of potato seed include temperature, stress, physical damage to tubers, and other factors influencing seed during growth and storage. While old seed will sprout earlier, it will have more stems, higher tubers set, smaller tuber size and less vigor. Young seed will take longer to sprout, have fewer stems, larger tubers and more vigor. It is difficult to visually determine physiological age of seed, but a simple test will give some idea: warm up (55-60 F) a sample of potatoes in mid-winter and observe how quickly they sprout. The longer a seed lot takes to sprout, the younger the seed.

Tubers should be warmed to 50° to 60°F before being handled or cut. If not using whole seed, precut and heal seed before planting. Curing cut seed (suberization) is best accomplished by placing seed in half-full pallet boxes or spread out in piles only a few feet deep with adequate air circulation, temperature between 55° and 60°F, and about 90 percent relative humidity. After cut seed has been held at optimal curing conditions for one week, the storage temperature should be lowered to between 40° and 45°F to maintain vigor and avoid excessive sprout growth. Seed should be warmed to 50 to 55F for 7 to 14 days before planting.

Green sprouting or "pre-sprouting," is the practice of exposing seed potatoes to conditions that promote numerous uniform, stubby, dark green sprouts that emerge quickly after planting. Potatoes thus treated may be harvested early and may avoid late blight and other insects and diseases that develop later in the season. Healing (suberizing) and greensprouting require different conditions and need to be done sequentially for best results. Green sprouting is more practical for hand planting. Read more about this in the Maine Organic Farmers and Gardeners Association newsletter. (Reference 35).

For most varieties grown in New York State, seed weight of 1.5 to 2 ounces is optimal. Cut seed should be blocky in shape to reduce the cross-sectional area and facilitate uniform planting by equipment. Mechanical seed cutters should be adjusted to seed size and shape, and seed should be graded to a uniform size before cutting. See Table 7.2.1.

Table 7.2.1 Potato seed (cwt) required to plant one acre.

Distance between seed in row	34" between rows Weight of seed pieces (oz)				36" between rows Weight of seed pieces (oz)			
	1	1.5	1.75	2	1	1.5	1.75	2
inches	cwt							
6	19	29	34	38	18	27	32	37
8	14	22	25	29	14	20	24	27
10	11	17	20	23	11	16	19	22
12	10	14	17	19	9	14	16	18
15	8	11	14	16	7	11	13	14

7.3 Planting

To encourage quick emergence and robust development, plant seed pieces at 4-6" depth into well drained soil as soon as soil is warm enough, and cultivate lightly. This favors plant development over disease development and creates vigorous plants that are better able to withstand early season feeding by Colorado potato beetle and flea beetles.

Biological seed treatments such as products containing *Trichoderma harzianum* and *Streptomyces griseoviridis* are not substitutes for disease-free seed or good sanitation and handling, but can reduce losses from disease when cut seed is held before planting or is planted into cold, wet soil. It can also prevent the introduction into non-infested soils of surface-borne organisms that cause diseases such as

Rhizoctonia black scurf and stem canker. These products require good soil moisture to activate the organisms. Check individual disease sections below for rates and more information.

Some growers have reduced seed piece decay by applying untreated finely ground fir bark to cut seed pieces. Fir bark enhances suberization by holding humidity at the cut seed surface and also prevents seedpieces from sticking together and then pulling apart, which can create open wounds on healed surfaces. Fir bark allows better seed movement through the planter. Always check with your certifier before using any product to be sure it is approved.

Once plants emerge one to several hilling operations are useful for weed control and providing more soil to minimize tuber greening. Hill when plants are 6 to 12 inches tall, before row closes, to avoid damaging roots and tops. Timely tillage improves the physical condition of the soil, which helps plant roots explore the soil profile, controls weeds, and incorporates organic materials. However, excessive tillage destroys soil structure and compacts the ground, besides wasting fuel. Working the soil when too wet can also destroy soil structure and compact the land.

8. Crop & Soil Nutrient Management

To produce a healthy crop, soluble nutrients must be available from the soil in amounts that meet the minimum requirements for the whole plant. The total nutrient needs of a crop are much higher than just the nutrients that are removed from the field when that crop is harvested. All of the roots, stems, leaves, and other plant parts require nutrients at specific times during plant growth and development. The challenge in organic systems is balancing soil fertility to supply these required plant nutrients at a time, and at sufficient levels, to support healthy plant growth. Restrictions in any one of the needed nutrients will slow growth and can reduce crop quality and yields.

Organic growers often speak of feeding the soil rather than feeding the plant. A more accurate statement is that organic growers focus their fertility program on feeding soil microorganisms rather than the plant. Soil microbes decompose organic matter to release nutrients and convert organic matter to more stable forms such as humus. This breakdown of soil organic matter occurs throughout the growing season, depending on soil temperatures, water availability and soil quality. The released nutrients are then held on soil particles or humus and are available to crops or cover crops for plant growth. Amending soils with compost, cover crops, or crop residues also provides a food source for soil microorganisms and when turned into the soil, starts the nutrient cycle again.

During the transition years and the early years of organic production, soil amendment with composts or animal manure can be a productive strategy for building organic matter, biological activity and soil nutrient levels. This practice of heavy compost or manure use is not, however, sustainable in the long-term. If composts and manures are applied in the amounts required to meet the nitrogen needs of the crop, phosphorous may be added at higher levels than required by most vegetable crops. This excess phosphorous will gradually build up to excessive levels, increasing risks of water pollution or invigorating weeds like purslane. A more sustainable, long-term approach is to rely more on legume cover crops to supply most of the nitrogen needed by the crop and use grain or grass cover crops to capture excess nitrogen released from organic matter at the end of the season to minimize nitrogen losses to leaching (See Section 3: *Cover Crops*). When these cover crops are incorporated into the soil, their nitrogen, as well as carbon, feeds soil microorganisms, supporting the nutrient cycle. Removing alfalfa hay from the field for several years can reduce phosphorus and potassium levels.

The primary challenge in organic systems is synchronizing nutrient release from organic sources, particularly nitrogen, with the crop requirements. In cool soils, microorganisms are less active, and nutrient release may be too slow to meet the crop needs. Once the soil warms, nutrient release may exceed crop needs. In a long-term organic nutrient management approach, most of the required crop nutrients would be in place as organic matter before the growing season starts. Nutrients required by the crop in the early season can be supplemented by highly soluble organic amendments such as poultry manure composts or organically approved bagged fertilizer products (see Tables 8.2.4 to 8.2.6). These products can be expensive, so are most efficiently used if banded at planting. The National Organic Program rules state that no more than 20% of nitrogen can be applied as Chilean nitrate. Confirm the practice with your organic certifier prior to field application.

Regular soil testing helps monitor soil pH and nutrient levels, in particular phosphorus (P), potassium (K) and micronutrients. Choose a reputable soil-testing lab (Table 8.0.1) and use it consistently to avoid discrepancies caused by different soil extraction methods used in various soil labs. Soil tests are required prior to micronutrient application to certified organic soil. Check with your organic certifier that the micronutrient source is approved for use.

Table 8.0.1 Nutrient Testing Laboratories.

Testing Laboratory	Soil	Compost/ Manure	References
Cornell Soil Nutrient Analysis Lab	x		16
Agri Analysis, Inc.		x	36
A&L Eastern Ag Laboratories, Inc.	x	x	37
Penn State Ag Analytical Services Lab.	x	x	38
University of Massachusetts	x	x	39
The Agro One Lab	x	x	40

Develop a plan for estimating the amount of nutrients that will be released from soil organic matter, cover crops, compost, and manure. A strategy for doing this is outlined in Section 8.2: *Preparing an Organic Nutrient Budget.*

8.1 Fertility

Recommendations from the Cornell Integrated Crop and Pest Management Guidelines indicate that on mineral soils an organic potato crop requires 150 lbs. of available nitrogen (N), 200 lbs. of phosphorus (P) and 200 lbs. of potassium (K) per acre. On muck soils, a potato crop requires 100 lbs. of available nitrogen (N), 80 lbs. of phosphorous (P) and 80 lbs. of potassium (K) per acre. These values are factored for an anticipated yield of 250-hundredweight organic potatoes per acre. If you regularly yield 300 hundredweight per acre, increase nutrient values by 15%. See Table 8.2.2 for the recommended application rates of nitrogen, phosphorus, and potassium. Nitrogen requirements increase with the length of time to harvest. Use knowledge of variety and nutrient potential of the soil to estimate yield potential, then adjust nutrient applications accordingly. Good record keeping on cultural practices including variety and fertility management and subsequent yield will help with decision making in future years.

Soils should be tested frequently for nutrient levels and pH. Many fields with a long history of potato production have accumulated large amounts of potassium (potash) and phosphorus. While high levels of potash can reduce internal defects such as hollow heart and brown center, it can depress specific gravity, an important factor in processing quality.Some soils are naturally high in P and K, or have a history of manure applications that have resulted in elevated levels. More nitrogen and phosphorus may be available from soils in fields under organic production, where cover crops are commonly used, than in soils under conventional tillage. N is slowly and continuously released from OM. Excess soil nitrogen can cause poor skin condition, delay maturity, affect storage, and increase Fusarium and Pythium incidence. If maturity is delayed, postpone harvest if possible, especially of red potatoes, which skin easily when not mature and can suffer water loss. When fields are harvested later, they are at increased risk from Colorado potato beetles and late blight. Excess nitrogen and phosphorous can also contaminate ground water and surface run off.

Maintaining a soil pH between 6.3 and 6.8 will maximize the availability of beneficial nutrients to plants. Low soil pH reduces the availability of phosphorus and increases the availability of toxic elements such as iron and aluminum. However, to control common scab, soil pH should be kept within a relatively narrow range (5.0 to 5.2). If scab-resistant varieties are used, potatoes can be grown in soil with pH levels near 6.0, increasing the availability of phosphorus and other soil nutrients.

All lime and fertilizer recommendations should be based on soil test history. Mineral soils should have pH determined in calcium chloride and should have measurements made of iron, aluminum, and manganese in addition to the traditional measurements of phosphorus (P), potassium (K), and magnesium (Mg). If soil magnesium is below 100, apply 190 pounds of magnesium sulfate per acre (30 lb magnesium per acre).

Many types of organic fertilizers are available to supplement the nutrients supplied by the soil. **ALWAYS check with your certifier before using any product to be sure it is approved**.

8.2 Preparing an Organic Nutrient Budget

Insuring an adequate supply of nutrients when the crop needs them requires careful planning. Developing an organic nutrient budget can help estimate the amount of nutrients released by various organic amendments as well as native soil organic matter. Table 8.2.3 estimates common nutrient content in animal manures, however actual compost and manure should be tested for nutrient content at the time of application. Analysis of other amendments as well as cover crops can be estimated using published values (Tables 8.2.4-8.2.6 and 3.1). Keeping records of these nutrient inputs and subsequent crop performance will help evaluate if the plan is providing adequate fertility during the season to meet production goals.

Remember that with a long-term approach to organic soil fertility, the N mineralization rates of the soil will increase. This means that more N will be available from organic amendments because of increased soil microbial activity and diversity. Feeding these organisms different types of organic matter is essential to helping build this type of diverse biological community and ensuring long-term organic soil and crop productivity. Consider submitting soil samples for a Cornell Soil Health Test (Table 8.0.1). This test includes an estimate of nitrogen mineralization rate, which indicates the potential for release of N from soil organic matter. Testing soils can be useful for monitoring changes in nitrogen mineralization rate during the transition, and over time, in organic production.

Estimating total nutrient release from the soil and comparing it with soil test results and recommendations requires record-keeping and some simple calculations. Table 8.2.1 below can be used as a worksheet for calculating nutrients supplied by the soil compared to the total crop needs.

Table 8.2.1 Calculating Nutrient Credits and Needs.

	Nitrogen (N) lbs/A	Phosphate (P_2O_5) lbs/A	Potash (K_2O) lbs/A
1. Total crop nutrient needs			
2. Recommendations based on soil test	Not provided		
3. Credits			
a. Soil organic matter		---	---
b. Manure			
c. Compost			
d. Prior cover crop			
4. Total credits:			
5. Additional needed (2 – 4 =)			

Line 1. Total Crop Nutrient Needs: Agricultural research indicates that a potato crop on mineral soil requires 120-175 lbs. nitrogen (N), 240 lbs. phosphorus (P), and 240 lbs. potassium (K) per acre to support an average yield (see Section 8.1: *Fertility* above and Table 6.1.1 for varietal nitrogen requirements).

Line 2. Recommendations Based on Soil Test: Use Table 8.2.2 to determine the amount of P and K needed based on soil test results.

<table>
<tr><th colspan="10">Table 8.2.2 Potato crop nutrient needs based on soil tests. (Factored for 250 hundred weight yield; reduce for lower yields[1])</th></tr>
<tr><th rowspan="2">Level shown in soil test</th><th>N Level</th><th colspan="3">Soil Phosphorus Level</th><th colspan="4">Soil Potassium Level</th></tr>
<tr><td>Not available</td><td>Low</td><td>med</td><td>high</td><td>low</td><td>med</td><td>high</td><td>Very high</td></tr>
<tr><td>Total nutrient recommendation</td><td>N lbs/A[2]</td><td colspan="3">P_2O_5 Pounds/A[3]</td><td colspan="4">K_2O Pounds/A</td></tr>
<tr><td>Mineral soils</td><td>100-150</td><td>200</td><td>150</td><td>100</td><td>200</td><td>100</td><td>62</td><td>50</td></tr>
<tr><td>Muck soils</td><td>60-100</td><td>80</td><td>60</td><td>40</td><td>80</td><td>65</td><td>50</td><td>50</td></tr>
</table>

1. Use knowledge of variety and field to estimate yield, then adjust nutrient applications accordingly. If you frequently get 300 cwt/a on a variety, increase the recommended rates in the table by 15%.

2. Apply 50- lb N/A in bands at planting, and then apply remainder when plants are 4-8 inches tall. Reduce N rate by 50 to 75 lb/A if a good stand of clover or alfalfa is plowed down. Adjust N rate to suit variety grown (see Table 6.1: *Cultural characteristics of Potato Varieties*).

3. If pH levels are below 5.2 or iron plus aluminum levels are above 200, apply 20 lb phosphate/A regardless of soil phosphate level. Banded phosphate is more available than broadcast applications.

Line 3a. Soil Organic Matter: Using the values from your soil test, estimate that 20 lbs. of nitrogen will be released from each percent organic matter in the soil. For example, a soil that has 2% organic matter could be expected to provide 40 lbs N per acre

Line 3b. Manure: Assume that applied manure will release N for three years. Based on the test of total N in any manure applied, estimate that roughly 50% is available to the crop in the first year, and then 50% of the remaining is released in each of the next two years. Remember, any raw manure applications must occur at least 120 days before harvest of a vegetable crop.

Line 3c. Compost: Estimate that between 10 to 25% of the N contained in most composts is available to the crop the first year. Compost maturity will influence how much N is available. If the material is immature, more of the N may be available to the crop in the first year. A word of caution: Using compost to provide for a crop's nutrient needs is not generally a financially viable strategy. The high total volume needed can be very expensive for the units of N available to the crop, especially if trucking is required. Most stable composts should be considered as soil conditioners, improving soil health, microbial diversity, tilth, and nutrient retaining capacity. Any compost applied on organic farms must be approved for use by the farm certifier. Compost generated on the farm must follow an approved process outlined by the certifier.

Line 3d. Cover Crops: Estimate that 50 percent of the fixed N is released for plant uptake in the current season when incorporated. Consult Table 3.1 to estimate the amount of N fixed by legume cover crops.

Line 4. Total Credits: Add together the various N values from soil organic matter, manure, compost, and cover crops to estimate the N supplying potential of the soil (see example below). There is no guarantee that these amounts will actually be available in the season, since soil temperatures, water, and crop physiology all impact the release and uptake of these soil nutrients. If the available N does not equal the minimum requirement for this crop, a sidedress application of organic N may be needed. There are several options for N sources for organic side dressing (see Table 8.2.4) as well as pelleted composts. Early in the organic transition, a grower may consider increasing the N budget supply by 30%, to help reduce some of the risk of N being limiting to the crop.

Table 8.2.3 includes general estimates of nutrient availability for manures and composts but these can vary widely depending on animal feed, management of grazing, the age of the manure, amount and type of bedding, and many other factors. See Table 3.1 for estimates of the nitrogen content of various cover crops.

Table 8.2.3 Estimated Nutrient Content of Common Animal Manures and Manure Composts.

	Total N	P_2O_5	K_2O	N1 [1]	N2 [2]	P_2O_5	K_2O
	Nutrient content lb/ton			*Available nutrients lb/ton in first season*			
Dairy (with bedding)	9	4	10	6	2	3	9
Horse (with bedding)	14	4	14	6	3	3	13
Poultry (with litter)	56	45	34	45	16	36	31
Composted dairy manure	12	12	26	3	2	10	23
Composted poultry manure	17	39	23	6	5	31	21
Pelleted poultry manure [3]	80	104	48	40	40	83	43
Swine (no bedding)	10	9	8	8	3	7	7
	Nutrient content lb/1000 gal.			*Available nutrients lb/1000 gal first season*			
Swine finishing (liquid)	50	55	25	25[a]	20+	44	23
Dairy (liquid)	28	13	25	14 [a]	11+	10	23

1-N1 is the estimated total N available for plant uptake when manure is incorporated within 12 hours of application. 2-N2 is the estimated total N available for plant uptake when manure is incorporated after 7 days. 3. Pelletized poultry manure compost. Available in New York from Kreher's. a injected, + incorporated. Adapted from *Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops* by Carl Rosen and Peter Bierman (Reference 42) and Penn State Agronomy Guide 2007-8 (Reference 42A).

Tables 8.2.4-8.2.6 list some commonly available fertilizers, their nutrient content, and the amount needed to provide different amounts of available nutrients.

Table 8.2.4 Available Nitrogen in Organic Fertilizer.

	Pounds of Fertilizer/Acre to Provide X Pounds of N Per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Blood meal, 13% N	150	310	460	620	770
Soy meal 6% N (x 1.5) [a] also contains 2% P and 3% K_2O	500	1000	1500	2000	2500
Fish meal 9% N, also contains 6% P_2O_5	220	440	670	890	1100
Alfalfa meal 2.5% N also contains 2% P and 2% K_2O	800	1600	2400	3200	4000
Feather meal, 15% N (x 1.5) [a]	200	400	600	800	1000
Chilean nitrate 16% N cannot exceed 20% of crop's need.	125	250	375	500	625

[a] Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil-testing lab (Reference 41).

Table 8.2.5 Available Phosphorous in Organic Fertilizers.

	Pounds of Fertilizer/Acre to Provide X Pounds of P_2O_5 Per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Bonemeal 15% P_2O_5	130	270	400	530	670
Rock Phosphate 30% total P_2O_5 (x4) [a]	270	530	800	1100	1300
Fish meal, 6% P_2O_5 (also contains 9% N)	330	670	1000	1330	1670

[a] Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil-testing lab (Reference 41).

Table 8.2.6 Available Potassium in Organic Fertilizers.

	POUNDS OF FERTILIZER/ACRE TO PROVIDE X POUNDS OF K_2O PER ACRE:				
SOURCES	20	40	60	80	100
Sul-Po-Mag 22% K_2O also contains 11% Mg	90	180	270	360	450
Wood ash (dry, fine, grey) 5% K_2O, raises pH	400	800	1200	1600	2000
Alfalfa meal 2% K_2O also contains 2.5% N	1000	2000	3000	4000	5000
Greensand or Granite dust 1% K_2O (x 4) [a]	8000	16000	24000	32000	40000
Potassium sulfate 50% K_2O	40	80	120	160	200

[a] Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Adapted by Vern Grubinger from the University of Maine soil-testing lab (Reference 41).

An example of how to determine nutrient needs for potatoes.

An acre of potatoes will be grown on mineral soil. The macronutrient requirement for a potato crop is 150 lb. N, 200 lb. P, and 200 lb K per acre. The soil test shows a pH of 6.0, with high P and medium K levels and recommends 150 lbs N/acre, 100 lbs P_20_5/acre and 100 lbs K_20/acre (see Table 8.2.2). Because the pH is above 5.5, scab resistant varieties will be used. The field has 3% organic matter and a stand of red clover that will be turned in a week or so prior to planting (see Table 3.1). Last summer 4000 gallons/acre of liquid dairy manure was applied and immediately incorporated after a hay harvest. Nutrient credits for soil organic matter, manure, and cover crop appear in Table 8.2.7.

Table 8.2.3 indicates about 56 lbs. of Nitrogen will be released in the first season from the 4000 gallons of liquid dairy manure. Estimate that each percent organic matter will release about 20 lbs. of N, so the 3% soil organic matter will supply 60 lbs. Looking at table 3.1, the red clover will release about half its fixed N, or 50 lbs. as it decomposes, for a total estimated N released and available for plant uptake of 166 lbs. per acre. No additional N is needed. The 40 lbs. of phosphate released from the dairy manure will need to be supplemented with an additional 60 lbs P_2O_5 This could be achieved by applying 400 lbs per acre of bone meal to meet the soil test recommendation of 100 lbs per acre. Potassium will also need to be supplemented in this example. The manure supplies 92 of the 100 lbs. K_2O needed. Broadcasting 16 lbs. of potassium sulfate from an organically approved product can supply the remaining 8 lbs. K_2O/acre.

Table 8.2.7 Example: Calculating Nutrient Credits and Needs Based on Soil Sample Recommendations.

	Nitrogen (N) lbs/acre	Phosphate (P_2O_5) lbs/acre	Potash (K_2O) lbs/acre
1. Total crop nutrient needs:	150	200	200
2. Recommendations based on soil test	150	100	100
3. Credits			
a. Soil organic matter 3%	60	0	0
b. Manure liquid dairy, 4000 gallons	56	40	92
c. Compost - none	0	0	0
d. Cover crop – red clover	50	0	0
4. Total credits:	166	40	92
5. Additional needed (2-4)	0	60	8

Additional Resources
Using Organic Nutrient Sources (reference 42b)
Determining Nutrient Applications for Organic Vegetables (Reference 42c)

9. MOISTURE MANAGEMENT

Water management and rainfall are among the most important factors determining yield and quality of potatoes. Growth cracks, hollow heart, blackspot, internal necrosis, knobby tubers, seed piece decay, Rhizoctonia and tuber late blight can be related to excessive amounts of water. Before growing potatoes, consider soil type, rainfall distribution and the ability to irrigate. Soil types can vary threefold in their respective water holding capacity. Also, note that potatoes have a relatively shallow root system, with an effective rooting depth of approximately 2 feet. Rainfall in the Northeast can provide adequate water for a crop, but it must be distributed evenly over the growing season to avoid drought stress. During mid-season crop evapotranspiration can easily exceed one inch per week. To prevent drought stress, soils should not be allowed to dry below 65 percent of field capacity. On some soil types rainfall or irrigation would have to occur on a weekly basis to provide the required water for productive crop growth. Rainfall use efficiency can be enhanced by not planting on steep slopes, properly preparing (tillage) soil to improve infiltration, and by placing small soil dams in furrows to reduce surface movement. If irrigation is used, water should be applied to the soil frequently in light amounts to maintain a uniform and adequate water supply. There are several irrigation methods, including center pivot irrigation, solid set sprinklers, wheel line sprinklers, gun and reel units, furrow irrigation and sub-irrigation. Sprinkler irrigation systems frequently provide the most flexibility and the best opportunity for efficient water application. Furrow and sub-irrigation require more uniform soil types and a relatively level field, and are more prone to uneven water application.

10. HARVESTING

10.1 Vine Killing

Potatoes need 2-3 weeks between vine kill and harvest to promote tuber maturity and adequate skin set. Mature skin protects tubers from disease, resists skinning and bruising during harvest and transport, and prolongs tuber storage life.

Optimally, vine killing is accomplished mechanically using a flail mower. A flame weeder might be used several days after mowing to assure complete vine kill. Care should be taken to minimize damage to tubers by mowing equipment or by dislodged rocks that can also injure tubers.

Vines can also be allowed to senesce naturally by reducing water applications in some cultivars. Another option is to allow frost to kill the vines. However, potatoes left to mature in the ground for 2-3 weeks after a frost are susceptible to damage by additional frosts and disease.

Herbicides allowed for certified organic production and labeled for vine kill in potato (e.g. Axxe) have recently come on the market. Research is needed to determine the effects of organically approved vine-kill products on tuber quality.

10.2 Early Maturity and Timely Harvest.

Use of early maturing varieties and scheduling vine killing/harvest as soon as the crop is mature eliminates the food source for the Colorado potato beetle and reduces the number and health of overwintering adults. This practice is also useful in minimizing crop damage by late-season pests, especially aphids and the virus pathogens they transmit. See updated Cornell postharvest storage notes (Reference 45)

10.3 Post Harvest Sanitation

Facilities and handling equipment such as bin pilers should be cleaned and disinfected properly before potatoes are placed in storage. See Table 10.3.1. Structural, mechanical, and electrical problems should be identified and repaired before the storage area is filled. Check for breaks in moisture barriers and insulation to avoid cold spots during the winter. The use of sanitizer wash treatments can prevent the spread of decaying bacteria by killing the organism on contact.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 10.3.1 Rates for Sanitizers Labeled for Postharvest Potato Crops and/or Postharvest Facilities

Active ingredient **Product name**	***Uses*** Food contact surfaces[1]	Hard surface, non-food contact[1]	Vegetable surface (spray or drench)	Vegetable rinse water
chlorine dioxide				
CDG Solution 3000	50 ppm solution	500 ppm dilution	-	5 ppm solution
Oxine[2]	100 ppm solution	500 ppm solution	-	In tanks, use a 5 ppm solution; for process waters use a chemical feed pump or other injector system at 3 ¼ fl oz per 10 gal water.[3]
Pro Oxine[2]	50-200 ppm solution	500 ppm solution	-	-
hydrogen peroxide/peroxyacetic acid				
Enviroguard Sanitizer	-	2.5-20 fl oz/5 gal water	1 fl oz/20 gal water	1 fl oz/20 gal water
Oxonia Active	1-1.4 oz/4 gal water	1 oz/8 gal water.	-	-
Peraclean 5	1-1.5 fl oz/5 gal water		-	-
Peraclean 15	0.33 fl oz/5 gal water		-	-
Perasan 'A'	1-2.4 fl oz/6 gal water	-	1 fl oz/20 gal water	1 fl oz/20 gal water
Per-Ox	1-2.25 fl oz/5 gal water	1-10 fl oz/15 gal water	1 fl oz/5 gal water	1 fl oz/5 gal water
*SaniDate 5.0	1.6 fl oz/ 5 gal water	1.6 fl oz/ 5 gal water	59.1 to 209.5 fl oz/ 1,000 gallons water	59.1 to 209.5 fl oz/ 1,000 gallons water
SaniDate 12.0	-	-	25.6 to 89.6 fl oz / 1,000 gallons water	25.6 to 89.6 fl oz / 1,000 gallons water

Table 10.3.1 Rates for Sanitizers Labeled for Postharvest Potato Crops and/or Postharvest Facilities				
Active ingredient **Product name**	***Uses***			
	Food contact surfaces[1]	**Hard surface, non-food contact[1]**	**Vegetable surface (spray or drench)**	**Vegetable rinse water**
Shield-Brite PAA 5.0	0.5 fl oz/5 gal water Apply with a mop, cloth, sponge, or hand trigger spray to wet all surfaces thoroughly. Allow to remain wet with solution for ten minutes. Rinse all treated surfaces thoroughly with potable water before operations are resumed.	1.6fl oz/5 gal water	0.5 fl-1.9 fl oz/ gal water. Prior to storage, spray diluted solution on tuber to runoff to achieve full and even coverage. The use of additional surfactant is acceptable to aid in sticking. Use 1 to 2 gal water/ton potatoes.	-
Shield-Brite PAA 12.0	-	-	25.6 to 89.6 fl.oz/1,000 gal water	25.6 to 89.6 fl.oz/1,000 gal water
StorOx 2.0	Apply 1.3 fl oz/ gal water with a mop, cloth, sponge, or hand trigger spray to wet all surfaces thoroughly. Allow to remain wet with solution for ten) minutes. Rinse all treated surfaces thoroughly with potable water before operations are resumed.	0.5 fl oz/1 gal water	1.25-2.5 fl. oz./ gal water. Prior to storage, spray diluted solution on tuber to runoff to achieve full and even coverage. The use of additional surfactant is acceptable to aid in sticking. Use 1 to 2 gals water/ton potatoes.	-
Tsunami 100	-	-	2.5-6.7 fl oz/100 gal water	2.5-6.7 fl oz/100 gal water
Victory	-	-	1 fl oz/16.4 gal water	1 fl oz/16.4 gal water
VigorOx Liquid Sanitizer and Disinfectant OA I	1-1.7 fl oz/5 gal water	1-11 fl oz/16 gal water	-	-
VigorOx 15 F & V	0.31-0.45 fl oz/5 gal water-	1.1-9.5 fl oz/5 gal water -	1 fl oz/ 16 gal water as spray or dip	0.54 fl oz/ 16 gal water
VigorOx LS-15	0.31-0.45 fl oz/5 gal water	1.1-9.5 fl oz/5 gal water	-	-
sodium hypochlorite				
San-I-King No. 451	100 ppm chlorine in solution	-	-	-
*Restricted-use pesticide in new York State				

1. Thoroughly clean all surfaces and rinse with potable water prior to treatment. 2. Requires acid activator. 3. After treatment, rinse with potable water.

10.4 Curing and Storage

Cuts and bruises heal most rapidly under conditions described previously for precutting seed (see 7.2: *Seed preparation and handling*). High relative humidity at 50° to 60°F should be provided for two to three weeks at the beginning of the storage period. After this, the temperature should be gradually lowered to 40°F for tablestock or seed potatoes, or maintained at 50°F for chipstock varieties such as Atlantic and at 45°F for Andover, Marcy, Reba or Snowden. When a condition such as field frost, late blight, or ring rot that favors decay is present, the curing period should be eliminated and the temperature dropped as soon as possible.

Desired storage temperature is best achieved with forced-air ventilation controlled thermostatically by an air proportioning system. Airflow should be uniform throughout the storage facility to maintain consistent temperature and oxygen levels. Airflow rates early in the storage season may range from a continuous flow of 1/2 to 1 cu. ft./cwt/min. with high relative humidity to enhance the curing process. Later a maintenance program should use an airflow of 1/2 to 4/5 cu. ft./cwt/min. as needed (five to ten percent of the time, or 1.2-2.5 hr/day). If severe rot potential exists, continuous airflow rates as high as two cu. ft./cwt/min. may be required to cool and dry the tubers. Excessive airflow rates, particularly at low relative humidity, will dehydrate tubers and interfere with the wound healing process. Relative humidity in storage should be as high as possible without causing condensation on the tubers and the storage structure. Good insulation properly protected with a vapor barrier reduces the danger of condensation.

10.5 Sprout Suppressors

Products available for sprout control in organic production are best described as sprout suppressors. Sprout suppressors, used in conjunction with good storage management may help extend the storage season. Although most potato varieties are dormant for two to three months after harvest, they will eventually sprout even in low temperature cold storage. Unlike chlorpropham (CIPC), the sprout inhibitor used by conventional growers, organically approved sprout management products require repeated applications. Sprout suppressors are most effective when applied before sprouts are one-eighth of an inch long. Application methods will depend on storage management and cultivars grown. See Table 10.5.1 and Reference 43. It is important to examine tubers in the center and at the base of the pile at frequent intervals during the storage season to make sure that storage rots, internal sprouting, or other disorders are not developing. Seed potatoes should not be treated or stored where sprout inhibitor vapors may reach them.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 10.5.1 Sprout Suppressors (See Reference 43 for more information on these products).

Class of Compounds **Product Name** **(*active ingredient*)**	**Rate/A Product**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Volatile Oils					
Certified organic peppermint oil[1]	10 lbs oil/1000cwt potatoes/ month	0	0	1	25(b) pesticide. Effective in 1/1 trial. Wick application method most effective; apply 50 ppm every two weeks, 75 ppm every three weeks, or a daily application of 4 ppm.
Certified organic clove oil[1]	5.2 lbs/1000 cwt	0	0	1	25(b) pesticide. Effective in 1/1 trial. Apply as thermal aerosol; repeat applications of 1.9 lbs/1000cwt necessary at 2-3 week intervals.
Decco 070 EC Potato Sprout Inhibitor *(clove oil)*	1 gal/69 gal water	0	0	1	25(b) pesticide. Effective in 1/1 trial. Apply on washed and damp dried potatoes using spray nozzles placed evenly across the rollers on which the potatoes are being moved.
Decco Aerosol 100 For Treatment of Potato in Storage *(clove oil)*	1 gal/2000-3000 cwt potatoes	0	0	1	25(b) pesticide. Effective in 1/1 trial. Designed for use through Forced Air Distribution System. Usually performed by lisenced applicators.

1 Check with your certifier before use. If potatoes are sold as a food crop, Reference 44 (Section 205.606 National Organic Standards) applies; since non-organically produced clove and peppermint oils are not on this approved products list, certified organic clove and peppermint oils are required. If potatoes are sold as seed potatoes, certified organic oil is not required. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

11. USING ORGANIC PESTICIDES

Given the high cost of many pesticides, and the limited amount of efficacy data from replicated trials with organic products, the importance of developing an effective system of cultural practices for insect and disease management cannot be emphasized strongly enough. **Pesticides should not be relied on as a primary method of pest control**. Scouting and forecasting are important for detecting symptoms of diseases at an early stage. When conditions do warrant an application, proper choice of materials, proper timing, and excellent spray coverage are essential.

11.1 Sprayer Calibration and Application

Calibrating sprayers is especially critical when using organic pesticides since their effectiveness is sometimes limited. For this reason, they tend to require the best spraying conditions to be effective. Read the label carefully to be familiar with the unique requirements of some products, especially those with live biological organisms as their active ingredient (e.g. Contans). The active ingredients of some biological pesticides (e.g. Serenade) are actually metabolic byproducts of the organism. Calculating nozzle discharge and travel speed are two key components required for applying an accurate pesticide dose per acre. Applying too much pesticide is illegal, can be unsafe and is costly whereas applying too little can fail to control pests or lead to pesticide resistance.

Resources

Cornell Integrated Crop & Pest Management Guidelines, Chap. 6 (Ref. 46).
Calibrating Backpack Sprayers (Reference 47)
Agricultural Pocket Pesticide Calibration Guide (Reference 48)
Knapsack Sprayers – General Guidelines for Use (Reference 49)
Herbicide Application Using a Knapsack Sprayer (Reference 50) (This publication is also relevant for non-herbicide applications.)
Pesticide Environmental Stewardship Community Page (Reference 53a)
Pesticide Environmental Stewardship Website (Reference 53b)
Vegetable Spraying (Reference 53c)

11.2 Regulatory Considerations

Organic production focuses on cultural, biological, and mechanical techniques to manage pests on the farm, but in some cases pesticides, which include repellents, allowed for organic production are needed. Pesticides mentioned in this organic production guide are registered by the United States Environmental Protection Agency (EPA) or meet the EPA requirements for a "minimum risk" pesticide. The pesticides mentioned in this guide are also registered by the New York State Department of Environmental Conservation (NYS DEC) for use in New York State. See Cornell's Product, Ingredient, and Manufacturer System website (reference 3) for pesticides currently registered for use in NYS. Additional products may be available for use in other states.

To maintain organic certification, products applied must also comply with the National Organic Program (NOP) regulations as set forth in 7 CFR Part 205, sections 600-606 (Reference 52). The Organic Materials Review Institute (OMRI) (Reference 8) is one organization that reviews products for compliance with the NOP regulations and publishes lists of compliant products, but other entities also make product assessments. Organic growers are not required to use only OMRI listed materials, but the list is a good starting point when searching for allowed pesticides.

Finally, farms grossing more than $5,000 per year and labeling products as organic must be certified by a NOP accredited certifier who must approve any material applied for pest management. ALWAYS check with the certifier before applying any pest control products. Some certifiers will review products for NOP compliance.

Note that "home remedies" may not be used. Home remedies are products that may have properties that reduce the impact of pests. Examples of home remedies include the use of beer as bait to reduce slug damage in strawberries or dish detergent to reduce aphids on plants. These materials are not regulated as pesticides, are not exempt from registration, and are therefore not legal to use.

Do you need to be a certified pesticide applicator? The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines two categories of pesticides: general-use and-restricted use. NYS DEC also defines additional restricted-use pesticides. Pesticide applicator certification is required to purchase and use restricted-use pesticides. Restricted-use pesticides mentioned in this guide are marked with an asterisk (*). Farmers who purchase and use only general-use pesticides on property they own or rent do not need to be certified pesticide applicators. However, we do encourage anyone who applies pesticides to become certified.

Worker Protection Standard training. If the farm has employees who will be working in fields treated with a pesticide, they must be trained as workers or handlers as required by the federal Worker Protection Standard (WPS). Having a pesticide applicator certification is one of the qualifications needed to be a WPS trainer. Certified pesticide applicators meet the WPS training requirements. For more information on the Worker Protection Standard see: How To Comply with the Worker Protection Standard (Reference 14a). Find more information on pesticide applicator certification from the list of State Pesticide Regulatory Agencies (Reference 14b) or, in New York State, see the Cornell Pesticide Management Education Program website at http://psep.cce.cornell.edu (Reference 14c).

11.3 Optimizing Pesticide Effectiveness

Information on the effectiveness of a particular pesticide against a given pest can sometimes be difficult to find. Some university researchers include pesticides approved for organic production in their trials; some manufacturers provide trial results on their web sites; some farmers have conducted trials on their own. Efficacy ratings for pesticides listed in this guide were summarized from university trials and are only provided for some products. Listing a pest on the pesticide label does not guarantee the effectiveness of a pesticide. The Resource Guide for Organic Insect and Disease Management (Reference 2) provides more comprehensive efficacy information for many approved materials.

In general, pesticides allowed for organic production may kill a smaller percentage of the pest population, could have a shorter residual, and may be quickly broken down in the environment. Read the pesticide label carefully to determine if water pH or hardness will negatively impact the pesticide's effectiveness. Use of a surfactant may improve organic pesticide performance. OMRI lists adjuvants on their website under *Crop Management Tools and Production Aids* (Reference 9). Regular scouting and accurate pest identification are essential for effective pest management. Thresholds used for conventional production may not be useful for organic systems because of the typically lower percent mortality and shorter residual of pesticides allowed for organic production. When pesticides are needed, it is important to target the most vulnerable stages of the pest. Thoroughly cover plant surfaces, especially in the case of insecticides, since many must be ingested to be effective. The use of pheromone traps or other monitoring or prediction techniques can provide an early warning for pest problems, and help effectively focus scouting efforts.

12. Disease Management

In organic systems, cultural practices form the basis of a disease management program. Promote plant health by maintaining a biologically active, well-structured, adequately drained and aerated soil that supplies the requisite amount and balance of nutrients. Choose varieties resistant to one or more important diseases whenever possible (see Table 6.1.2). Plant only clean, disease-free seed and maintain the best growing conditions possible.

Rotation is an important management practice for pathogens that overwinter in soil or in crop debris. Rotating between crop families is useful for many diseases, but may not be effective for pathogens with a wide host range, such as Sclerotinia white mold, Rhizoctonia black scurf, Colletotrichum black dot, Verticillium wilt, common scab, or nematodes. Rotation with a grain crop, preferably a sod that will be in place for one or more seasons, deprives many disease-causing organisms of a host, and also contributes to a healthy soil structure that promotes vigorous plant growth. The same practices are effective for preventing the buildup of root damaging nematodes in the soil, but keep in mind that certain grain crops are also hosts for some nematode species. See more information on crop rotation in Section 4.2.

Other important cultural practices can be found under each individual disease listed below. Maximizing air movement and leaf drying is a common theme. Many plant diseases are favored by long periods of leaf wetness. Any practice that promotes faster leaf drying, such as orienting rows with the prevailing wind, or using a wider row or plant spacing, can slow disease development. Fields surrounded by trees or brush, that tend to hold moisture after rain or dew, should be avoided if possible, especially for a crop like potatoes, with a long list of potential disease problems.

Insect damage can create susceptibility to disease. Feeding by the European corn borer (ECB) can create an avenue for disease infection by *Erwinia spp.*, the pathogen that causes black leg and bacterial soft rot. Survival and establishment of ECB larvae vary depending on potato cultivar and field conditions. Larval survival on three popular cultivars, from highest to lowest, follows: Monona > Superior > Katahdin. Under field conditions, Monona is more susceptible to attack by ECB's and to infection by aerial blackleg than other cultivars.

Scouting fields weekly is key to early detection and evaluation of control measures. The earlier a disease is detected, the more likely it can be suppressed with organic fungicides. Accurate identification of disease problems, especially recognizing whether they are caused by a bacterium or fungus, is essential for choosing an effective control strategy. Anticipate which diseases are likely to be problems and be ready to take control action in a timely manner. Allowing pest populations to build past thresholds can leave few or no options for control. Thresholds presented here were developed for use with conventional fungicides, and may need to be adjusted downward when using materials approved for organic production, which tend to be less effective and have shorter residual activity.

When available, scouting protocols can be found in the sections for each individual disease. While following a systematic scouting plan, keep watch for other disease problems when walking a field.

All currently available fungicides allowed for organic production are protectants meaning they must be present on the plant surface before disease inoculum arrives to effectively prevent infection. Biological products must be handled carefully to keep the microbes alive. In addition to disease control, fungicides containing copper may have antifeedant activity against some insect pests including the Colorado potato beetle. Follow label instructions carefully to achieve the best results.

Use weather-based disease forecasting programs when available to help time applications to periods of favorable weather or the arrival of inoculum. The movement of some pathogens that do not overwinter in the Northeast may be tracked online to help determine when control measures are needed. Contact New York State IPM's network for the environment and weather (Reference 4) for late blight forecasting in your area.

Contact your local cooperative extension office to see if newsletters and pest management updates are available for your region, for example, in western New York, the Cornell Vegetable Program offers subscriptions to *VegEdge* a report that gives timely information regarding crop development, pest activity and control. Enrollment in the Eastern New York Commercial Horticulture Program includes a subscription to *Produce Pages* and weekly seasonal newsletters for vegetables, tree fruit, grapes and small fruit. On Long Island, see the *Long Island Fruit and Vegetable Update.*

Organic farms must comply with all other regulations regarding pesticide applications. See Section 11: *Using Organic Pesticides* for details. **ALWAYS check with your organic farm certifier when planning pesticide applications**.

Resources:

Cornell Vegetable MD Online (Reference 57).

Resource Guide for Organic Insect and Disease Management (Reference 2).

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.1.1 Pesticides Labeled for Organic Potato Disease Management.

CLASS OF COMPOUNDS **Product Name (*active ingredient*)**	**BACTERIAL SOFT ROT,**	**FUSARIUM DRY ROT**	**EARLY BLGHT**	**LATE BLIGHT**	**VERTICIUM WILT**	**FUSARIUM WILT**	**BLACK DOT ROOT ROT**	**CANKER AND BLACK SCURF**	**BOTRYTIS VINE ROT**	**WHITE MOLD**	**COMMON SCAB**	**PINK ROT**	**POWDERY SCAB**	**PYTHIUM LEAK**	**SILVER SCURF *i***	**VIRUSES**
BIOLOGICAL																
ActinoGrow (*Streptomyces lydicus*)	c	a, b	c	a	a, b	a, b		a, b	c	a, b, c		a, b		a, b		
Actinovate AG (*Streptomyces lydicus*)	c	b, c	c		a, b	a, b		a, b	b, c	b, c		a, b, c		a, b, c		
Actinovate STP (*Streptomyces lydicus*)		a			a	a		a		a		a		a		
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)		b			b	b		b		b		b		b		
Contans WG (*Coniothyrium minitans*)										b						
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747*)	c	b	c	c	b	b		b	c	c		b		b		
Double Nickel LC (*Bacillus amyloliquefaciens str. D747*)	c	b	c	c	b	b		b	c	c		b		b		
MycoStop Biofungicide (*Streptomyces griseoviridis*)		b	b			b										
MycoStop Mix (*Streptomyces griseoviridis*)		b	b			b										
Optiva (*Bacillus subtilis str. QST 713*)			c	c					c	c						
Prestop Biofungicide (*Gliocladium catenulatum Str. J1446*)		b			b	b		b	c			b		b	a	
Regalia Biofungicide (*Reynoutria sachalinensis*)		b	c	c	b	b		b	c	c	b	b		b		
RootShield Granules (*Trichoderma harzianum Rifai strain T-22*)		b				b		b						b		
RootShield PLUS+ WP (*Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*)		a,b		a				a,b				a,b		a,b		
Rootshield WP (*Trichoderma harzianum st T-22*)		a, b				a, b		a, b						a, b		
Serenade ASO (*Bacillus subtilis*)			c	c					c	c						
Serenade MAX (*Bacillus subtilis*)			c	c					c	c						
Serenade Optimum (*Bacillus subtilis*)									c	c						
Serenade Soil (*Bacillus subtilis*)	b	b			b	b		b				b		b		
SoilGard (*Gliocladium virens str. GL-21*)								b						b		
Taegro Biofungicide (*Bacillus subtilis var. amyloliquefaciens str.n FZB24*)		a, b				a, b		a, b								

Table 12.1.1 Pesticides Labeled for Organic Potato Disease Management.

CLASS OF COMPOUNDS Product Name (*active ingredient*)	BACTERIAL SOFT ROT,	FUSARIUM DRY ROT	EARLY BLGHT	LATE BLIGHT	VERTICIUM WILT	FUSARIUM WILT	BLACK DOT ROOT ROT	CANKER AND BLACK SCURF	BOTRYTIS VINE ROT	WHITE MOLD	COMMON SCAB	PINK ROT	POWDERY SCAB	PYTHIUM LEAK	SILVER SCURF *i*	VIRUSES
Zonix *(Rhamnolipid Biosurfactant)*				c								b		b		
COPPERS[e]																
Badge X2 *(copper oxychloride, copper hydroxide)*			c	c												
Basic Copper 53 *(copper sulfate)*			c	c												
Champ WG *(copper hydroxide)*			c	c												
***Copper Sulfate Crystals** *(copper sulfate pentahydrate)*				c												
CS 2005 *(copper sulfate pentahydrate)*			c	c												
Cueva Fungicide Concentrate *(copper octanoate)*			c	c												
Nordox 75 WG (*cuprous oxide)*			b	c												
NuCop 50DF *(copper hydroxide)*			c	c												
Nu-Cop 50 WP (*cupric hydroxide*)			c	c												
Nu-Cop HB *(cupric hydroxide)*			c	c												
***Quimag Quimicos Aguila Copper Sulfate Crystal** *(copper sulfate)*				c												
OIL																
JMS Stylet Oil *(paraffinic oil)*																c
Organic JMS Stylet Oil *(paraffinic oil)*																c
Pure clove oil *(clove oil[1])*															d	
PureSpray Green *(petroleum oil)*																c
Trilogy *(hydrophobic extract of neem oil)*			c						c	c	c		c			
OTHER																
EcoMate ARMICARB 0 (*potassium bicarbonate*)			c				c		c							
Milstop (*potassium bicarbonate*)									c							
PERpose Plus (*hydrogen peroxide/dioxide*)	c	c	c	c	c	c		c	c	c	c	c	c	c		
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*			c	c				a,b,c								
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	b	b			b	b		b				b		b		

* Restricted use pesticide. Restricted-use pesticides can be purchased only by certified applicators and used by certified applicators or by those under the direct supervision of a certified applicator. a = seed treatment, b = in furrow/ soil drench, c = foliar treatment, d= post harvest treatment, e = fixed copper fungicides include basic/tribasic copper sulfate, copper oxychloride sulfate, as well as copper hydroxide. Copper will build up in the soil, depending on a variety of factors. In general, copper hydroxides are less toxic than copper sulfates. See copper products fact sheet in the Resource Guide for Organic Insect and Disease Management (Reference 2) for more information about using copper.

1. For post harvest control of silver scurf on a food potato crop, clove oil must be certified organic. For post harvest silver scurf control for seed potato crop, clove oil must be 100% pure, but not necessarily certified organic. (Reference 44) See 12.16: Silver scurf. a, b, c or d = labeled for pest in New York and OMRI listed

12.1 Bacterial Soft Rot, *Erwinia spp*.

Time for concern: At planting, and between harvesting and marketing. Wet, anaerobic soils favor the disease.

Key characteristics: This bacterial pathogen can cause soft rot of infected tubers, resulting in seed piece decay and reduced yield and quality at harvest. Erwinia infection can also produce symptoms known as 'black leg': stunted, yellow stems that become black and rotted at ground level. Tubers are infected through wounds or lenticels, and develop tan or water-soaked areas on the tuber surface. Advanced infections will be seen as soft rot of the tuber flesh. The amount of damage depends on the population of the bacteria on and in the seed, seed storage and handling practices, and variety susceptibility. See Cornell fact sheet (Reference 55) and Ohio State fact sheet (Reference 56) for photos and more information.

Injury to potato plants by the European corn borer can cause sites for above and below ground *Erwinia* infection.

Relative risk: Reduce risk to this wound pathogen by avoiding injuries and providing conditions favorable to wound healing at planting and harvest. See Sections 7.2: *Seed preparation and handling*, 7.3: *Planting* and 10.4: *Curing and storage*.

Management Option	Recommendation for Bacterial Soft Rot
Scouting/thresholds, Crop rotation	These are not currently viable management options.
Site selection	Choose well-drained soils; wet, anaerobic conditions favor disease development. Infection of the lenticels is common in saturated soils.
Resistant varieties	No resistant varieties are available. Plant varieties less susceptible to European corn borer.
Seed selection/treatment	The primary source of inoculum is infected seedpieces. Plant only phytosanitary certified seed (See Section 7.1: *Seed sources*). Some growers have reduced seed piece decay by applying untreated fir bark to suberized seed pieces.
Planting	The bacteria can spread to healthy seedpieces during cutting and planting. Clean and sanitize cutting equipment before use, during the cutting process and between seed lots.
Harvest	Avoid injuries to tubers during harvest and avoid harvesting when soil temperatures are higher than 70°.
Postharvest	Provide good conditions for wound healing (55° to 60°F and 95 percent relative humidity, with good ventilation) for two to three weeks. Following the curing period, temperatures should be kept as low as possible.
Storage	Severely affected tuber lots should not be stored. Do not move potatoes unnecessarily during the storage period because new wounds will be created. Soft rot bacteria can also act as secondary pathogens in tubers infected with other diseases.
Notes	Tubers grown with excessive amounts of nitrogen are very susceptible to soft rot.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.1 Pesticides Labeled for Management of Bacterial Soft Rot

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
SOIL TREATMENT					
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qt/A Soil drench or in furrow	0	4	?	

Table 12.1 Pesticides Labeled for Management of Bacterial Soft Rot					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/ transplanting. 25 fl oz/200 gal water/1000 ft^2 soil Soil treatment with established plants.	Up to day of harvest	0	?	
FOLIAR TREATMENT					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	3-12 oz/A Foliar treatment	0	1 or when spray has dried	?	Label recommends using a spreader sticker for foliar applications.
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.25-3 lbs/A Foliar treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-6 qts/A Foliar treatment	0	4	?	
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.

PHI = pre-harvest interval, REI = restrictedentry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.2 Fusarium Dry Rot Seed piece decay primarily *Fusarium sambucinum*, but also *F. coeruleum and F. graminearum*

Time for concern: During planting, harvest, and postharvest, if soil is cold and pathogen is present.

Key characteristics: Fusarium spp. fungi cause dry rot in stored tubers and seed piece decay. Symptoms include sunken and shriveled areas on the surface of the tubers. The rot may extend to the center of the tuber and contain a fungal growth that is pink, white, or yellow. Soft rot bacteria can colonize dry rot lesions, making diagnosis difficult. The fungus originates in contaminated seed or infested soil. See Cornell general fact sheet (Reference 55) and dry rot fact sheet (Reference 58) for photos and more information.

Relative risk: Dry rot occurs annually and is perhaps the most important cause of post harvest potato losses in the northeastern United States.

Management Option	Recommendation for Fusarium Dry Rot
Scouting/thresholds	Inspect seed for Fusarium dry rot before purchasing. If necessary, grade out affected tubers before cutting seed.
Site selection	To reduce disease spread, plant seed in warm ground and cover with as little soil as practical. Avoid fields with a history of Fusarium dry rot.
Resistant varieties	No resistant varieties are available.

Management Option	Recommendation for Fusarium Dry Rot
Seed selection/treatment	Seed quality is the most important factor in minimizing losses due to this disease. Plant only phytosanitary certified seed. Carefully inspect seed at the time of receipt. If possible, evaluate the seed before it is shipped. Warm seed to at least 50°F before handling and cutting to minimize injury and promote growth. Bruising the seed during handling spreads the disease. Protect seed from wind and sunlight during planting because dehydration weakens seed. Cut only as much seed as can be planted in 24 hours. Cut with sharp knives and disinfect seed cutting and handling equipment often. Always disinfect between seed lots. Do not mix seed lots.
Planting	Shallow planting and light cultivation to break up compact soil will increase soil temperature, improve oxygen levels aroung the seed piece, and speed plant growth.
Crop rotation/Sanitation	These are not currently viable management options.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.2 Pesticides Labeled for Management of Fusarium Dry Rot

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICAL					
Actinovate AG *(Streptomyces lydicus)*	1-12 oz./A Soil treatment at planting 3-12 oz/A Soil treatment in season 2-18 oz/cwt of seed Seed treatment	0	1 or when spray has dried	?	Reapply every 7-14 days.
Actinovate STP *(Streptomyces lydicus)*	4–32.0 oz/ cwt seed Seed treatment	-	1 or when spray has dried	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Banded	-	1	?	
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	

Table 12.2 Pesticides Labeled for Management of Fusarium Dry Rot					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
MycoStop Mix *(Streptomyces griseoviridis str. K 61)*	7.6-30 oz/A Soil spray or drench 0.5-1 lb/ treated acre Band, in-furrow or side dress	-	4	?	Use at planting; no pre-harvest interval noted. Irrigate within 6 hours after soil spray or drench with enough water to move Mycostop into the root zone. Lightly incorporate furrow or band applications.
Mycostop Biofungicide *(Streptomyces griseoviridis* str. K61)	15-30 oz/A Soil spray or drench	-	4	?	Irrigate within 6 hours after soil spray or drench with enough water to move Mycostop into the root zone.
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench -treat only growth substrate	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are available.
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal water Soil drench 1-4 qt/A In-furrow	0	4	?	
RootShield Granules *(Trichoderma harzianum Rifai strain T-22)*	5-12 lbs/ A In furrow	-	0	?	
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-1.5 lbs/20 gal water (seed piece dip) or 0.03-3.0 lbs/cwt (seed piece dust) 16-32 oz/A In-furrow	0	4	1	Trichoderma harzianum products effective in 1/1 trial. Do not apply when above-ground harvestable food commodities are present.
RootShield WP (*Trichoderma harzianum str. T-22 (KRL-AG2)*)	0.3-3oz/cwt seed Seed treatment 16 – 32 oz/A In furrow	-	Until sprays have dried	?	For use in planter box only.
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qt/A Soil drench or in furrow application.	0	4	?	
Taegro Biofungicide (*Bacillus subtilis var. amyloliquefaciens str. FZB24*)	2.6 oz/ 100 gal water Soil drench 3 tsp/gal water Tuber treatment 2.6 oz/100 gal water for 2 acres In furrow at time of planting	-	24	?	Dip tubers for 10 to 30 minutes before planting. For best results, make two or three applications spaced one week apart. For best results make 2 or 3 applications one week apart.

Table 12.2 Pesticides Labeled for Management of Fusarium Dry Rot					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/transplanting. 25 fl oz/200 gal water/1000 ft^2 soil; 25 to 100 gals of solution / acre-row. Soil treatment with established plants.	Up to day of harvest	0	?	

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.3 Early Blight, primarily *Alternaria solani*

Time for concern: Early to mid-July through harvest in warm and humid weather.

Key characteristics: This fungus causes leaf lesions that are dark brown and appear leathery with faint, concentric rings giving a "target-spot" effect. Spots grow to 1/2 inch. Under prolonged warm and humid conditions, spots may enlarge or coalesce, causing leaf yellowing and early senescence. Severe defoliation will reduce yields. Tuber infections appear as small, irregular, brownish black spots that are usually sunken. The rotted tuber tissue is firm, hard, and somewhat corky. Tuber infection is much less common than foliar infection. Early blight overwinters in infected plant debris and potato tubers. See Cornell general fact sheet (Reference 55), early blight fact sheet (Reference 59) and Michigan State photos (Reference 60).

Relative Risk: Prevalent in most growing seasons, but in comparison with late blight, this disease is less serious. There is a high risk for significant defoliation and yield reduction when susceptible varieties are grown in a warm, wet year.

Management Option	Recommendation for Early Blight
Scouting/thresholds	Record the occurrence and severity of early blight. Thresholds have not been established for organic production
Site selection	Select well-drained fields. Avoid planting adjacent to other solanaceous hosts such as tomato and eggplant, or adjacent to fields that were infected with early blight in the previous season, since these fields may serve as inoculum sources.
Planting	Plant rows in an east-west direction and used wide row spacing, 36 inches, to reduce prolonged leaf wetness.
Crop rotation	Minimum two-year rotation without potatoes, tomatoes, or eggplants if severe outbreaks have occurred.
Resistant varieties	Potato varieties differ in their susceptibility to early blight. Late maturing varieties are usually more

Management Option	Recommendation for Early Blight
	resistant to early blight. See Section 6: *Varieties*.
Seed selection/treatment	Plant phytosanitary certified seed. See Section 7.1: *Seed sources*.
Irrigation	Drip irrigation or very early morning overhead irrigation, which will allow the leaves to be dry for long periods, is preferred.
Vine killing	Allowing tubers to mature in the ground for at least two weeks after the vines die can reduce infection to tubers. Dig when the vines are dry.
Harvest	Avoid wounding tubers during harvest and post harvest operations.
Sanitation	Plow under all plant debris and volunteer potatoes immediately after harvest.
Storage	Examine tubers and discard infected tubers before storage. Periodically check stored tubers for disease symptoms.
Notes	Environmental stresses such as drought and nitrogen and phosphorous deficiencies increase susceptibility to early blight.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.3 Pesticides Labeled for Management of Early Blight

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICAL					
Bacillus spp.					
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.25-3 lbs/A Foliar treatment	0	4	?	Suppression only.
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-6 qts/A Foliar treatment	0	4	?	Provides suppression only.
Optiva *(Bacillus subtilis str. QST 713)*	14-24 oz/A Foliar treatment	0	4	?	For suppression. Repeat on a 5-7 day interval or as needed.
Serenade ASO *(Bacillus subtilis)*	2-6 qts/A Foliar treatment	0	4	?	For suppression, begin applications of Serenade ASO or Serenade MAX soon after emergence and when conditions are conducive to disease development. Repeat on 5 to 7 day intervals or as needed.
Serenade MAX *(Bacillus subtilis)*	1-3 lb/A Foliar treatment	0	4	?	
Reynoutria					
Regalia Biofungicide (*Reynoutria sachalinensis*)	1–4 qts/A Foliar treatment	0	4	?	Apply every 5 – 7 days.
Streptomyces					
Actinovate AG *(Streptomyces lydicus)*	3-12 oz/A Foliar treatment	0	1 or when spray has dried	3	Streptomyces lydicus products effective in 0/1 trial. Reapply every 7-14 days. Use a spreader sticker.

BOTANICAL AND MINERAL OILS					
Trilogy *(hydrophobic extract of neem oil)*	0.5-1% in 25-100 gal of water/A Foliar treatment	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/acre/application.
COPPER			Copper based products effective in 1/2 trials. In warm, wet weather, significant defoliation will occur. Copper can build up in the soil.		
Badge X2 *(copper oxychloride, copper hydroxide)*	0.5-1.75 lbs/A Foliar treatment	-	48	2	
Basic Copper 53 *(copper sulfate)*	3-6 lb/A Foliar treatment	Up to day of harvest	24	2	
Champ WG *(copper hydroxide)*	1-4 lbs/A Foliar treatment	-	48	2	For Champ WG apply 1-1.5 lbs/A where disease is light and up to 3 to 4 lbs/A where disease is more severe. Application of Champ WG at rates and timing recommended for control of Early and Late Blight may provide suppression of Colorado Potato Beetle.
CS 2005 *(copper sulfate pentahydrate)*	19.2-32 oz/A Foliar treatment	-	48	2	
Cueva Fungicide Concentrate *(copper octanoate)*	0.5-2.0 gal/100 gal water Foliar treatment	Up to day of harvest	4	2	Apply at 50-100 gallons of spray mix/A.
Nordox 75 WG (*cuprous oxide*)	0.66 – 4 lbs/A Foliar treatment	-	12	2	Apply Nordox 75 WG every 7-10 days when plants are 6 inches high until harvest.
NuCop 50DF *(cupric hydroxide)*	1-4 lb/A Foliar treatment	1	24	2	
Nu-Cop 50 WP (*copper hydroxide*)	1 – 1.5 lbs /A (light infestation) Foliar treatment 3 – 4 lbs /A (heavy infestation) Foliar treatment	1	24	2	Apply Nu Cop 50 WP every 7-10 days when plants are 6 inches high. Use lower rate where disease is light and higher rate where disease is more severe.
Nu-Cop HB *(cupric hydroxide)*	0.5-2 lbs/A Foliar treatment	1	24	2	
HYDROGEN DIOXIDE					
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water (curative) Foliar treatment 32 fl oz/100 gal water (preventative) Foliar treatment	0	Until sprays have dried	?	Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 32 fl oz/100 gal preventative rate after completion of third treatment and maintain 5-day interval spray cycle until harvest.
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment 0.25-0.33 fl oz/gal (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
OTHER					
EcoMate ARMICARB 0 (*potassium bicarbonate*)	2.5-5 lbs/100 gal water Foliar treatment	0	4	?	Apply mixed solution at a minimum of 20 gal/A.

PHI = pre-harvest interval, REI = restrictedentry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.4 Late Blight, *Phytophthora infestans*

Time for concern: Throughout the growing season and in storage. High moisture and moderate temperatures (60-80°F) favor late blight development; disease will stall in hot weather.

Key characteristics: This fungus causes lesions on leaves and stems that appear as small flecks within three to five days after infection. The infected tissue is initially water-soaked but becomes brown or black in a few days. Lesions are often surrounded by a halo of light green tissue. Under high humidity, sporulation is visible as a delicate, white mold surrounding the lesion. Rain may wash spores down the stems and infect tubers. Infected tubers develop a shallow reddish-brown corky dry rot. Bacterial soft rot often follows. Late blight overwinters on infected, stored tubers or tubers left in the field. See Cornell fact sheet (Reference 61), disease cycle (Reference 62), control options (Reference 63),and organic management options (Reference 63 B).

Relative Risk: This disease is occurring with increasing regularity and can be totally devastating when present. In very wet cool weather, infections can spread quickly, leading to 50% or greater reductions in yield even with copper sprays, and complete yield loss if no control measures are taken. Hot weather slows disease progress.

Management Option	Recommendation for Late Blight
Scouting/thresholds	Scout fields weekly for late blight symptoms. A forecasting system for late blight is available for some New York locations through the Network for Environment and Weather Awareness Potato late blight forecast (Reference 4). The forecasting system has two parts: early season prediction of first appearance of late blight (Blitecast), and subsequent recommended spray intervals (Simcast). Late blight is first expected to appear 1-2 weeks after 18 Blitecast Severity Values (SV) have accumulated, starting with the emergence of green tissue from the source of late blight inoculum. The source of inoculum could be plants growing from infected tubers in a cull pile, volunteers growing from infected tubers that survived the winter, or infected seed tubers. For a more comprehensive disease management system, sign up for an account on the Late Blight Decision Support System. Start scouting soon after 18 SV have accumulated if a late blight forecast is available for your area, or when potatoes are 4-6" high. Conventional farmers begin applying fungicides at this point and maintain coverage until harvest, adjusting spray intervals to reflect weather conditions as described below. If late blight is found early in the season it may not be possible to control it adequately using approved copper products, and the field may need to be disked under. Track where late blight has been found in NY and monitor potential sources of late blight spores from off your farm at usablight.org (Reference 64). If late blight is found in your county or adjacent counties and you choose to use copper, apply an approved copper fungicide immediately even if late blight has not been found in your field. The fungicide must be present before infection occurs to have a chance of successful control. Coverage should be excellent throughout the canopy. Once fungicide applications have started, use the Simcast Forecast help determine spray intervals. Be aware that copper can build up in the soil. See Resource Guide for Organic Insect and Disease Management (Reference 2) and organic management options (Reference 63B) for more information about using copper fungicides. If present, harvest the crop early before it becomes contaminated. Harvest new potatoes and sell early, if possible.
Site selection	Avoid fields that cannot be effectively sprayed. Fields surrounded by trees that shade and slow air movement, or those remaining damp late into the morning are at higher risk for infection.
Crop rotation	Do not plant potatoes near a field where late blight occurred the previous year and there is a potential for volunteer plants growing from unharvested tubers.
Resistant varieties	Potato varieties differ slightly in their susceptibility, but commercial varieties do not have useful levels of resistance. Late variety Elba has foliar resistance but not tuber resistance. Choose early maturing varieties that will allow early harvest.

Management Option	Recommendation for Late Blight
Seed selection/treatment	Infected seed potatoes serve as an important source of inoculum. Plant phytosanitary certified seed (See Section 7.1: Seed sources). Know your seed grower. Even state phytosanitary certified seed may have a low percentage of late blight. Obtain plant health certification from state certifying agency indicating if late blight was present in the field. Phytosanitary certified seed must have no more than 1% late blight tuber rot.
Planting	Plant on proper row spacing to ensure adequate air flow around leaves and leaf drying.
Hilling	Proper hilling practices reduce the exposure of tubers to spores.
Vine killing	Proper vine-killing practices reduce the exposure of tubers to spores. See Section 10.1: Vine killing. If a field has significant infection, destroy foliage by mowing or flaming to prevent infection of other fields including tomatoes.
Harvest	Foliage and vines should be completely dead and dry before harvest to avoid inoculating tubers. Providing at least 2-3 weeks post-vinekill prior to harvesting will improve skin set and allow many blight infected tubers to develop visual symptoms that can be graded out prior to storage or marketing.
Postharvest	Cool tubers as quickly as possible to 50 degrees and maintain good air circulation. Maintain proper storage temperature depending on variety grown (See Section 10.4). Monitor storage potatoes for infection.
Sanitation	Eliminate cull piles and volunteers before plants emerge in the spring. Infected shoots from these plants can provide initial inoculum for field infection.
Notes	High nitrogen rates can lead to excessive foliage that will prevent adequate airflow and thus slow foliage drying.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.4 Pesticides Labeled for Management of Late Blight

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Bacillus					
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.25-3 lbs/A Foliar treatment	0	4	?	Suppression only.
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-6 qts/A Foliar treatment	0	4	?	Provdes suppression only.
Optiva *(Bacillus subtils str. QST 713)*	14-24 oz/A Foliar treatment	0	4	?	For suppression. Repeat on a 5-7 day interval or as needed.
Serenade ASO *(Bacillus subtilis)*	2-6 qts/A Foliar treatment	0	4	?	For suppression, begin applications of Serenade ASO and Serenade MAX soon after emergence and when conditions are conducive to disease development. Repeat on 5 to 7 day interval or as needed.
Serenade MAX *(Bacillus subtilis)*	1-3 lb/A Foliar treatment	0	4	?	
Reynoutria					
Regalia Biofungicide (*Reynoutria sachalinensis*)	1–4 qts Foliar treatment	0	4	?	Apply every 5 – 7 days.
Trichoderma					
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-1.5 lbs/20 gal water Seed piece dip 0.03-3.0 lbs/cwt (seed piece dust)	0	4	1	Trichoderma harzianum products effective in 1/1 trial.
Other					
Zonix *(Rhamnolipid Biosurfactant)*	0.5-0.8 oz/gal Foliar treatment	-	4	?	Contact biofungicide that controls disease upon contact with zoospores. Thorough coverage is necessary.
COPPERS			Copper based proucts effective in 3/3 trials. Copper based products effective but must be applied often and thoroughly. Copper products may suppress disease under ideal conditions but will not protect under heavy pressure. This is not a substitution for an integrated disease management approach.		
Badge X2 *(copper oychloride, copper hydroxide)*	0.5-1.75 lbs/A Foliar treatment	-	48	1 +	
Basic Copper 53 (*copper sulfate*)	3-6 lbs/A Foliar treatment	Up to day of harvest	24	1 +	
Champ WG (*copper hydroxide*)	1-4 lbs/A Foliar treatment	-	48	1 +	Apply 1-1.5 lbs/A where disease is light and up to 3 to 4 lbs/A where disease is more severe. Application of Champ WG at rates and timing recommended for control of Early and Late Blight may provide suppression of Colorado Potato Beetle.
*Copper Sulfate Crystals *(copper sulfate pentahydrate)*	10 lbs/A Foliar treatment	0	24	1 +	

Table 12.4 Pesticides Labeled for Management of Late Blight					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
CS 2005 *(copper sulfate pentahydrate)*	19.2-32 oz/A Foliar treatment	-	48	1 +	
Cueva Fungicide Concentrate *(copper octanoate)*	2.0 gal/A Foliar treatment	Up to day of harvest	4	1 +	Apply in 50 to 100 gallons of water.
Nordox 75 WG (*cuprous oxide*)	1.25 – 2.5 lbs/A Foliar treatment	-	12	1 +	
NuCop 50DF *(cupric hydroxide)*	1-4 lbs/A Foliar treatment	1	24	1 +	
Nu-Cop 50 WP (*copper hydroxide*)	1 – 1.5 lbs/A (light infestation) Foliar treatment 3 – 4 lbs/A (heavy infestation) Foliar treatment	1	24	1 +	Apply every 7-10 days when plants are 6 inches high. Use lower rate where disease is light and higher rate where disease is more severe.
Nu-Cop HB *(cupric hydroxide)*	0.5-2 lbs/A Foliar treatment	1	24	1 +	
*Quimag Quimicos Aguila Copper Sulfate Crystal *(copper sulfate pentahydrate)*	10 lbs/A Foliar treatment	-	48	1 +	Use alone through harvest to suppress late blight.
HYDROGEN DIOXIDE					
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water (curative) Foliar treatment 32 fl oz/100 gal water (preventative) Foliar treatment	0	Until spray has dried	3	Hydrogen peroxide products effective in 0/3 trials. Begin when plants are small. Apply first three treatments using the curative rate at 5-day intervals. Reduce rate to 32 fl oz/100 gal preventative rate after completion of third treatment and maintain 5-day spray interval until harvest.
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	3	Hydrogen peroxide products effective in 0/3 trials. For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.

* = Restricted-use pesticide. Restricted-use pesticides can only be purchased by certified applicators and used by certified applicators or someone under the direct supervision of a certified applicator.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

+/- = May be ineffective under high disease pressure; ++++=highly effective.

12.5 Verticillium Wilt, *Verticillium albo-atrum and V. dahliae*

Time for concern: Mid-season to harvest, in cool soils.

Key characteristics: Wilt symptoms result from the growth of the fungi in the water-conducting tissues of the tuber, root and stem. Yellowing, wilting, and defoliation are the first symptoms, which typically occur on one side of a leaf or one side of the plant. These symptoms may be more apparent at higher temperatures when the plants are trying to transport more water. When affected stems are cut diagonally at the base, brown streaks are visible (Reference 55). Infected tubers develop a light brown discoloration of the vascular tissue. Wilting and chlorosis of the foliage is similar to Fusarium wilt. Laboratory isolation of the fungus is necessary for positive identification. Verticillium survive as microsclerotia in the soil. See Cornell general fact sheet (Reference 55).

Yield losses are more severe when lesion nematode (*Pratylenchus penetrans*) is also present, even at low soil population levels; the nematode/verticillium complex is called early dying.

Relative risk: Sandy soil is a risk factor; uncommon in heavier soils of Upstate NY.

Management Option	Recommendation for Verticillium Wilt
Scouting/thresholds	Record the occurrence and severity of Verticillium wilt. Thresholds have not been established for organic production
Crop rotation	Rotation with grains reduces soil populations. The pathogen survives for several years without a host crop and will infect and reproduce on many weeds. Plan a minimum of 3-4 years without tomato, eggplant or pepper and maintain good weed control in rotational crops.
Resistant varieties	For tuber symptoms, late-maturing varieties are more resistant than early-maturing varieties. See Section 6: *Varieties*. Superior is particularly susceptible, while Atlantic is tolerant, Genesee is resistant, and Reba is moderately resistant.
Cultivation/Hilling	Avoid late cultivation and hilling of susceptible varieties, because root pruning increases risk of infection.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.5 Pesticides Labeled for Management of Verticillium Wilt

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	1-12 oz/ A Soil treatment at planting 3-12 oz/A Soil drench in season 2-18 oz/cwt of seed Seed treatment	0	1 or when spray has dried	?	
Actinovate STP *(Streptomyces lydicus)*	4–32.0 oz/cwt seed Seed treatment	-	1 or when spray has dried	?	
BIO-TAM *(Trichoderma asperellum, Trichoderma gamsii)*	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Banded	-	1	?	
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	

Table 12.5 Pesticides Labeled for Management of Verticillium Wilt

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are available.
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal water Soil drench 1-4 qt/A In-furrow	0	4	?	
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qts/A Soil drench or in furrow	0	4	?	
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Soil drench at seeding, planting and periodic	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/ transplanting. 25 fl oz/200 gal water/1000 ft2 soil Soil treatment with established plants.	Up to day of harvest	0	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.6 Fusarium Wilt, *F. oxysporum and F. solani*

Time for concern: Mid-season to harvest. Infection is favored by hot weather and high soil moisture.

Key characteristics: Fusarium, a soil borne fungi, can cause a variety of symptoms including tuber lesions and vascular discoloration in tuber, root and stem. Wilt symptoms result from the growth of the fungi in the water-conducting tissues of the root and stem. Wilting and chlorosis of the foliage is similar to Verticillium wilt. Laboratory isolation of the fungus is necessary for positive identification. There are no chemical control options. See Cornell general fact sheet (Reference 55) for photos of symptoms and more information.

Relative risk: Yield loss can be up to 50 % in severely affected fields.

Management Option	Recommendation for Fusarium Wilt
Scouting/thresholds	Record the occurrence and severity of Fusarium wilt. Thresholds have not been established for organic production
Site selection	Avoid fields that have had severe outbreaks in the past.
Crop rotation	Crop rotation is not useful because the fungi survive in the soil for long periods without host plants.
Resistant varieties	No resistant varieties are available. Kenebec is highly susceptible.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.6 Pesticides Labeled for Management of Fusarium Wilt

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Actinovate AG (*Streptomyces lydicus WYEC 108*)	1-12 oz/ A Soil treatment at planting 3-12 oz/A Soil drench in season 2-18 oz/cwt of seed Seed treatment	0	1 or when spray has dried	?	
Actinovate STP *(Streptomyces lydicus)*	4–32.0 oz/cwt seed Seed treatment	-	1 or when spray has dried	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Band	-	1	?	
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	
MycoStop Mix *(Streptomyces griseoviridis str. K 61)*	7.6-30 oz/A Soil spray or drench 0.5-1 lb/ treated acre Band, in-furrow or side dress	-	4	?	Use at planting; no pre-harvest interval noted. Irrigate within 6 hours after soil spray or drench with enough water to move Mycostop into the root zone. Lightly incorporate furrow or band applications.
Mycostop Biofungicide *(Streptomyces griseoviridis* str. K61)	15-30 oz/A Soil spray or drench	-	4	?	Irrigate within 6 hours after soil spray or drench with enough water to move Mycostop Biofungicide into the root zone.
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench -treat only growth substrate	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are present.
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal water Soil drench 1-4 qt/A In-furrow	0	4	?	
RootShield Granules *(Trichoderma harzianum Rifai strain T-22)*	5-12 lbs/ A In furrow	-	0	?	
RootShield WP *(Trichoderma harxianum str. T-22 (KRL-AG2))*	0.03-3oz/cwt seed Seed treatment 16 – 32 oz/A In-furrow spray	-	Until spray has dried	?	For use in planter box only.

Table 12.6 Pesticides Labeled for Management of Fusarium Wilt					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qts/A Soil drench or in furrow	0	4	?	
Taegro Biofungicide (*Bacillus subtilis var. amyloliquefaciens str. FZB24*)	2.6 oz/ 100 gal water Soil drench 3 tsp/gallon of water Tuber treatment 75 g/100 gal for 2 acres In furrow at time of planting	-	24	?	Dip tubers for 10 to 30 minutes before planting. For best results, make two or three applications spaced one week apart. For best results make 2 or 3 applications one week apart.
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Soil drench at seeding, planting and periodic	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/ transplanting. 25 fl oz/200 gal water/1000 ft2 soil Soil treatment with established plants.	Up to day of harvest	0	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.7 Black Dot Root Rot, *Colletotrichum coccodes*

Time for concern: Growing season and into storage. Disease incidence increases later in the season, when soil temperatures are high. High temperatures and moisture on tuber surfaces promotes disease in storage.

Key characteristics: This fungal disease is also referred to as "black dot" because of the numerous black, fungal structures that appear on tubers, stolons, roots, and stems both above and below ground. Root growth is reduced and appears brown to black in color. Tuber infection appears as brown to gray discoloration over a large part of the tuber surface or as round spots larger than 1/4 inch in diameter. Black dot survives up to 2 years on infected plant debris and soil. See fact sheet (Reference 65), interactive black dot of potato photo (Reference 66) and Michigan State University life cycle (Reference 67).

Relative risk: Black dot root rot occurs sporadically but can result in 75% yield loss in severely infected fields. Can be destructive because it causes symptoms on all plant parts.

Management Option	Recommendation for Black Dot Root Rot
Scouting/thresholds	Record the occurrence and severity of root rot. Thresholds have not been established for organic production
Crop rotation	Minimum 3-4 year rotation that includes a grain crop. Maintain good management of solanaceous weeds in rotational crops. Do not rotate with tomatoes.
Resistant varieties	No resistant varieties are available, but late-maturing varieties are more vulnerable to yield reduction. Varieties that appear to be moderately resistant (based upon tuber ratings) include Eva, Genesee, Keuka Gold, Lehigh, Norland, and Norwis. Varieties that are moderately susceptible to susceptible include Andover, Banana, Chieftain, Monona, Pike, Reba, Superior, and Yukon Gold. See Section 6: Varieties.
Seed selection	Plant phytosanitary certified seed. See Section 7.1: Seed sources.
Site selection	Choose well-drained field if possible.
Postharvest	Deep plowing will bury infected debris and promote decomposition.
Notes	Provide adequate water and fertilizer because crop stress increases vulnerability to black dot.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.7 Pesticides Labeled for Management of Black Dot Root Rot

Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
EcoMate ARMICARB 0 (*potassium bicarbonate*)	2.5-5 lbs in 100 gal water Foliar treatment	0	4	?	Apply mixed solution at a minimum of 20 gal/A at first sign of disease.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.8 Canker and Black Scurf, *Rhizoctonia solani*

Time for concern: Growing season. Cool wet soils favor disease development.

Key characteristics: This fungus causes a variety of symptoms on tubers including cracking, malformation, and russeting. The 'black scurf' symptom found on infected tubers appears as numerous dark, hard reproductive structures, called sclerotia. The sclerotia may be flat and superficial or large, irregular, and lumpy. Sclerotia on stored tubers do not cause damage or spread the disease in storage. However, sclerotia in soil or on seed pieces can germinate and infect young, susceptible sprouts and stolons, causing lesions, or cankers. In cool wet soils, when plants are growing slowly, disease can progress rapidly, causing reduced stands and stunted plants. See Cornell fact sheet (Reference 68), Michigan fact sheet (Reference 69), and interactive black scurf potato photo (Reference 66).

Relative risk: This disease is very common in New York.

Management Option	Recommendation for Canker and Black Scurf
Scouting/thresholds	Record the occurrence and severity of canker. Thresholds have not been established for organic production
Site selection	Heavy, poorly drained soils should be avoided.
Crop rotation	Minimum three-year rotation to corn or grain crops. Plant a grass or cereal green manure such as a sorghum-sudan grass hybrid or Japanese millet the year before potatoes are grown.
Cover crops	One Michigan State study found reduced Rhizoctonia incidence in a potato crop planted after incorporating a spring brassica cover crop.
Resistant varieties	No resistant varieties are available.
Seed selection	Plant phytosanitary certified seed (See Section 7.1: Seed sources). Inoculum can be introduced into fields on potato seed tubers. See Section 7: Planting methods.
Planting	Plant in warm soils and plant shallowly to encourage rapid emergence. Best if soil organic matter is decomposed before planting.
Vine killing	Minimize the time tubers stay in the soil after vine death.
Sanitation	Inoculum can also be introduced to the fields by contaminated soil.
Notes	If conditions are cold and wet, potatoes should be planted shallowly or planted deeply and covered shallowly. This encourages rapid emergence and reduces the chance of damage to new sprouts, 'sprout burn'

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.8 Pesticides Labeled for Management of Canker and Black scurf

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Bacillus spp					
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	

Table 12.8 Pesticides Labeled for Management of Canker and Black scurf					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qts/A Soil drench or in furrow	0	4	?	
Taegro Biofungicide (*Bacillus subtilis var. amyloliquefaciens str. FZB24*)	3.5 fl oz/ 100 gal Soil drench 3 tsp/gallon of water Tuber treatment 2.6 oz/100 gallons of water for 2 acres In furrow	-	24	?	Dip tubers for 10 to 30 minutes before planting. For best results, make two or three applications spaced one week apart. For best results make 2 or 3 applications one week apart.
Gliocladium spp.					
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are present.
SoilGard (*Gliocladium virens str. GL-21*)	2 – 10 lbs/A Band drench in-furrow.	0	Until spray has dried	?	Apply in 50 – 100 gallons of water
Reynoutria					
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal Soil drench 1-4 qt/A In-furrow	0	4	?	
Streptomyces lydicus					Streptomyces lydicus products effective in 0/6 trials.
Actinovate AG *(Streptomyces lydicus WYEC 108)*	1-12 oz/ A Soil treatment at planting 3-12 oz/A Soil drench in season 2-18 oz/cwt of seed Seed treatment	0	1 or when spray has dried	3	
Actinovate STP *(Streptomyces lydicus)*	4–32.0 oz/cwt seed Seed treatment	-	1 or when spray has dried	?	
Trichoderma spp.					
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Banded	-	1	?	
RootShield Granules *(Trichoderma harzianum Rifai strain T-22)*	5-12 lbs/ A In furrow	-	0	?	
RootShield WP (*Trichoderma harzianum str. T-22 (KRL-AG2)*)	0.03-3oz/cwt seed Seed treatment 16 – 32 oz. In-furrow spray	-	Until spray has dried	3	Trichoderma based products effective in 0/4 trials. For use in planter box only.
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.03-3 lb/cwt seed Preplant dust 16-32 oz/A In furrow	0	4	3	Trichoderma based products effective in 0/4 trials. For use in planter box only.

Table 12.8 Pesticides Labeled for Management of Canker and Black scurf					
CLASS OF COMPOUNDS **Product Name** (***active ingredient***)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) Soil drench at seeding, planting and periodic	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/transplanting. 25 fl oz/200 gal water/1000 ft2 soil Soil treatment with established plants.	Up to day of harvest	0	?	

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.9 Botrytis Vine Rot, *Botrytis cinerea*

Time for concern: Growing season, especially under wet conditions and prolific vine growth.

Key characteristics: This fungus infects dead tissue and can be seen as a fuzzy, gray growth on dead blossoms or senescent leaves. It is sometimes mistaken for late blight. Under wet conditions and when vine growth is lush, the fungus may move into the stem tissue. The stem rot is initially wet and slimy. The fungus sporulates on infected tissue and produces a dense, gray to off-white growth. See Canada fact sheet (Reference 70).

Relative Risk: Occurs sporadically and usually does not result in significant yield loss.

Management Option	Recommendation for Botrytis Vine Rot
Scouting/thresholds	Record the occurrence and severity of Botrytis vine rot if it will cause disease problems within the crop rotation. Thresholds have not been established for organic production
Site selection	Avoid planting in fields with soils that drain poorly. Avoid areas where foliage remains wet from dew for long periods. Fields surrounded by trees that shade and slow air movement, or those remaining damp late into the morning are at higher risk.
Resistant varieties	No resistant varieties are available.
Crop rotation, Seed selection, Post-harvest, and Sanitation	These are not currently viable management options.
Notes	Nitrogen rates that result in excess vine growth aggravate this disease.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.9 Pesticides Labeled for Management of Botrytis Vine Rot

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	3-12 oz/A Foliar treatment	0	1 or when spray has dried	?	Label recommends using a spreader sticker for foliar applications.
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.25-3 lbs/A Foliar treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-6 qts/A Foliar treatment	0	4	?	
Optiva *(Bacillus subtilis str. QST 713)*	14-24 oz/A Foliar treatment	0	4	?	Repeat on a 7-10 day interval or as needed.
Prestop Biofungicide (*Gliocladium catenulatum str. J1446*)	3.5 oz/5 gal water applied at 0.5 gallons of mix per 100 sq. ft. Foliar treatment	-	0	?	Apply only when no above-ground harvestable food commodities are present.
Serenade ASO *(Bacillus subtilis str. QST 713)*	2-6 qt/A Foliar treatment	0	4	?	Repeat on a 7-10 day interval or as needed.
Serenade MAX *(Bacillus subtilis str. QST 713)*	1-3 lbs/A Foliar treatment	0	4	?	Repeat on a 7-10 day interval or as needed.
Serenade Optimum (*Bacillus subtilis*)	14-20 oz/A Foliar treatment	0	4	?	
Regalia Biofungicide (*Reynoutria sachalinensis*)	1–4 qts/A Foliar treatment	0	4	?	Apply every 5 – 7 days.
OTHER					
EcoMate ARMICARB 0 *(potassium bicarbonate)*	2.5-5 lbs/A Foliar treatment	0	4	?	Apply mixed solution at a minimum of 20 gal/A
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/Gal (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative.
Milstop (*potassium bicarbonate*)	2-5 lbs/A Foliar treatment	0	1	?	
Trilogy *(hydrophobic extract of neem oil)*	0.5-1% in 25-100 gal of water/A Foliar treatment	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/acre/application.

PHI = pre-harvest interval, REI = restrictedentry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.10 White Mold, *Sclerotinia sclerotiorum*

Time for concern: Mid-season to harvest. Favored by wet or humid plant canopy and poor air circulation.

Key characteristics: The fungus is soil borne and generally infects stems at the soil line, but the infection may occur on any part of the plant. Symptoms include dense, cottony, white growth and the production of hard, black, irregularly shaped sclerotia on infected tissue. This disease is not common on potatoes in New York. See Michigan State fact sheet (Reference 71).

Relative risk: White mold is a risk if soil is infested with sclerotia, in wet seasons and with excessive irrigation.

Management Option	Recommendation for White Mold
Scouting/thresholds	Scout the previous crop in the field prior to harvest to determine the need for treatment with Contans WG after harvest to reduce overwintering inoculum. Keep an accurate history of white mold incidence and severity in all fields.
Coverage	The best coverage can be obtained by using a minimum of 50 gallons per acre and high pressure (100 to 200 psi). Thoroughly cover initials, buds, and blossoms.
Crop rotation	Rotation with grains reduces soil populations and is an important management tool. Avoid rotations with beans. Plant potatoes only every 5th year if white mold is a problem. If there is a field history of white mold, potatoes should not be preceded by a bean (including soybeans), tomato, lettuce, or crucifer crops.
Resistant varieties	No resistant varieties are available.
Site selection	Avoid planting in shaded areas and in small fields surrounded by trees; do not plant in fields that drain poorly or have a history of severe white mold.
Planting	Plant rows in an east-west direction.
Fertilization	Avoid over-fertilization.
Irrigation	Avoid over watering.
Postharvest	Incorporate crop debris immediately following harvest to allow soil microorganisms the opportunity to feed on the survival structures called sclerotia.
Sanitation	Manage weed hosts such as lambsquarters and pigweed.
Note(s)	The disease tends to be worse in fields where there is poor weed management, leaves have mechanical damage or pesticide injury, and where dead leaves are on the ground. The fungus can grow on dead and living material.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.10 Pesticides Labeled for Management of White Mold

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICAL					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	1-12 oz/ A Soil treatment at planting 3-12 oz/A Foliar or soil treatment in season 2-18 oz/cwt of seed Seed treatment	0	1 or when spray has dried	?	Label recommends using a spreader sticker for foliar applications.

Table 12.10 Pesticides Labeled for Management of White Mold					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Banded	-	1	?	
Contans WG *(Coniothyrium minitans)*	1-4lbs/A Soil treatment	-	4	1	Effective in 1/1 trial against sclerotia in the soil. Apply Contans to Sclerotinia infested ground immediately following harvest at 1 lb/A and incorporate the debris into the soil and/or apply at 2 lb/A to a planted crop right after planting followed by shallow incorporation (or irrigate) to about a 1 to 2 inch depth. Do not turn the soil after application of Contans to avoid bringing untreated soil that contains viable sclerotia near the surface. Since the active ingredient is a living organism, keeping the product in the refrigerator or freezer enhances storage life.
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.25-3 lbs/A Soil and foliar treatment	0	4	?	Apply at or immediately following planting (but before plant emergence) as a banded seedline treatment 4 to 6 inches wide. Make second application at thinning or cultivation in sufficient water and multiple nozzles to ensure thorough coverage of lower leaves and surrounding soil surface. Incorporation with light irrigation after application may improve disease control. Repeat at 10-14 day intervals if conditions promoting disease persist.
Double Nickel LC ***(****Bacillus amyloliquefaciens str. D747)*	0.5-6 qts/A Foliar treatment	0	4	?	
Optiva *(Bacillus subtilis str. QDT 713)*	14-24 oz/A Foliar treatment	0	4	?	For suppression. Begin application soon after emergence or transplant and when conditions are conducive to disease development. Repeat on a 7-10 day interval or as needed.
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-4 qt/A Foliar treatment	0	4	?	
Serenade ASO (*Bacillus subutilis*)	2-6 qts/A Foliar treatment	0	4	?	
Serenade MAX *(Bacillus subtilis)*	1-3 lb/A Foliar treatment	0	4	?	
Serenade Optimum *(Bacillus subtilis)*	14-20 oz/A Foliar treatment	0	4	?	
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Trilogy *(hydrophobic extract of neem oil)*	0.5-1% in 25-100 gal of water/A	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/A/application.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.11 Potato Common Scab, *Streptomyces scabies* and *S. acidiscabies*

Time for concern: Flower to end of season. Thought to be more prevalent during dry weather.

Key characteristics: Both species of Streptomyces cause similar symptoms that range from superficial russeting to deep pitting. Bacteria survive in the soil, in cull potatoes left in the field and on infected seed pieces in storage. Disease does not progress in storage but the pathogen infects newly planted tubers through the lenticels or through wounds. The severity of common scab is significantly reduced when soil pH is maintained below 5.2. See Cornell fact sheet (Reference 72).

Relative risk: Most common on soils with pH 5.5-7.5; usually does not reduce yields but cosmetic damage can significantly affect marketability, especially in tablestock potatoes.

Management Option	Recommendation for Common Scab
Scouting/thresholds	No thresholds are available. Look for and keep a record of disease incidence in late August and at harvest.
Site selection	Fields with a history of scab should be avoided. Light-textured soils favor scab infection. Maintaining pH levels below 5.2 will prevent common scab, although this practice can make nutrient management and crop rotations difficult and may limit crop diversity. Although severe scab occurs at high soil pH, Streptomyces acidiscabies can occur in soils with a pH below 5.2.
Cover crops	There is no evidence that planting and plowing under a legume cover crop prior to planting potatoes increases the incidence of potato scab. Biofumigant cover crops, such as brassicas, may suppress scab.
Crop rotation	Rotate with alfalfa, rye, soybeans and corn. Rotate with green manure crops such as rye, millet and oats. Do not rotate with common scab hosts such as spinach, turnip, parsnip, radish, beet, and carrot.
Resistant varieties	Planting resistant or tolerant varieties in fields where scab has been a problem is useful, but not sufficient to prevent scab under high disease pressure. Superior is the standard for resistance in the Northeast. Other very resistant, tolerant, resistant or moderately resistant varieties include Andover, Atlantic, Carola, Chieftain, Eva, Genesee, Keuka Gold, Lehigh, Reba, Red Norland, Salem, Yukon Gold.
Seed selection	Avoid planting scab-infested seed.
Irrigation	Maintain moisture during the six weeks following tuberization.
Organic matter management	Warnings against the use of manure and legume green manures that appear in guidelines for conventional potato production do not seem to apply in organic production, perhaps due to the differences in microbial communities and the way organically and conventionally managed soils assimilate new additions of organic matter. Manure from cows fed infected tubers can spread the disease because common scab bacteria can survive an animal's digestive track.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.11 Pesticides Labeled for Management of Common Scab

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal water Soil drench) 1-4 qt/A In-furrow	0	4	?	

OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Trilogy *(hydrophobic extract of neem oil)*	0.5-1% in 25-100 gal of water/A	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/acre/application.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.12 Bacterial Ring Rot, *Clavibacter michiganensis* subsp. *sepedonicus*

Time for concern: Seed purchase, planting, throughout season, and at harvest.

Key characteristics: When infected tubers are cut crosswise, a creamy yellow to brown breakdown of the vascular ring is observed. In severe infections, squeezing the infected tuber causes a cream-colored, cheesy exudate to ooze from the vascular ring. Secondary organisms attack infected tubers in storage and may cause skin cracks and a reddish brown discoloration. Symptoms are not always dramatic but laboratory tests should be done if presence of this bacterium is suspected. See Cornell fact sheet (Reference 55) and Ohio State fact sheet (Reference 75) for photos and more information.

Relative risk: Rarely seen in New York; serious damage when present because it can spread rapidly and cause significant losses. There is zero tolerance for this bacterium in seed potatoes. Environmental conditions are not as important in disease development as clean seed and good sanitation practices.

Management Option	Recommendation for Bacterial Ring Rot
Scouting/thresholds	Record the occurrence and severity of bacterial ring rot. No thresholds have been established for organic production.
Resistant varieties	No resistant varieties are available.
Seed selection/treatment	This is a seed borne disease, therefore using phytosanitary certified seed is key to preventing outbreaks (see Section 7.1: Seed sources). Serious crop losses can result if infected seed is used because the pathogen is readily spread during seed cutting and planting operations.
Planting	Disinfect equipment and containers between seed lots and periodically during planting operations. See Table 10.3.1: Equipment and Storage Facility Disinfectants. Even healthy seed can be infected by contaminated equipment.
Sanitation	All tuber handling equipment and storage areas must be disinfected if this disease occurs. See Table 10.3.1: Equipment and Storage Facility Disinfectants.
Crop rotation, site selection	These are not currently viable management options.

12.13 Pink Rot, *Phytophthora erythroseptica*

Time for concern: Growing season through marketing. Disease development is favored by cool weather and excessive soil moisture. Infection occurs early in the season; symptoms appear in late August.

Key characteristics: External symptoms on tubers appear as decay around the stem end or eyes and lenticels. The infected area turns purple to dark brown with a black band. When cut, the infected tissue turns pink in a matter of minutes, then darkens to brown and finally to black. This soil borne fungus is common in many soils but causes more damage in areas that stay wet. See Cornell fact sheet (Reference 55), and update (Reference 76), Michigan fact sheet (Reference 77) and Idaho management options (Reference 78).

Relative risk: Pink rot can be frequent and serious in low, wet areas.

Management Option	Recommendation for Pink Rot
Scouting/thresholds	Thresholds have not been established for organic production. Decay originates at stem base and progresses upward; begin looking in late August. Keep track of fields with a history of pink rot.
Crop rotation	Use 4 year crop rotations with non-host plants including legumes, field corn, sweet corn, and onion. The pathogen has been recovered from the roots of small grains.
Site selection	This disease is favored by cool weather and wet soils. Avoid planting in poorly drained areas.
Resistant varieties	No resistant varieties are available. Varieties that appear to be moderately resistant (based upon tuber inoculation tests) include Andover, Atlantic, Keuka Gold, Marcy, Norwis, Pike, Snowden, and Superior. Varieties that are moderately susceptible or susceptible include Allegany, Chieftain, Eva, Lehigh, Norland, Reba, and Yukon Gold. See Table 6.1.2.
Seed selection/treatment	Plant phytosanitary certified seed (See Section 7.1: Seed sources).
Irrigation	Avoid over-irrigation and ponding of water in the field.
Weed management	Nightshade and kochia host pink rot.
Harvest	Harvest when tuber pulp temperatures are lower than 65°. Avoid wounding during harvest.
Postharvest	This pathogen will spread in storage if tubers are not kept dry. If pink rot is found in storage, make a note of field where that crop was grown.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.13 Pesticides Labeled for Management of Pink Rot

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	1-12 oz/ A Soil treatment at planting 3-12 oz/A Soil treatment 2-18 oz/acre of seed Seed treatment	0	1 or when spray has dried	?	
Actinovate STP (Streptomyces lydicus)	4–32.0 oz/ cwt seed Seed treatment	-	1 or when spray has dried	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A Banded	-	1	?	

Table 12.13 Pesticides Labeled for Management of Pink Rot					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are present.
Regalia Biofungicide *(Reyoutria sachalinensis)*	1-3 qt/100 gal water Soil drench 1-4 qt/A In-furrow	0	4	?	
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-1.5 lb/20 gal water Seed dip 0.03-3.0 lbs/cwt (seed piece dust) 16-32 oz/A In-furrow	0	4	?	Do not apply when above-ground harvestable food commodities are present.
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qt/A Soil drench or in furrow	0	4	?	
Zonix *(Rhamnolipid Biosurfactant)*	0.5-0.8 oz/gal water Soil drench or in furrow	-	4	?	
Other					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row Soil treatment prior to seeding/transplanting. 25 fl oz/200 gal water/1000 ft^2 soil Soil treatment with established plants.	Up to day of harvest	0	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2-effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.14 Powdery Scab, *Spongospora subterranean*

Time for concern: Growing season through marketing. Infection favored by high soil moisture and low soil temperature (58-68°F).

Key characteristics: Lesions are similar to common scab lesions, but are usually smaller and more uniform in size. Lesions are first visible as purple spots on the tuber surface then as cankers without spore masses. Mature spore masses appear as raised olive green to brown areas inside the canker and have a powdery texture. Small root galls also develop. This protozoan survives on seed and in soil and can vector potato Mop

Top virus. See Cornell fact sheet (Reference 55) and University of Maine life cycle (Reference 79)

Relative risk: This is a less critical disease for potatoes in New York.

Management Option	Recommendation for Powdery Scab
Scouting/thresholds	Record the occurrence and severity of powdery scab. Thresholds have not been established for organic production
Site selection	Avoid planting in low spots with poor drainage and wet soils. Powdery scab can occur over a wider pH range than common scab.
Resistant varieties	No resistant varieties are available. Red, white and yellow skinned varieties are more susceptible.
Crop rotation	Select a field with no history of powdery scab and grow potatoes only every 4th or 5th year. Avoid pepper, tomato and solanaceous weeds.
Seed selection/treatment	Plant phytosanitary certified seed (See Section 7.1: Seed sources).
Postharvest and sanitation	These are not currently viable management options.
Notes	Zinc foliar nutrients can reduce disease incidence.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 12.14 Pesticides Labeled for Management of Powdery Scab

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
Trilogy *(hydrophobic extract of neem oil)*	0.5-1% in 25-100 gal of water/A Foliar treatment	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/A/application.
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water(initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal water (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.15 Leak, *Pythium* spp.

Time for concern: Infection usually occurs at harvest, especially when internal pulp temperatures are above 65˚F

Key characteristics: This soil borne fungus infects potato tubers through wounds at harvest. External symptoms consist of gray to brown lesions with water-soaked appearance around wounds. Tubers become rubbery or spongy and exude a liquid when squeezed. If advanced, then secondary bacteria are already decaying tissue and "shell rot" results. See Cornell fact sheet (Reference 55) and update (Reference 76).

Relative risk: Annual occurrence and especially serious if tubers are dug when soil temperatures are high. Avoid digging from soils that are waterlogged.

Management Option	Recommendation for Pythium Leak
Scouting/thresholds	If fields have been flooded, scout for infection. Thresholds have not been established for organic production
Site selection	Select fields with low levels of this pathogen, as determined by pre-plant soil sampling.
Resistant varieties	Snowden and Marcy show some tolerance.
Crop rotation	Rotate out of potatoes at least 4 years.
Seed selection/treatment	Plant phytosanitary certified seed. See 7.1: Seed sources.
Harvest	Avoid harvesting immature tubers during hot or wet weather. Avoid wounding tubers during harvest since this is the only means of entry for this Oomycete.
Postharvest	Keep storage temperature low (40° to 45°F) if the disease is detected.

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Table 12.15 Pesticides Labeled for Management of Pythium Leak

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Actinovate AG (*Streptomyces lydicus WYEC 108*)	1-12 oz/ A Soil treatment at planting 3-12 oz/A Soil treatment 2-18 oz/acre of seed Seed treatment	0	1 or when spray has dried	?	
Actinovate STP *(Streptomyces lydicus)*	4–32.0 oz/ cwt seed Seed treatment	-	1 or when spray has dried	?	
BIO-TAM (*Trichoderma asperellum, Trichoderma gamsii*)	1.5-3 oz/1000 row ft In furrow 2.5-3 lbs/A banded	-	1	?	
Double Nickel 55 *(Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A Soil treatment	0	4	?	
Double Nickel LC *(Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pints/A Soil treatment	0	4	?	
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water Soil drench	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are available.

Table 12.15 Pesticides Labeled for Management of Pythium Leak

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
Regalia Biofungicide *(Reynoutria sachalinensis)*	1-3 qt/100 gal water Soil drench 1-4 qt/A In-furrow	0	4	?	
RootShield Granules *(Trichoderma harzianum Rifai strain T-22)*	5-12 lbs/ A In furrow	-	0	?	
RootShield WP (*Trichoderma harzianum str. T-22 (KRL-AG2)*)	0.3-3oz/cwt seed Seed treatment 16 – 32 oz/A In-furrow	-	Until spray has dried	?	For use in planter box only.
RootShield PLUS+ WP*(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.03-3 lb/cwt seed, Pre-plant dust 16-32 oz/A, In-furrow spray	0	4	?	
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qts/A Soil drench or in furrow	0	4	?	Used as a soil drench or in furrow application.
SoilGard (*Gliocladium virens str.GL-21*)	2 – 10 lbs/A Band drench in-furrow	0	Until spray has dried	?	Apply in 50 – 100 gallons of water
Zonix *(Rhamnolipid Biosurfactant)*	0.5-0.8 oz/gal water Soil drench or in furrow	-	4	?	
OTHER					
PERpose Plus *(hydrogen peroxide/dioxide)*	1 fl oz/gal water (initial/curative) Foliar treatment; soil drench at seeding, planting and periodic 0.25-0.33 fl oz/gal (weekly/preventative) Foliar treatment	-	Until dry	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
TerraClean 5.0 *(hydrogen dioxide, peroxyacetic acid)*	128 fl oz/100 gal water; spray 25-100 gal solution /acre row 25 fl oz/200 gal water/1000 ft^2 soil	Up to day of harvest	0	?	Soil treatment prior to seeding/transplanting. Soil treatment with established plants.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2-effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

12.16 Silver Scurf, *Helminthosporium solani*

Time for concern: At planting, through growing season, post harvest and storage. Warm, wet soil favors sporulation and disease spread in the field. Post harvest handling and first weeks of storage are the primary times of infection and spread of silver scurf. Warm pulp temperatures and high relative humidity greatly favor spread of silver scurf in storage

Key characteristics: This seed and soil borne fungus infects only the skin of the potato. Symptoms appear at the stolon end as small, pale, brown spots. Severe browning of the surface layers of tubers may occur, followed by sloughing-off of the outer layers of the periderm. Lesions are circular. The silvery appearance of older lesions is most obvious when the tubers are wet. See the Pacific Northwest fact sheet(Reference 81), Cornell fact sheet(Reference 82) and interactive silver scurf potato photo (Reference 66).

Relative risk: This disease occurs annually and is especially noticeable on red, blue and purple-skinned varieties.

Management Option	Recommendation for Silver Scurf
Scouting/thresholds	Lesions may be difficult to detect at harvest, but applying moisture to the tuber surface reveals a silvery sheen. Tubers often develop symptoms in storage along with extensive sporulation.
Resistant varieties	No resistant varieties are available, but thin-skinned varieties are more susceptible and blemishes on red and purple-skinned varieties are very noticeable.
Seed selection/treatment	Infected seed pieces are the primary source of inoculum. Plant phytosanitary certified seed (see Section 7.1: *Seed sources*). Seed can be tested for presence of silver scurf.
Harvest	Harvest tubers as soon as they are mature. Vine killing 2-3 weeks before harvest showed less silver scurf than when tubers were harvested green.
Postharvest	Disinfect storages to kill spores that remain from the previous years' crop. High relative humidity (90-95%) and warm temperatures (47-56˚F) favor the development and spread of silver scurf in storage. Lowering the temperature to 39-45˚F and the relative humidity to 85-90% as quickly as possible in the first month of storage can delay sporulation. Monitor storage conditions to eliminate free moisture on tuber surfaces. For more information on storage conditions, see the Pacific Northwest Extension fact sheet (Reference 81)
Crop rotation	Soil-borne inoculum has been implicated in the seasonal occurrence of silver scurf. Maintain minimum of 2 year rotation of potatoes.
Sanitation	Clean and disinfect storage facilities (see 10.3.1: Equipment and Storage Facility Disinfectants).

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Table 12.16 Pesticides Labeled for Postharvest Treatment of Silver Scurf

CLASS OF COMPOUNDS Product Name (active ingredient)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Prestop Biofungicide *(Gliocladium catenulatum str. J1446)*	Dip or spray bulbs and tubers with a 0.75% suspension before storage.	-	0	?	
BOTANICAL					
Certified organic clove oil[1]	67 ppm initial, then 23 ppm/ 1 ton potatoes	-	-	1	25(b) pesticide. Effective in 1/1 trial. Postharvest application. Thermal aerosol applications; lower concentration was repeated 7 times.
Decco Aerosol 100 For Treatment of Potato in Storage *(clove oil)*	1 gal/900 cwt potatoes	0	0	1	25(b) pesticide. Effective in 1/1 trial. Designed for use through Forced Air Distribution System. Usually performed by lisenced applicators.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

1 Check with your certifier before use. For potatoes sold as a food crop, non-organically produced clove oil is not on the approved products list for post harvest use; therefore certified organic clove oil must be used. For post harvest use on potatoes sold as seed, clove oil must be 100% pure, but does not need to be certified organic. (National Organic Program section 205.606) (Reference 44).

12.17 Viruses of Potatoes

Time for Concern: Throughout the growing season and into storage

Key Characteristics: Virus infections can cause distorted growth, stunting, distortions in leaf coloration, yield reductions, external and internal tuber necrosis and small misshapen tubers. See Cornell fact sheet(Reference 84) and updated fact sheet (Reference 85B).

Relative risk: The PVY group is now considered one of the most prevalent and important viruses in potatoes.

Management Option	Recommendation for Viruses
Seed selection/treatment	The major method for controlling viruses in potatoes is through the production of disease free seed potatoes. This is controlled through the New York Foundation and Certified Seed programs. See the New York State Seed Directory Maine Seed Directory and the Colorado Seed Directory. (References 32-34)
Site selection	Avoid planting fields immediately downwind of any barrier. Hedgerows, wood lots, or hilly terrain reduce wind velocity and increase the number of dispersing aphids falling into fields.
Sanitation	Eliminate weeds in and around fields that can serve as the primary inoculum source early in the season. Cull symptomatic plants from the field as soon as they are discovered to reduce transmission of viruses.
Compounds	The focus for virus control is mitigating the transmission and spread of viruses by the aphid vectors. It can take less than a minute of probing on top leaf surfaces for aphids to acquire or inoculate potato plants with a virus. Repeated foliar applications of Stylet oil impede virus transmission by blocking the virus from entering or exiting the plant through the aphid's mouthparts.

Table 12.17.1 Virus Diseases of Potatoes.

Disease/Symptoms	Spread by	Management options	Resistant Varieties	Notes
Major Potato Viruses				
Potato Leaf Roll Virus (PLRV) Primary infection: upper leaves pale, upright, rolled; lower leaves may be asymptomatic. Secondary infection: lower leaves severely rolled and general plant stunting and chlorosis. Net necrosis on tubers in some varieties. See Cornell photos of primary secondary and tuber infections (Reference 85) and factsheet (Reference 85B).	Aphids, tuber seedpieces, volunteer potatoes and some weed hosts	Plant phytosanitary certified seed; use stylet oil to limit virus transmission	Resistant: Atlantic Moderately resistant: Chieftain and Norland	One of the three most important viruses affecting potatoes.
Potato Virus Y (PVY) Symptoms vary, depending on strains and interaction with other viruses, from rugose mosaic, general mosaic, and veinal necrosis to severe necrosis. The common strain =	Aphids, tuber seedpiece, volunteer potato plants, weed hosts.	Plant phytosanitary certified seed; use stylet oil to limit virus transmission	Some varieties are hypersensitive and display field resistance. Some resistance or tolerance: Eva, Dk Red Norland, Belrus, HiLite Russet, Kennebec,	The most prevalent virus infecting potato. Can interact with PVA and PVX to create greater yield losses.

Table 12.17.1 Virus Diseases of Potatoes.

Disease/Symptoms	Spread by	Management options	Resistant Varieties	Notes
PVY^{O}. The tuber necrotic strain = PVY^{NTN}. See Cornell photo(Reference 85B).			Monona, Norwis and Sebago. (Reference 85C). Yukon Gold is very susceptible to PVY^{NTN}.	
Potato Virus X (PVX) Plants can show no symptoms and symptoms from an interaction with PVA and PVY. See fact sheet (Reference 85B).	Tuber seedpiece and mechanical activity. Tobacco, pepper and tomato also host this virus.	Plant high quality phytosanitary certified seed.	Some varieties with resistance or tolerance are HiLite Russet, Atlantic, Norwis, and Sebago (Reference 85C).	A widely distributed virus. Often interacts with PVA and PVY, making symptoms difficult to discern.
Minor Potato Viruses				
Potato Virus A (PVA) Symptoms range from mild mosaic to mixed symptoms when interact with other viruses.	Aphids, tuber seedpiece, volunteer potato plants, some weed hosts	Plant high quality phytosanitary certified seed, use stylet oil to limit virus transmission; plant resistant varieties.	Katahdin, Kennebec, Sebago reported to show field resistance.	
Potato Viruses S and M (PVS and PVM) See fact sheet (Reference 85B).	Tuber seedpiece and aphids			These viruses may be most important when present with other viruses.
Alfalfa Mosaic Virus (AMV) Produces characteristic calico symptoms. See Cornell photo (Reference 85) and fact sheet (Reference 85B).	Many aphid species, legume crops and tuber seedpieces	Concern when adjacent alfalfa or clover fields are cut and infective aphids fly over to potatoes.		Does not result in significant yield losses.
Potato Spindle Tuber Viroid (PSTV) Tubers are spindle shaped or oblong; plants appear stiff, with unusual upright growth pattern. See Cornell photo and plant symptoms (Reference 85) and factsheet (Reference 85B).	Tuber seedpiece, mechanically; also through pollen and true seed. Insects can transmit, but not as important.			Use certified seed. Viroid has not occurred in NYS for the past 15 years.
Potato Mop Top Virus See photo (Reference 85B)	Powdery Scab pathogen, *Spongospora subterranea*			The virus currently does not occur in NYS, although the fungal vector does.

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Table 12.17 Pesticides Labeled for Management of Viruses

CLASS OF COMPOUNDS Product Name (active ingredient)	Product Rate/A	PHI (days)	REI (hours)	Efficacy	Comments
OIL					
JMS Stylet Oil *(paraffinic oil)*	3 qt/100 gal water Foliar treatment	0	4	2	Only labeled for control of potato leafroll virus and potato virus Y. Thorough coverage of upper leaf surfaces is important. Spray weekly through harvest. Expect to work best on viruses that are transmitted by aphids in a persistent manner like potato leaf roll virus. Do not apply within 10-14 days of a sulfur application.
Organic JMS Stylet oil *(paraffinic oil)*	3 qt/100 gal water Foliar treatment	0	4	2	
PureSpray Green *(petroleum oil)*	0.75 gals/A in 50-100 gals water Foliar treatment	Up to day of harvest	4	?	

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

13. Nematode Management

13.1 Northern Root-Knot (*Meloidogyne hapla*) and Root-Lesion (*Pratylenchus spp.*)

Time for concern: Before and during planting. Long-term planning is required for sustainable management.

Key characteristics: The populations and damage of lesion nematodes has steadily increased in recent years, probably due to the increased use of grains as cover and rotational crops to improve soil quality and health. Potato serves as a good host for both nematodes and will tend to increase populations when planted in infested fields. Plants heavily infested with either nematode do not exhibit diagnostic above ground symptoms, but only general stunting and uneven growth. However, diagnostic symptoms are found on roots as galls and brown - black, narrow lesions caused by the root-knot and lesion nematodes, respectively. The presence of nematodes in roots or in soil around roots is the only definitive evidence of their involvement. See Cornell fact sheet (Reference 86).

Risk assessment: Both the root-knot nematode and the lesion nematode are widespread in New York soils and at high populations can cause significant yield losses for potatoes. Lesion nematode even at low soil population levels interacts with *Verticillium dahliae* to cause early dying disease.

Management Option	Recommendation for Root-Knot and Root-Lesion Nematodes
Scouting/thresholds	Record symptoms of damage and assay roots and soil for the presence and density of nematodes. Threshold level of root-knot nematode on potatoes in organic soil is between 4-8 eggs/cc soil. A density as low as 1 lesion nematode/cc soil has caused damage to potatoes. Use a soil bioassay with lettuce and/or soybean to assess soil root-knot and root-lesion nematode infestation levels, respectively. Or, submit the soil sample(s) for nematode analysis at a public or private nematology lab (Reference 87). See Section 4: Field Selection for more information as well as the following Cornell publications for instructions: Soil Sampling for Plant Parasitic Nematodes (Reference 88) Visual Assessment of Root-Knot Nematode Soil Infestation Levels Using a Lettuce Bioassay (Reference 89) A Soil Bioassay for the Visual Assessment of Soil Infestations of Lesion Nematode (Reference 90).

Management Option	Recommendation for Root-Knot and Root-Lesion Nematodes
Crop rotation	Both nematodes have a wide host range, thus it is difficult to design a practical, economic, and effective crop rotation. Grain crops such as wheat, rye, oats, barley, corn, and sudangrass are not hosts for the root-knot nematode and therefore effective at reducing the nematode population. However, onion, carrot, lettuce, celery, soybeans, clover, alfalfa, and beans are good hosts to the root-knot nematode. All grain crops are good hosts to lesion nematode, except a number of cultivars of ryegrass and forge pearl millet. In addition, most cultivars of clovers, soybean, alfalfa, vetch and beans are also good hosts to lesion nematode. If both root-lesion and root-knot nematodes are present in the same field then rotation with a grain crop may increase the root-lesion nematode population to a damaging level for the next crop. In addition to grain crops, root-lesion nematode has over 400 hosts including many vegetables that are planted in rotation with potatoes thus making it difficult to manage root-lesion nematode strictly using a crop rotation. Depending on the size of the infested site, marigold varieties such as 'Polynema' and 'Nemagone' are very effective at reducing nematode populations, where marigold can be established successfully.
Site selection	Damage from these nematodes is especially high on sandy and organic soils as well as in poor health soils.
Resistant varieties	No resistant varieties are available.
Seed selection/treatment	Select vigorous, phytosanitary certified seed pieces (see Section 7.1: Seed sources). Nematodes can be seed born making infested seed less vigorous.
Cover crops	Grain crops are "non-hosts" to the northern root-knot nematode (Meloidogyne hapla), the only root-knot nematode species found outdoors in NY. Bio-fumigant cover crops can be effective against both the root-knot and lesion nematodes when incorporated as green manures (before drying and/or freezing). Soil incorporation of green manure of sudangrass before the first frost will reduce the population of both nematodes and their damage to potatoes. Certain white clover and flax lines have given similar results. Also, cruciferous crops including rapeseed, mustard, oil seed radish and others are effective in reducing populations of these nematodes when incorporated as green manures in warm soils.
Biofumigant cover crops	Grain cover crops such as winter rye and oat are poor or non-hosts for the root-knot nematode, thus they are effective at reducing the population. Cover crops with a biofumigant effect, used as green manure are best used for managing root-lesion nematode and will also reduce root-knot nematode populations. It is important to note that many biofumigant crops including Sudangrass, white mustard, and rapeseed are hosts to root-lesion nematode and will increase the population until they are incorporated into the soil as a green manure at which point their decomposition products are toxic to nematodes. Research has suggested that Sudangrass hybrid 'Trudan 8' can be used effectively as a biofumigant to reduce root-lesion nematode populations. Cover crops such as forage pearl millet 'CFPM 101' and 'Tifgrain 102', rapeseed 'Dwarf Essex', and ryegrass 'Pennant' are poor hosts, and thus will limit the build-up or reduce root-lesion nematode populations when used as a "standard" cover crop.
Sanitation	Wash equipment after use in infested fields. Avoid moving soil from infested fields to uninfested fields via equipment and vehicles, etc. Also limit/avoid surface run-off from infested fields.
Weed Control	Many common weeds including lambsquarters, redroot pigweed, common purslane, common ragweed, common dandelion and wild mustard are hosts to root-lesion nematode; therefore effective weed management is also important.

At the time this guide was produced, the following materials were labeled in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. Those pesticides meeting requirements in EPA Ruling 40 CFR Part 152.25(b) (also known as 25(b) pesticides) do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS website) http://pims.psur.cornell.edu/ (Reference 3). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 13 Pesticides Labeled for Management of Nematodes

CLASS OF COMPOUNDS Product Name (active ingredient)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
MeloCon WG Biological Nematicide (*Paecilomyces lilacinus str. 251*)	6-9 lbs/A	-	4	?	Pre-plant or drench at transplant
Molt-X *(azadirachtin)*	15 oz/A	0	4	?	Apply in sufficient amount of water to penetrate in the soil to a depth of 12 inches. Repeat applications every 3 or 4 weeks or as needed.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

14. Nonpathogenic Disorders

Environmental factors can cause symptoms that appear to be diseases but are actually not caused by a pathogen or insect. Table 14.1.1 provides a list of disorders that may be confused with diseases.

Table 14.1.1 Nonpathogenic disorders.

Disorder	Management Option	Recommendation
Air pollution	Variety selection.	Andover and Norland are particularly sensitive varieties.
Hollow heart	Variety selection. Maintain uniform growing conditions.	Varieties differ in severity. Avoid growing oversized tubers. Utilize appropriate plant spacing. Irrigate and fertilize for specific variety requirements.
Internal necrosis	Variety selection. Minimize heat stress.	Varieties differ in susceptibility. Irrigation reduces soil temperatures and increases calcium uptake.
Blackspot	Avoid bruising tubers. Maintain tuber turgor.	Minimize impact events during harvesting, transporting, grading, and handling. Store in high humidity and warm before handling operations.
Secondary tubers	Avoid old seed.	Purchase good quality seed and keep in cold storage.
Greening	Avoid tuber exposure to light.	Keep tubers well covered with soil in the field and store them in the dark after harvest.
Growth cracks	Maintain even soil moisture.	Maintain even soil moisture, especially during rapid tuber growth stage. See Section 9: *Moisture Management*
Knobs	Maintain even soil moisture and fertility.	See Section 9: *Moisture Management*. Maintain uniform soil fertility conditions.
Weed damage to tubers (Quack grass and Canada thistle grow through tubers)	Weed management.	Have a program to reduce perennial weeds in fields.
Secondary tubers	Avoid old seed.	Purchase good quality seed and keep in cold storage.

15. INSECT MANAGEMENT

Effective insect management relies on accurate identification of pests and beneficial insects, an understanding of their biology and life cycle, knowledge of economically important levels of pest damage, a familiarity with allowable control practices, and their effectiveness, in other words, Integrated Pest Management (IPM).

Regular scouting and accurate pest identification are essential for effective insect management. Thresholds used for conventional production may not be useful for organic systems because of the typically lower percent mortality and shorter residual of control products allowed for organic production. The use of pheromone traps or other monitoring or prediction techniques can provide an early warning for pest problems, and help effectively focus scouting efforts.

The contribution of crop rotation as an insect management strategy is highly dependent on the mobility of the pest. Crop rotation tends to make a greater impact on reducing pest populations if the pest has limited mobility. In cases where insects are highly mobile, leaving a greater distance between past and present plantings is better.

Natural Enemies

Learn to identify naturally occurring beneficial insects, and attract and conserve them in your fields by providing a wide variety of flowering plants in or near the field and avoiding broad-spectrum insecticides. In most cases, a variety of natural enemies are present in the field, each reducing pest populations. The additive effects of multiple species of natural enemies, attacking different host stages, is more likely to make an important contribution to reducing pest populations than an individual natural enemy species operating alone. Natural enemies need a reason to be present in the field, either a substantial pest population, alternative hosts, or a source of pollen or nectar, and may not respond to pest buildup quickly enough to keep populations below damaging levels. Releasing insectary-reared beneficial organisms into the crop early in the pest outbreak may help control some pests but sometimes these biocontrol agents simply leave the area. For more information, see Cornell's Natural Enemies of Vegetable Insect Pests (Reference 94), and Biological Control: A Guide to Natural Enemies in North America (Reference 95).

Regulatory

Organic farms must comply with all regulations regarding pesticide applications. See Section 11 for details. **ALWAYS check with your** organic **farm certifier when planning pesticide applications.**

Efficacy

In general, insecticides allowed for organic production may kill a smaller percentage of the pest population, could have a shorter residual and may be more quickly broken down in the environment than conventional insecticides. Agricultural pesticide manufacturers are not required to submit efficacy data to the EPA as part of the registration process. Listing a pest on the pesticide label does not guarantee the effectiveness of a pesticide. See Section 11.3 for more information.

Cultural control options available for potato insects include (see individual pests for specific recommendations):

- ❑ rotation to non-hosts (do not follow next season with potatoes, tomatoes or eggplant)
- ❑ hand removal
- ❑ propane flaming
- ❑ floating row cover
- ❑ yellow sticky traps and tape
- ❑ trench trap around perimeter
- ❑ trap tubers around perimeter
- ❑ vacuum - leaf blower operated for suction
- ❑ early or late planted trap rows of potatoes
- ❑ remove solanaceous weeds from areas bordering potato fields
- ❑ straw mulch

When conditions do warrant an insecticide application, proper choice of materials, proper timing, and excellent spray coverage are essential. Thresholds developed using conventional pesticides are often not useful when using organic approved products, which are often less effective than synthetic pesticides.

Resources:

Resource Guide for Organic Insect and Disease Management (Reference 2)

Natural Enemies of Vegetable Insect Pests (Reference 94)

Biological Control: A Guide to Natural Enemies in North America (Reference 95)

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**COLORADO POTATO BEETLE**	**APHIDS**	**POTATO LEAF-HOPPER**	**FLEA BEETLES**	**CUTWORMS**	**EUROPEAN CORN BORER**	**WIREWORMS**	**SYMPHYLAN**	**SPIDER MITES**	**SLUGS & SNAILS**
BIOLOGICAL										
Biobit (*Bacillus thuringiensis subsp. kurstaki*, str. ABTS-351)					A, B					
Deliver (*Bacillus thuringiensis kurstaki*)					A, B	X				
Dipel DF (*Bacillus thuringiensis*)					A, B					
Entrust Naturalyte Insect Control(*spinosad*)	X					X				
Entrust SC (*spinosad*)	X					X				
Grandevo (*Chromobacterium subtsugae str. PRAA4-1*)		X	X			X				
Javelin WG (*Bacillus thuringiensis kurstaki*)					B	X				
Mycotrol O (*Beauveria bassiana*)	X	X	X	X		X				
PFR-97 20% WDG *(Isaria fumosorosea)*		X			X	X	X	X	X	
Seduce Insect Bait (*spinosad*)					X					
Xen Tari (*Bacillus thuringiensis*)					X					
BOTANICAL										
Aza-Direct (*azadirachtin*)	X	X	X	X	A,B	X	X		X	
AzaGuard (*azadirachtin*)	X	X	X	X	A, B	X	X		X	
AzaMax (*azadirachtin*)	X	X	X	X	A, B	X	X		X	
AzaSol (*azadirachtin*)	X	X		X	A, B	X	X			
Azatrol EC (*azadirachtin*)	X	X	X	X	A,B				X	
Azera (*azadirachtin and pyrethrins*)	X	X	X	X	X	X	X	X	X	
BioLink (*garlic juice*)	X	X	X	X	A, B	X	X		X	X
BioLink Insect & Bird Repellant (*garlic juice*)	X	X	X	X	A, B	X			X	X
Ecozin PLUS 1.2% ME (*azadirachtin*)	X	X	X	X	B	X				
Envirepel 20 *(garlic juice)*	X		X	X				X	X	X
Garlic Barrier (*garlic juice*)	X		X	X				X	X	X
Molt-X *(azadirachtin)*	X	X	X	X	A,B	X				
Neemazad 1% EC (*azadirachtin*)	X	X	X							
Neemix 4.5 (*azadirachtin*)	X	X	X	X	X					
Pyganic Crop Protection EC 1.4 II (*pyrethrins*)	X	X	X	X	A,B	X		X	X	
PyGanic Crop Protection EC 5.0 II (*pyrethrins*)	X	X	X	X	A,B	X			X	
Safer Brand #567 (*pyrethrin & soap*)	X	X	X	X	B	X			X	
Trilogy (*neem oil*)		X							X	
OIL										
BioRepel *(garlic oil)*		X	X							
Cedar Gard *(cedar oil)*	X		X	X	A,B	X				
Ecotec *(rosemary and peppermint oil)*		X	X						X	
Ecotec – G *(clove, cinnamon and thyme oils)*							X	X		
GC-Mite *(cottonseed, clove, and garlic oil)*		X							X	
Cinnerate *(cinnamon oil)*									X	
Glacial Spray Fluid (*mineral oil*)	X	X	X	X					X	

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**COLORADO POTATO BEETLE**	**APHIDS**	**POTATO LEAF-HOPPER**	**FLEA BEETLES**	**CUTWORMS**	**EUROPEAN CORN BORER**	**WIREWORMS**	**SYMPHYLAN**	**SPIDER MITES**	**SLUGS & SNAILS**
Golden Pest Spray Oil (*soybean oil*)	X	X	X	X					X	
Oleotrol-I (*soybean oil*)		X							X	
Organic JMS Stylet-Oil (*paraffinic oil*)			X						X	
Organocide 3-in-1 *(sesame oil)*		X							X	
PureSpray Green *(petroleum oil)*	X	X	X	X	A,B	X			X	
SuffOil-X (*petroleum oil*)		X							X	
TriTek *(petroleum oil)*		X							X	
IRON PHOSPHATE										
Bug-N-Sluggo® Insect, Slug and Snail Bait *(iron phosphate and spinosad)*					X					X
Sluggo-AG (*iron phosphate)*										X
Sluggo Slug & Snail Bait (*iron phosphate*)										X
SOAP										
M-Pede (*potassium salts of fatty acids*)		X	X						X	
SULFUR										
Kumulus DF (*sulfur*)									X	
Micro Sulf *(sulfur)*									X	
Microthiol Disperss *(sulfur)*									X	
Thiolux *(sulfur)*									X	
OTHER										
Nuke Em *(citric acid)*		X							X	
Sil-Matrix (*potassium silicate*)		X							X	
Surround WP (*kaolin*)			X	X						

[1] Sulfur can be phytotoxic at temperatures above 90º therefore read and follow the label carefully. A=labeled for subterranean and/or surface cutworm, B=labeled for climbing cutworm

15.1 Colorado Potato Beetle (CPB), *Leptinotarsa decemlineata*

Time for concern: Late April through vine-kill

Key characteristics: The adults have alternate black and yellowish orange stripes that run lengthwise on the wing covers, five of each color on each wing. The beetles are 3/8 inch long by 1/4 inch wide and convex in shape. The eggs are yellowish orange and deposited in masses that contain between 20 and 40 eggs. Larvae are small, humpbacked, and red with two rows of black spots on each side of their body. See Cornell fact sheet (Reference 96), life cycle photos(Reference 97) and an older but informative fact sheet (Reference 98). Adults and larvae feed on leaves and stems. Adults hibernate in the ground in and near potato fields, emerge in the spring and disperse to solanaceous host plants where they feed and give rise to 1 or 2 larval generations in upstate New York.(Reference 93).

Risk assessment: Colorado potato beetle is a serious pest of potatoes. If left uncontrolled, it can devastate yields with reductions up to 90%. Most varieties can tolerate moderate defoliation (up to 30%) in the early season without affecting yield. Next to leafhopper, this is the most serious insect pest of potatoes.

Management Option	Recommendation for Colorado Potato Beetle
Scouting/thresholds	Take a representative sample of the field weekly. Sample five vines at five sites. For fields of an acre or less, this constitutes your entire sample. Compute means and compare to thresholds below. For larger fields, count the number of adults, small larvae (less than 1/4 inch), and egg masses. Count egg masses with less than ten eggs as half an egg mass. If the number of CPB in a particular life stage falls within the range given below or if the field is >30 acres, sample 25 more vines. The basic sample unit should be a plant "hill" until plants are 12 inches in height and a single main stem the remainder of the season.

Management Option	Recommendation for Colorado Potato Beetle

Life stage	Number of CPB counted on 25 vines		
	LOW	INTERMEDIATE	HIGH
	Stop	Sample 25	Stop
	Compute Mean	more vines	Compute Mean
Small larvae	<52	53-199	>200
Large larvae	<22	23-67	>68
Adults	<7	8-22	>23

If mean counts are lower than values given above, sample again next week. If any counts are higher than the values given above, sample 25 more plants and compute the means. Don't sample more than 50 vines per field. Report mean numbers of adults and larvae per 50 vines. If mean values exceed threshold values, apply insecticide. If thresholds are not reached but hot spots are found, flag hot spots and apply insecticide.

	Thresholds/50 vines
Egg masses	4 with at least 25% of the earliest deposited egg masses hatched or in the process of hatching
Small larvae	76
Large larvae	31

Resistance management

Given the phenomenal ability of the CPB to develop resistance to insecticides, a major goal in managing this pest is to delay the onset of resistance. Entrust Naturalyte Insect Control is very vulnerable to resistance development because it is so effective that it is tempting to overuse it. Do not rely exclusively on Entrust Naturalyte Insect Control for CPB control. Employ all possible cultural practices to minimize the number of insecticide sprays applied. Rotate with other insecticides.

Before July 15

Overwintered Adults (trap cropping and then flaming or vacuuming; floating row cover; trench trapping)

1st Larval Generation (Focus your Entrust Naturalyte Insect Control use on this important stage)

After July 15

Summer Adults (try to minimize the number of larvae surviving to adulthood and avoid treating this stage. Remember that potatoes can tolerate 10-15% damage without yield loss)

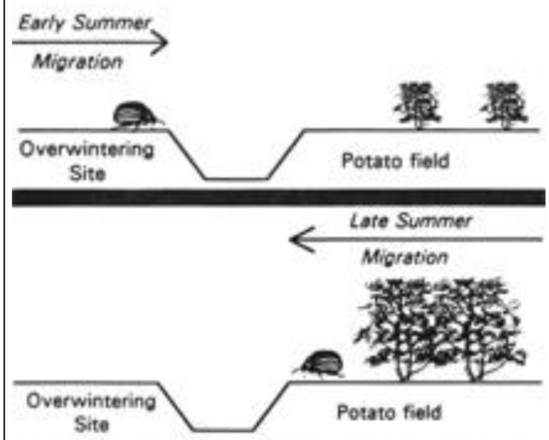
2nd Larval Generation (Do not apply Entrust Naturalyte Insect Control to both generations of larvae; an azadirachtin product may be a useful alternative. Late season applications of Mycotrol-O (Beauveria bassiana) may help reduce overwintering populations by causing mortality to pupae and adults in the soil.)

To minimize selection for resistance, only use insecticides when needed; use the minimum dosage necessary to provide control; rotate insecticides of different chemical classes and modes of action; create refuges untreated by insecticides where susceptible populations can survive to mate with resistant individuals and dilute the frequency of resistant genes in pest populations.

Natural enemies

Naturally-occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Biological Control: A Guide to Natural Enemies in North America (Reference 95) to identify natural enemies.

Management Option	Recommendation for Colorado Potato Beetle
Resistant varieties	Elba, Prince Hairy and King Harry are resistant to CPB's. Varieties that mature in 75-88 days and thus avoid peak CPB infestations include: Caribe, Norland, Redsen, Sunrise, Superior and Yukon Gold.
Crop rotation	One year rotation to non-host crops such as small grains or corn can result in greater than 90 percent reduction of early-season adult infestation. Other non-hosts to add in rotation include crucifers and forage crops. Avoid tomatoes, eggplants, and other species belonging to the solanaceae family. Rotation is most effective when large blocks are rotated on a farm or coordinated among adjacent farms. On diversified vegetable farms, rotate tomatoes, potatoes, and eggplant as a block. Minimize the presence of volunteer potatoes in rotational crops by avoiding fall plowing, leaving the tubers on the surface to freeze. Plant slow-emerging or late-season varieties to fields that did not have potatoes the previous year.
Site selection	Avoid planting potatoes near fields where late-season cultivars with high CPB populations were grown the previous year.
Planting	Plants that are strong and well established before CPB attack will better withstand feeding damage. Planting as early as possible and covering as shallowly as possible will give plants a head start. Growers in the most northern regions of New York avoid CPB by planting mid to late June; yields are somewhat reduced but they find the trade off worthwhile.
Flaming	Adult CPB's overwinter in hedgerows and wooded areas adjacent to potato fields. Flaming is most effective when used around the borders (the outside eight to 16 rows) of the field. However, in the case of widespread colonization by adults, flaming is more successful when used throughout the field. The most effective time to use a propane flamer is from plant emergence until the plants reach six inches in height. Best control is achieved on warm, sunny days with little wind when adults are actively feeding in the upper foliage. Flaming is ineffective when done in the early morning, late evening, or on cool, cloudy days when adults are in the lower portion of the plant or near the soil level. Burners should be operated eight to ten inches above the soil at four to six miles per hour. Plant injury from flaming is minimal and does not reduce yields. See Reference 99 for videotapes that detail flame weeding.
Vacuum/leaf blower	Adult beetles can be removed from trap crop using a retail leaf blower (many brands can be operated in reverse as vacuums). This practice may not be advisable when pathogens like powdery mildew and gray mold are present and might be spread by the vacuum.
Trap strips & trap tubers	Early season: Plant strips of a fast-emerging early variety along the edges of the field as early as weather and soil conditions will allow. Cover seed shallowly to promote rapid emergence. The trap crop should emerge before the main crop so trap plants are larger and able to withstand feeding and so sufficient foliage remains to keep the trap crop attractive. A flamer or vacuum can be used to remove the adults on the trap crop. Late season: Plant strips of late emerging, late maturing cultivar such as Elba or Allegany. Foliage of these varieties will remain green and attractive to dispersing adults much longer than those of shorter season cultivars. A flamer or vacuum can be used to remove adults on the trap crop. Cut tubers placed along the perimeter of a potato field prior to sprout emergence can also be effective in arresting and congregating adult potato beetles for control by flaming.

Management Option	Recommendation for Colorado Potato Beetle
Trench trap	 *Adapted from* Boiteau, G. et al. 1993. Plastic Trench Barrier for Protection of Potatoes From Walking Adult Colorado Potato Beetles. pp. 14-16. Entomology Program Research Summary, Fredericton Research Station. Agriculture Canada. Trench traps effectively control adult beetles when hibernation areas are known. Install plastic-lined trench traps next to hibernation sites or between adjacent fields at least one week before adults emerge. Adults dispersing by walking (50-75% of the overwintered population) are trapped in the trench and die of dehydration. Trenches should be one to two feet deep and six to 24 inches wide at the top. They can be U or V shaped with sidewalls sloping at angles between 65 and 90 degrees. Level the crown at the top of the trench and line the trench with mulching plastic. For a more detailed description, see video (Reference 99). Summer adults may likewise be trapped as they disperse from the potato fields to their overwintering sites.
Harvest	Scheduling vine killing/harvest as soon as the crop is mature eliminates the food source for the Colorado potato beetle and reduces the number and health of overwintering adults.
Postharvest	Flooding (which occurs naturally on many muck fields) can reduce overwintering populations.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.1 Pesticides Labeled for Management of Colorado Potato Beetle

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
FOLIAR AND SOIL APPLIED TREATMENTS					
BIOLOGICALS					
Entrust Naturalyte Insect Control (*spinosad*)	1-2 oz/A Foliar treatment	7	4	1	Spinosad based products effective in 14/14 trials. Very good control of all larval stages but no control of adults or eggs.
Entrust SC (*spinosad*)	3-10 fl oz/A Foliar treatment	7	4	1	Spinosad based products effective in 14/14 trials. Very good control of all larval stages but no control of adults or eggs.
Mycotrol O (*Beauveria bassiana*)	1/2 – 1 qt/A Foliar treatment	Up to day of harvest	4	2	Beauveria based products effective in 2/7 trials. For use against 1st and 2nd instar larvae. Ineffective against large larvae and adults. Nontoxic to predators and parasites. Does not provide immediate mortality. Foliage contact and coverage extremely important. UV sensitive. Most effective

Table 15.1 Pesticides Labeled for Management of Colorado Potato Beetle					
CLASS OF COMPOUNDS **Product Name** (***active ingredient***)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
					in moist environments.
BOTANICALS					
Azadirachtin					Azadirachtin based products effective in 3/3 trials. Consult label for application timing. Best control is achieved at the upper end of the use range. Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
Aza-Direct	1-2 pints/A Foliar treatment	0	4	1	
AzaGuard	8-16 fl oz/A Foliar treatment	0	4	1	
AzaMax	1.33 fl oz/1000 ft2 Foliar treatment	0	4	1	
AzaSol	6 oz/50 gal water/A Foliar treatment	-	4	1	
Azatrol EC	0.11-0.22 fl oz/1000 ft2 Foliar treatment	0	4	1	
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Foliar treatment	-	12	1	
Ecozin PLUS 1.2% ME	15-30 oz/A Foliar treatment	0	4	1	
Molt-X	8 oz/A Foliar treatment	0	4	1	For Molt-X, use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
Neemix 4.5	7-16 fl oz/A Foliar treatment	0	4	1	
Neemazad 1% EC	18 -72 fl oz/A Foliar treatment	-	4	1	Target nymphs and larvae.
pyrethrin					
Pyganic Crop Protection EC 1.4 II (*pyrethrins*)	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	1	Pyrethrum based products effective in 3/3 trials.
Pyganic Crop Protection EC 5.0 II (*pyrethrins*)	4.5-17 fl oz/A Foliar treatment	0	12	1	Pyrethrum based products effective in 3/3 trials. Target first instars. Foliage contact and coverage extremely important; UV sensitive.
SOAP					
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/galwater Foliar treatment	Until spray has dried	12	?	Applied at 1 gal mixed spray/700 ft^2 of plant surface area.
OILS					Plant and petroleum oil based products effective against beetles in 0/1 trial.
BioLink (*garlic juice*)	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide

Table 15.1 Pesticides Labeled for Management of Colorado Potato Beetle					
CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
Cedar Gard *(cedar oil)*	1 qt/A Foliar treatment	-	-	3	25(b) pesticide.
Garlic Barrier *(garlic juice)*	1gal/99 gal water; mix, spray at 10 gal mix/A Foliar treatment	-	4	?	25(b) pesticide
Glacial Spray Fluid *(mineral oil)*	0.75-1 gal/100 gal water Foliar treatment	Up to day of harvest	4	3	See label for specific application volumes. For beetle larvae only.
Golden Pest Spray Oil *(soybean oil)*	2 gal/A Foliar treatment	-	4	3	Only for use against larvae.
PureSpray Green *(petroleum oil)*	0.75-1.5 gals/A in 50-100 gals water Foliar treatment	Up to day of harvest	4	3	Labeled for beetle larvae.

. PHI = pre-harvest interval, REI = restricted entry interval.   - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.2 Aphids, primarily the green peach aphid, *Myzus persicae*; Potato Aphid, *Macrosiphum euphorbiae*; Melon Aphid, *Aphis gossypii*; Buckthorn Aphid, *Aphidula rhamni*; and Foxglove Aphid, *Aulacorthum solani*

Time for concern: June through vine-kill

Key characteristics: Adults of the potato infesting aphid species are approximately 1/25 to 2/25 inch in length and vary in color from yellow to black. They may be winged or wingless. In the fall, winged aphids are produced and mate. The eggs are black and less than 1/50 inch in length. See Cornell aphid fact sheet (Reference 101), melon aphid fact sheet (Reference 102) and aphid photos (Reference 103).

Relative Risk: Aphids are rarely a problem on organic farms due to the higher numbers of parasites and predators, but they can transmit viruses, which will affect yield of potatoes and other crops susceptible to viruses. Virus infection is more serious for growers who save their own seed.

Management Option	Recommendation for Aphids
Scouting/thresholds	Early detection of migrant aphids is extremely important to **seed growers** who must minimize spread of potato leafroll virus and other aphid-vectored virus diseases in their fields. Yellow sticky traps and tape are useful in determining initial arrival of winged aphids and their seasonal presence/absence. Plant damage from feeding by aphids is often subtle and seldom reflected, at least in the early stages, by obvious changes in plant growth, growth form, or foliage color. Large populations may be detected by the appearance of cast skins, sooty mold, or shiny honeydew accumulations on lower foliage and the soil. Put up either yellow sticky traps or water-pan traps. Traps should be examined twice a week and the number of winged aphids recorded and removed. A total catch of ten aphids per trap over a seven day period is an alert to the possible need for application of an insecticide. When the number of aphids per trap increases, examine one fully expanded leaf from each of five different plants in different rows at each of ten sites per field. Count all of the aphids. Apply insecticide when the following action threshold is reached.

Management Option	Recommendation for Aphids
	PLANT GROWTH STAGE — ACTION THRESHOLD Before tuber initiation — 100 aphids/50 leaves Tuber initiation[1] to 2 weeks before vine kill — 200 aphids/50 leaves Within 2 weeks of vine kill — 500 aphids/50 leaves In addition, seed potato growers may consider applying stylet oil to hinder virus transmission by aphids (see Section 12.17: Virus Diseases).
Site selection	Avoid planting fields immediately downwind of any barrier. Hedgerows, wood lots, or hilly terrain reduce wind velocity and increase the number of dispersing aphids falling into fields.
Resistant varieties	Although all currently available potato cultivars are susceptible to infection by the potato leaf roll virus (PLRV), many cultivars are resistant to the manifestation of virus infection (net necrosis) in tubers.
Seed selection/treatment	Plant phytosanitary certified seed.
Mulches	Aphids are repelled by ultra violet light. Reflective mulches have been effective in limiting virus transmission by winged migrant aphids.
Natural enemies	Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Guide to Natural Enemies (Reference 95) to identify natural enemies.
Yellow sticky traps and tape	Traps should be located away from tree lines and tall weeds where they might be obscured and should be at least 12 inches above the plant canopy. Mount traps vertically along the edges of the field by stapling to a wooden stake.
Water-pan traps	Traps should be located away from tree lines and tall weeds where they might be obscured and should be at least 12 inches above the plant canopy. Any watertight container holding a minimum of one gallon of water with a minimum diameter of twelve inches can be used. If metal containers are used, they must be painted a deep yellow. The trap must be equipped with an overflow for rainwater by cutting a circular hole one inch in diameter in the side of the pan about two inches below the rim. A small piece of window screen should be cemented over the hole to retain aphids when rainwater raises the level of water in the pan. Fill the pan with several inches of water, several drops of liquid dishwashing detergent, and one teaspoon of disinfectant (See Section 10.3: *Storage Facility Sanitation*)
Floating row covers	Don't use floating row covers on areas where emerging insects from last year will be trapped.
Vacuum/leaf blower	Aphids can be vacuumed from leaves using a leaf blower operated for suction. This practice may not be advisable when pathogens like powdery mildew and gray mold are present and might be spread by the vacuum.
Harvest	Vine kill and harvest the crop as early as possible to minimize vulnerability to late-season aphid colonization and virus infection.
Sanitation	Maintain effective management of weeds in and on the margins of fields. Eliminate volunteer plants and rogue diseased plants.
Note(s)	Aphid populations may decline rapidly during periods of heavy rainfall. Insecticides applied for leafhoppers may also suppress aphids.

[1]Tuber initiation and bulking coincides with the period following flowering for many cultivars

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.2 Pesticides Labeled for Management of Aphids

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICAL					
Grandevo (*Chromobacterium subtsugae str. PRAA4-1*)	2-3 lbs/A Foliar treatment	0	4	?	
Mycotrol O *(Beauveria bassiana)*	1/4 – 1 qt/A Foliar treatment	Up to day of harvest	4	2	Beauveria products effective in 2/7 trials. Foliage contact and coverage extremely important; UV sensitive. Most effective in moist environments.
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lbs/A Foliar treatment	-	4	?	Repeat at 3-10 day intervals as needed to maintain control.
BOTANICAL					
Azadirachtin	Azadirachtin based products effective on green peach aphid in 4/7 studies and on other aphids in 3/4 studies. Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage essential.				
Aza-Direct	1-2 pt/A Foliar treatment	0	4	1	
AzaGuard	10-16 fl oz/A Foliar treatment	0	4	1	Use AzaGuard with spray oil.
AzaMax	1.33 fl oz/1000 ft^2 Foliar treatment	0	4	1	
AzaSol	6 oz/50 gal water/A Foliar treatment	-	4	1	
Azatrol EC	0.24-0.96 fl oz/1000 ft^2 Foliar treatment	0	4	1	
Ecozin PLUS 1.2% ME	15-30 oz/A Foliar treatment	0	4	1	
Molt-X	10 oz/A Foliar treatment	0	4	1	For Molt-X, use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
Neemazad 1% EC	22.5-31.5 fl oz/A Foliar treatment	-	4	1	Suppression and adult feeding deterrence.
Neemix 4.5	5-7 fl oz/A Foliar treatment	0	4	1	
garlic					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
pyrethrin					
Pyganic Crop Protection EC 1.4$_{II}$ (*pyrethrins*)	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	2	Pyrethrum based products effective in 1/3 trials.
Pyganic Crop Protection EC 5.0$_{II}$ *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	2	Pyrethrum based products effective in 1/3 trials. Foliage contact and coverage essential; UV sensitive.

Table 15.2 Pesticides Labeled for Management of Aphids					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Apply at 1 gal mixed spray/700 ft^2 of plant surface area.
OIL					Oil based products effective in 2/5 trials.
BioRepel *(garlic oil)*	1 part BioRepel with 100 parts water Foliar treatment	-	-	2	25(b) pesticide
Ecotec *(rosemary and peppermint oil)*	1-4 pints/A Foliar treatment	0	4	?	25(b) pesticide
GC-Mite *(cottonseed, clove, and garlic oil)*	1gal/100 gal water; spray to cover surface Foliar treatment	-	-	2	25(b) pesticide
Glacial Spray Fluid (*mineral oil*)	0.75-1 gal/100 gal water Foliar treatment	Up to day of harvest	4	2	See label for specific application volumes.
Golden Pest Spray Oil (*soybean oil*)	2 gal/A Foliar treatment	-	4	2	
Oleotrol-I (*soybean oil*)	1 part Oleotrol-I with 300 parts water Foliar treatment	0	-	2	
Organocide 3-in-1 *(sesame oil)*	1-2 gal/100 gal water Foliar treatment	-	-	2	25(b) pesticide
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gal water Foliar treatment	Up to day of harvest	4	2	
SuffOil-X *(petroleum oil)*	1-2 gal/100 gal water Foliar treatment	Up to day of harvest	4	2	Do not mix with sulfur products.
Trilogy *(hydrophobic extract of neem oil)*	1-2% in 25-100 gal of water / A Foliar treatment	Up to day of harvest	4	?	Limited to a maximum of 2 gallons/A/application.
TriTek *(petroleum oil)*	1-2 gal/100 gal water Foliar treatment	Up to day of harvest	4	2	
SOAP					
M-Pede *(potassium salts of fatty acids)*	1 –2% volume to volume Foliar treatment	0	12	3 green peach aphids 1 other aphids	Soap based products effective in 0/9 trials on green peach aphid but effective in 6/8 trials on other aphids. Apply in sufficient volume to wet both upper and lower leaf surfaces. Foliage contact and coverage extremely important. For aphid control, M-Pede must be mixed with another labeled insecticide.
OTHER					
Azera *azadirachtin and pyrethrins*	1-3.5 pints/A Foliar treatment	-	12	1	

Table 15.2 Pesticides Labeled for Management of Aphids					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Nuke Em *(citric acid)*	1 fl oz/31 oz water to 2 fl oz/30 fl oz water Foliar treatment	0	-	?	
Sil-Matrix (*potassium silicate*)	0.5-1% solution Foliar treatment	0	4	?	Apply 20 gallons finished spray/A.

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.3 Potato Leafhopper, *Empoasca fabae*

Time for concern: Early June through August

Key characteristics: Adult is wedge-shaped, iridescent green in color, and 1/8 inch long. The body is widest at the head. Eggs are laid singly on the underside of leaves. Both adults and nymphs are very active, running forward, backward, or sideways. The potato leafhopper (PLH) feeds on plant sap in leaflets, petioles and stems causing a physiological response called "hopperburn." PLH damage can stunt potato plants, and kill seedlings. The first sign of hopperburn is whitening of the veins. These areas become flaccid and yellow in color, then desiccate, turn brown, and die. Leaf curling may occur. The entire process takes four to five days. See Alternative Management Techniques video (Reference 105), fact sheet (Reference 106) and life cycle and damage (Reference 107).

Relative Risk: Leafhoppers are a threat every growing season. Short of late blight, leafhoppers are the most serious pest of potato. Yield reductions on susceptible varieties can be up to 50% to 90% depending on how early in the season the damage occurs. Leafhoppers normally move into New York on air currents from the south and west resulting in more serious problems in Western NY.

Management Option	Recommendation for Potato Leafhopper
Scouting/thresholds **Scouting/thresholds**	Spring migrations of adult leafhoppers pose a risk over large areas and it is difficult to predict potential for damage without monitoring the pest population. Check for the presence of adult PLH's by using a sweep net or by placing yellow sticky traps near the field edges. If yellow sticky traps indicate the presence of adult leafhoppers in the area, sweep sampling should be initiated. At each of ten sites, make ten sweeps with the sweep net. Each sweep consists of a single 180 degree pass across the canopy, perpendicular to the row. The net should brush the top of the canopy but not injure the plants. Empty the net and count the number of adults. Nymphs are best sampled by visual examination of the undersides of leaves on the lower half of the plant. Threshold: treat when more than one adult is found per sweep or more than 15 nymphs are found on 50 leaves. Scout weekly.
Resistant varieties	Elba, and King Harry are resistant to the potato leafhopper. 'Green Mountain', some russets, 'Snowden', 'Ontario', and 'Katahdin are more tolerant. Early maturing cultivars like Superior and Norland, are unusually susceptible to yield reduction caused by leafhopper feeding.
Natural enemies	Although a variety of natural enemies of potato leafhopper have been reported, their impact on infestations is not well known. Use Reference 94 or Cornell's Guide to Natural Enemies (Reference 95) to identify natural enemies.
Cultural	High pressure water will dislodge nymphs. Increase pressure of spray mix to increase effectiveness of treatment.
Floating row cover	Row covers can be used to exclude leafhoppers early in the season. Don't use floating row covers on areas where overwintering insect pests such as adult CPB and flea beetles from last year will be trapped.

Management Option	Recommendation for Potato Leafhopper
Sticky traps and tape	Use yellow sticky traps placed near field edges to monitor leafhopper migration into field. Traps should be located away from tree lines and tall weeds where they might be obscured and should be at least 12 inches above the plant canopy. Mount traps vertically along the edges of the field by stapling to a wooden stake.
Vacuum/leaf blower	Leafhoppers can be vacuumed from leaves using a leaf blower set in reverse. This practice may not be advisable when pathogens like powdery mildew and gray mold are present and might be spread by the vacuum.
Site selection	Avoid planting fields immediately downwind of any barrier. Hedgerows, wood lots, or hilly terrain reduce wind velocity and increase the number of dispersing leafhoppers falling into fields. Potatoes grown near large acreages of alfalfa are particularly vulnerable because of the dispersal of adults from alfalfa following cutting.
Sanitation	If area around the potato field is mowed, mow frequently, or leafhopper populations will build up in weeds and mowing will send leafhoppers into potatoes.
Notes	Nymphs are very susceptible to starvation when dislodged from plants in spring and summer rainstorms.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.3 Pesticides Labeled for Management of Potato Leafhopper

CLASS OF COMPOUNDS Product Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Grandevo (*Chromobacterium subtsugae str. PRAA4-1*)	2-3 lbs/A Foliar treatment	0	4	?	
Mycotrol O *(Beauveria bassiana)*	1/4 – 1 qt/A Foliar treatment	Up to day of harvest	4	?	Foliage contact and coverage extremely important; UV sensitive, spray late in the day. Most effective in moist environments.
BOTANICALS					
azadirachtin					Azadirachtin based products effective in 1 recent trial. Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
Aza-Direct	1-2 pt/A Foliar treatment	0	4	1	
AzaGuard	10-16 fl oz/A Foliar treatment	0	4	1	
AzaMax	1.33 fl oz/1000 ft^2 Foliar treatment	0	4	1	
Azatrol EC	0.24-0.96 fl oz/1000 ft^2 Foliar treatment	0	4	1	
Ecozin PLUS 1.2% ME	15-30 oz/A Foliar treatment	0	4	1	

Table 15.3 Pesticides Labeled for Management of Potato Leafhopper					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Molt-X	10 oz/A Foliar treatment	0	4	1	For Molt-X, use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
Neemazad 1% EC	31.5-72 fl oz/A Foliar treatment	-	4	1	Target nymphs
Neemix 4.5	7-16 fl oz/A Foliar treatment	0	4	1	
other botanicals					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
Garlic Barrier *(garlic juice)*	1gal/99 gal water mix, spray at 10 gal mix/A Foliar treatment	-	4	?	25(b) pesticide
Pyganic Crop Protection EC 1.4II (*pyrethrins*)	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	1	Pyrethrum based products effective in 1/1 trial.
Pyganic Crop Protection EC 5.0II *(pyrethrins)*	4.5-17 oz/A Foliar treatment	0	12	1	Pyrethrum based products effective in 1/1 trial. Reinfestation is likely so repeated applications at tight intervals might be necessary. Foliage and contact extremely important. UV sensitive.
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Applied at 1 gal mixed spray/700 ft^2 of plant surface area.
SOAP					
M-Pede *(potassium salts of fatty acids)*	1-2% volume to volume Foliar treatment	0	12	3	Soap products effective in 0/1 trial.
OILS					
BioRepel *(garlic oil)*	1 part BioRepel with 100 parts water Foliar treatment	-	-	?	25(b) pesticide
Cedar Gard *(cedar oil)*	1 qt/A Foliar treatment	-	-	?	25(b) pesticide.
Ecotec *(rosemary and peppermint oil)*	1-4 pints/A Foliar treatment	0	4	?	25(b) pesticide
Glacial Spray Fluid (*mineral oil*)	0.75-1 gal/100 gal water Foliar treatment	Up to day of harvest	4	?	See label for specific application volumes
Golden Pest Spray Oil (*soybean oil*)	2 gal/A Foliar treatment	-	4	?	

Table 15.3 Pesticides Labeled for Management of Potato Leafhopper					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
JMS Stylet Oil Organic JMS Stylet Oil (*paraffinic oil*)	3-6 qt/100 gal water Foliar treatment	0	4	?	Do not apply within 10-14 days of sulfur applications.
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gal water Foliar treatment	Up to day of harvest	4	?	
OTHER					
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Foliar treatment	-	12	1	
Surround WP (*kaolin*)	25 – 50 lbs/A Foliar treatment	Up to day of harvest	4	3	Effective in 0/3 trials. Suppression only. Apply every 7 -10 days, starting prior to infestation.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.4 Flea Beetles, *Epitrix cucumeris*, *Systena frontalis* & other species

Time for concern: May through August

Key characteristics: Shiny, black beetle, about 1/16 inch long, that jumps when disturbed and chews tiny holes in foliage. Larvae are slender white worms that usually feed on roots; second generation larvae sometimes feed on tubers producing pits and roughness. See Cornell fact sheet (Reference 108) and life cycle and damage (Reference 109).

Relative risk: Foliage feeding by adult flea beetles rarely causes yield reduction but high larval populations in the soil can lead to serious tuber defects.

Management Option	Recommendation for Flea Beetles
Scouting/thresholds	Use sticky traps to monitor for first seasonal appearance (or presence/absence) of adult flea beetles. Check for the presence of adult flea beetles by using a sweep net or by examining foliage. Begin treatment at threshold of 2 adults per sweep and/or 15 feeding holes per terminal leaf.
Resistant varieties	King Harry is resistant to flea beetles.
Planting	Plants that are strong and well established before flea beetles attack will better withstand feeding damage. Planting as early as possible and covering as shallowly as possible will give plants a head start.
Natural enemies	Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Guide to Natural Enemies (Reference 95) to identify natural enemies.
Floating row cover	Protect young plants from flea beetle damage with floating row covers. Remove row covers before temperatures get very hot in mid-summer.
Yellow sticky traps & tape	Sticky traps and tape may be useful in providing some control of adults.
Vacuum/leaf blower	Flea beetles can be vacuumed from leaves using a leaf blower set operated for suction. This practice may not be advisable when pathogens like powdery mildew and gray mold are present and might be spread by the vacuum.
Crop rotation, Site selection, Postharvest, and Sanitation	Not effective.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.4 Pesticides Labeled for Management of Flea Beetles

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICAL					
Mycotrol O *(Beauveria bassiana)*	1/4 - 1qt/A Foliar treatment	Up to day of harvest	4	2	Foliage contact and coverage extremely important; UV sensitive. Most effective in moist environments.
BOTANICAL					
Azadirachtin					Azadirachtin based products effective in 1/3 trials. Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
Aza-Direct	1-2 pt/A Foliar spray	0	4	2	
AzaGuard	8-16 fl oz/A Foliar spray	0	4	2	Use with an OMRI approved spray oil.
AzaMax	1.33 fl oz/1000 ft² Foliar spray	0	4	2	
AzaSol	6 oz/50 gal water/A Foliar spray	-	4	2	
Azatrol EC	0.11-0.22 fl oz/1000 ft² Foliar treatment	0	4	2	
Ecozin PLUS 1.2% ME	15-30 oz/A Foliar spray	0	4	2	
Molt-X	8 oz/A Foliar spray	0	4	2	For Molt –X, use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
Neemix 4.5	7-16 fl oz/A Foliar treatment	0	4	2	
garlic					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
Garlic Barrier *(garlic juice)*	1gal/99 gal water mix, spray at 10 gal mix/A Foliar treatment	-	4	?	25(b) pesticide
pyrethrins					
Pyganic Crop Protection EC 1.4II (*pyrethrins*)	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	1	Pyrethrum based products effective in 4/6 trials.
Pyganic Crop Protection EC 5.0II *(pyrethrins)*	4.5-17 oz/A Foliar treatment	0	12	1	Pyrethrum based products effective in 4/6 trials. Foliage and contact extremely important. UV sensitive.

Table 15.4 Pesticides Labeled for Management of Flea Beetles					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Apply at 1 gal mixed spray/700 ft^2 of plant surface area.
OILS					Oil products effective in 0/1 trial against beetle species.
Cedar Gard *(cedar oil)*	1 qt/A Foliar treatment	-	-	3	25(b) pesticide.
Glacial Spray Fluid (*mineral oil*)	0.75-1 gal/100 gal water Foliar treatment	Up to day of harvest	4	3	Only for use against larvae. See label for specific application volumes.
Golden Pest Spray Oil *(soybean oil)*	2 gal/A Foliar treatment	-	4	3	Only for use against larvae.
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gals water Foliar treatment	Up to day of harvest	4	3	Labeled for beetle larvae.
OTHER					
Azera *azadirachtin and pyrethrins*	1-3.5 pints/A Foliar spray	-	12	2	
Surround WP (*kaolin*)	25 – 50 lbs/A Foliar treatment	Up to day of harvest	4	3	Surround effective in 0/4 trials. Suppression only. Apply every 7 -10 days, starting prior to infestation.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.5 Subterranean and Surface Cutworms

Time for concern: May through harvest

Key characteristics: Many species of cutworms attack potatoes. The larvae are brown or gray and grow to about 1/5 inch in length. Some species cut the stems at the soil level, while others feed underground. Subterranean cutworms stay underground and feed on potato roots. Surface cutworms feed at the surface and are famous for severing new seedlings at or slightly above ground level. See Cornell's fact sheet(Reference 110) and cutworm life cycle(Reference 112).

Relative Risk: These pests are not a consistent problem in New York potatoes.

Management Option	Recommendation for Subterranean and Surface Cutworms
Scouting/thresholds	Thresholds have not been established for organic production.
Resistant varieties	No resistant varieties are available.
Site selection	Weedy fields are at greater risk of attracting moths for egg laying, which can lead to a build up of larvae.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.5 Pesticides Labeled for Management of Subterranean and and Surface Cutworms

CLASS OF COMPOUNDS Product Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Biobit HP (*Bacillus thuringiensis* subsp. *Kurstaki str. ABTS-351*)	0.5-1 lb/A Foliar treatment	0	4	?	Must be eaten by larvae. Not recommended for subterranean cutworm since applied to foliage.
Deliver (*Bacillus thuringiensis* subsp. *kurstaki*)	0.25-1.5 lb/A Foliar treatment	0	4	?	Must be eaten by larvae. Not recommended for subterranean cutworm since applied to foliage.
Dipel DF *(Bacillus thuringiensis)*	0.5-1 lb/A Foliar treatment	0	4	?	Must be eaten by larvae. Not recommended for subterranean since applied to foliage.
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lbs/A Soil treatment	-	4	?	Labeled for caterpillars.
Pyganic Crop Protection EC 1.4II *(pyrethrins)*	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	?	Not recommended for subterranean since applied to foliage.
Pyganic Crop Protection EC 5.0II *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	?	Not recommended for subterranean since applied to foliage.
Seduce Insect Bait (*spinosad*)	20-44 lb/A Soil treatment	7	4	?	Broadcast granular formulation
Xen Tari (*Bacillus thuringiensis subsp. Aizawai, str. ABTS-1857*)	0.5 – 1.5 lbs/A Foliar treatment	0	4	?	Must be eaten by larvae. Not recommended for subterranean since applied to foliage.
BOTANICALS					
Aza-Direct (*azadirachtin*)	1-2 pt/A Foliar spray or soil drench	0	4	?	
AzaGuard (*azadirachtin*)	8-16 fl oz/A Foliar spray or soil drench	0	4	?	Use with an OMRI approved spray oil.
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2 Foliar spray or soil drench	0	4	?	
AzaSol (*azadirachtin*)	6 oz/50 gal water/A Foliar spray or soil drench	-	4	?	
Azatrol EC (*azadirachtin*)	0.24-0.96 fl/1000 ft^2 Foliar treatment	0	4	?	
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide. Not recommended for subterranean cutworm since applied to foliage.
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide. Not recommended for subterranean cutworm since applied to foliage.
Molt-X *(azadirachtin)*	8 oz/A Foliar spray or soil drench	0	4	?	Use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.

Table 15.5 Pesticides Labeled for Management of Subterranean and and Surface Cutworms					
CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
Neemix 4.5 *(azadirachtin)*	4-10 fl oz/A Foliar treatment	0	4	2	Not recommended for subterranean since applied to foliage.
Pyganic Crop Protection EC 1.4II *(pyrethrins)*	16-64 fl oz/A Foliar treatment	Until spray has dried	12	?	Labeled for caterpillars.
Pyganic Crop Protection EC 5.0 II *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	?	Labeled for caterpillars.
IRON PHOSPHATE					
Bug-N-Sluggo® Insect, Slug and Snail Bait *(iron phosphate and spinosad)*	20-44 lbs/A Soil treatment	7	4	?	
OILS					
Cedar Gard *(cedar oil)*	1 qt/A Foliar treatment	-	-	?	25(b) pesticide.
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gals water Foliar treatment	Up to day of harvest	4	?	Labeled for caterpillars.
OTHER					
Azera (*azadirachtin and pyrethrin*)	1-3.5 pints/A Foliar spray or soil drench	-	12	?	

PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.6 Climbing Cutworm, primarily the variegated cutworm, *Peridroma margaritosa*

Time for concern: June through August

Key characteristics: The adult is a brown moth that lays eggs in masses of 60 or more. Larvae are nocturnal, seldom seen during the day, and curl into a C when disturbed. Mature larvae, 1 1/4 to 1 3/4 inches in length, may appear "greasy." Larvae feed on aerial parts of the potato plant, producing defoliation similar in appearance to that caused by the Colorado potato beetle except that most feeding occurs on the lower half of the plant. Tubers are seldom damaged by direct feeding. Yields can be reduced if substantial defoliation occurs during tuber initiation and bulking. See Reference 111, Cornell fact sheet (Reference 110) and life cycle (Reference 112).

Risk Assessment: This is an occasional problem in potatoes

Management Option	Recommendation for Climbing Cutworm
Scouting/thresholds	Examine the foliage in the evening for the presence of larvae and signs of feeding. Also examine wet, low- lying areas of the field for the presence of larvae. Examine 25 randomly chosen plants. Threshold: when the population reaches an average of three larvae per stem or if post-bloom defoliation exceeds 15 percent of the vine.
Resistant varieties	No resistant varieties are available.
Natural enemies	Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Guide to Natural Enemies (Reference 95) for identification of natural enemies.

Management Option	Recommendation for Climbing Cutworm
Insecticide use	Larvae are present on the foliage only during the evening, and insecticides will be most effective if applied during this period or near dusk. Thorough coverage of the foliage and soil surface is essential for good management. This may require the use of application equipment delivering at least 50 GPA at pressures of 60 psi or more.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.6 Pesticides Labeled for Management of Climbing Cutworms

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
Biobit HP (*Bacillus thuringiensis* subsp. *Kurstaki str. ABTS-351*)	0.5-1 lb/A Foliar treatment	0	4	?	
Deliver (*Bacillus thuringiensis* subsp. *kurstaki*)	0.25-1.5 lb/A Foliar treatment	0	4	?	
Dipel DF *(Bacillus thuringiensis)*	0.5-1 lb/A Foliar treatment	0	4	?	Residue on foliage must be eaten by larvae. Does not provide immediate mortality.
Javelin WG (*Bacillus thuringiensis* subsp. *kurstaki*)	0.12-1.5 lbs/A Foliar treatment	0	4	?	
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lbs/A Soil treatment	-	4	?	Labeled for caterpillars.
Pyganic Crop Protection EC 1.4II *(pyrethrins)*	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	?	
Pyganic Crop Protection EC 5.0 II *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	?	
Seduce Insect Bait (*spinosad*)	20-44 lb/A Soil treatment	7	4	?	Broadcast granular formulation
Xen Tari (*Bacillus thuringiensis subsp. Aizawai, str. ABTS-1857*)	0.5 – 1.5 lbs/A Foliar treatment	0	4	?	
BOTANICALS					
Aza-direct *(azadirachtin)*	1-2 pt/A Foliar spray or soil drench	0	4	?	Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
AzaGuard (*azadirachtin*)	8-16 fl oz/A Foliar spray or soil drench	0	4	?	Use with an OMRI approved spray oil.
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2 Foliar spray or soil drench	0	4	?	
AzaSol (azadirachtin)	6 oz/50 gal water/A Foliar spray or soil drench	-	4	?	

Table 15.6 Pesticides Labeled for Management of Climbing Cutworms					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Azatrol EC (*azadirachtin*)	0.24-0.96 fl/1000 ft² Foliar treatment	0	4	?	
Azera (*azadirachtin and pyrethrin*)	1-3.5 pints/A Foliar spray or soil drench	-	12	?	
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Ecozin PLUS 1.2% ME *(azadirachtin)*	15-30 oz/A Foliar spray or soil drench	0	4	?	
Molt-X *(azadirachtin)*	8 oz/A Foliar spray or soil drench	0	4	?	Use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
Pyganic Crop Protection EC 1.4 II *(pyrethrins)*	16-64 fl oz/A Foliar treatment	Until spray has dried	12	?	Labeled for caterpillars.
Pyganic Crop Protection EC 5.0 II *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	?	Labeled for caterpillars.
IRON PHOSPHATE					
Bug-N-Sluggo® Insect, Slug and Snail Bait *(iron phosphate and spinosad)*	20-44 lbs/A Soil treatment	7	4	?	
OILS					
Cedar Gard *(cedar oil)*	1 qt/A. Foliar treatment	-	-	?	25(b) pesticide.
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gals water Foliar treatment	Up to day of harvest	4	?	Labeled for caterpillars.
OTHER					
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Apply at 1 gal mixed spray/700 ft² of plant surface area.

59B PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.
Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.7 European Corn Borer (ECB), *Ostrinia nubilalis*

Time of concern: June and July

Key characteristics: Eggs are white and laid in scale-like masses on the underside of leaves. The larvae are gray with rows of brown spots and a dark brown head capsule. Larvae are 3/4 inch long when fully developed. The adult is a yellowish/reddish brown moth, about one inch in length. See Reference 113A to accurately determine if moths in the field are actually ECB moths. See Cornell fact sheet (Reference 113), life cycle (Reference 114) and management bulletin (Reference 115).

Relative risk: European corn borer is a sporadic problem usually affecting potatoes grown near infested corn fields. Isolated potato farms rarely see this insect even though it is a fairly strong flyer. Economically, this is normally a minor pest unless there is black leg on the seed or in wet weather on some varieties. In the absence of blackleg inoculum, economic damage from the corn borer alone is insignificant except at infestation levels exceeding 35% infested stems.

Management Option	Recommendation for European Corn Borer
Scouting/thresholds	The optimum time for application of an insecticide coincides with hatching of egg masses and is best determined by the detection of peak flight periods. Monitor peak flight periods using blacklight and pheromone traps or by caging infested corn stalks from a nearby field in a screened enclosure. Apply insecticide on a schedule when moths are in the area and flying to provide best control. It is also advisable to sample the grassy areas bordering fields since the adults frequent these areas during daylight hours and may be more readily found in these areas than within cropped areas. Sampling for egg masses is impractical in potatoes. Furthermore, monitoring for larvae and for broken or wilted stems serves no useful purpose because control cannot be achieved once larvae have penetrated stems.
Site selection	Avoid planting potatoes in fields that have been rotated to corn. If this is not feasible, cut corn stubble as short as possible and shred stalk material over a wide area to destroy the majority of overwintering larvae.
Resistant varieties	Survival and establishment of larvae vary depending on potato cultivar and field conditions. Larval survival on three popular cultivars follows: > Monona > Superior > Katahdin. Under field conditions, Monona is more susceptible to attack by ECB's and to infection by aerial blackleg than other cultivars.
Natural enemies	Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Guide to Natural Enemies (Reference 95) to identify natural enemies. Trichogramma ostriniae releases have been found effective. See T. ostriniae to help manage ECB (Reference 116) for more information.
Plowing	Up to 60 percent of overwintering larvae may be killed by moldboard or chisel plowing or disking prior to moth emergence. If corn is included in the rotation, silage corn is less likely to harbor ECB larvae than ear (or seed) corn. With the latter, cut stalks as short as possible following harvest and shred to further reduce overwintering larvae. This tactic is effective when implemented over a large area.
Sanitation	Mow adjacent weeds and grass, where moths take shelter during the day, to force females to move away from potato fields. Remove volunteer corn that may attract ECB moths to the potato field.
Harvest	A simple mechanical device that attaches to the harvester can be used to crush potato stems where larvae overwinter. Initial studies in Canada showed that crushing the stems resulted in a 95% reduction in larval survival. See Canadian Pest Management Centre article (Reference 117)

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.7 Pesticides Labeled for Management of European Corn Borer

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate/**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
Deliver (*Bacillus thuringiensis* subsp. *kurstaki*)	0.25-1.5 lb/A Foliar treatment	0	4	3	Bacillus thuringiensis products effective in 0/2 trials.
Entrust Naturalyte Insect Control (*spinosad*)	1-2 oz/A Foliar treatment	7	4	1	Spinosad based products effective in 3/4 trials. Need to be applied at or just before egg hatch. Foliage contact and coverage extremely important; short residual activity.

Table 15.7 Pesticides Labeled for Management of European Corn Borer					
CLASS OF COMPOUNDS Product Name (*active ingredient*)	**Product Rate/**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Entrust SC (*spinosad*)	3-10 fl oz/A Foliar treatment	7	4	1	Spinosad based products effective in 3/4 trials.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1*)	1-3 lbs/A Foliar treatment	0	4	?	
Javelin WG (*Bacillus thuringiensis* subsp. *kurstaki*)	0.12-1.5 lbs/A Foliar treatment	0	4	3	Bacillus thuringiensis products effective in 0/2 trials.
Mycotrol O *(Beauveria bassiana)*	1/4 – 1 qt/A Foliar treatment	Up to day of harvest	4	?	Foliage contact and coverage extremely important; UV sensitive. Most effective in moist environments.
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lbs/A Soil treatment	-	4	?	Labeled for caterpillars.
BOTANICALS					
azadirachtin					
Aza-Direct	1-2 pt/A Foliar spray or soil drench	0	4	?	Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
AzaGuard	8-16 fl oz/A Foliar spray or soil drench	0	4	?	Use with an OMRI approved spray oil.
AzaMax	1.33 fl oz/1000 ft^2 Foliar spray or soil drench	0	4	?	
AzaSol	6 oz/50 gal water/A Foliar spray or soil drench	-	4	?	
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Foliar spray or soil drench	-	12	?	
Ecozin PLUS 1.2% ME	15-30 oz/A Foliar spray or soil drench	0	4	?	
Molt-X	8 oz/A Foliar spray or soil drench	0	4	?	Use in combination with an organic 0.25-1% nonphytotoxic crop oil in sufficient water to cover undersides of leaves.
garlic					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
pyrethrins					
Pyganic Crop Protection EC 1.4$_{II}$ (*pyrethrins*)	16 – 64 fl oz/A Foliar treatment	Until spray has dried	12	?	
PyGanic Crop Protection EC 5.0 II (*pyrethrins*)	4.5-17 fl oz/A Foliar treatment	0	12	?	
PyGanic EC 5.0 $_{II}$ *(pyrethrins)*	4.5-17 fl oz/A Foliar treatment	0	12	?	Labeled for caterpillars.
OILS					
Cedar Gard *(cedar oil)*	1 qt/A Foliar treatment	-	-	?	25(b) pesticide.

Table 15.7 Pesticides Labeled for Management of European Corn Borer					
CLASS OF COMPOUNDS **Product Name** (***active ingredient***)	**Product Rate/**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gal water Foliar treatment	Up to day of harvest	4	?	Labeled for caterpillars.
OTHER					
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (pyrethrin & potassium salts of fatty acids)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Apply at 1 gal mixed spray/700 ft^2 of plant surface area.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label. Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.8 Wireworms. Primarily the **Wheat Wireworm**, *Agriotes mancus*; **Eastern Field Wireworm**, *Limonius ectypus*; and to a lesser extent, **Corn Wireworm**, Melanotus communis

Time for concern: June through September

Key characteristics: The adults are known as "click beetles" because of the structure on the ventral side with which they are able to right themselves if inverted. The head and thorax of adults are dark brown; the legs and wing covers vary from pale yellow to mahogany. Eggs are small, pearly white, and spherical. The newly hatched larva or wireworm is white and 2/25 inch long. Mature larvae are cylindrical, tan, and range from 1/2 to 1 inch in length. Wireworms can create holes in potato tubers. See Cornell life cycle and damage (Reference 118).

Relative risk: Wireworm can be serious especially if potatoes are grown in fields directly after sod, grassy weeds, or hay.

Management Option	Recommendation for Wireworms
Scouting/thresholds	Prior to planting, bait stations can be used to monitor populations. Delay sampling as late in the spring as possible because wireworms burrow deep into the soil in the winter and move up only after the soil warms. Place several ounces of coarse whole-wheat flour or a mixture of untreated corn and wheat seed or pieces of carrot or potato into a fine mesh pouch (e.g. panty hose), and bury six to 14 inches. Cover the soil over the bait station first with a piece of black polyethylene plastic and then with a piece of clear polyethylene film. Secure the edges of the film with soil. Prior to planting, remove the soil above and around the bait station and count the larvae in and around the bait. Alternatively, sample in midsummer by sifting one square foot of soil to a depth of six to 14 inches and counting the wireworms. Use a box with a base made of 1/4-mesh hardware cloth as a sieve. Take six to 12 samples, starting in low, wet areas. Threshold: if half or more of the bait stations or soil samples contain one or more wireworms, don't plant potatoes on that ground.
Site selection	Avoid planting in poorly drained soils or wet areas.
Crop rotation	Allow 3 years between grassy crops or cover crops to avoid wireworm with the exception of grains or grasses that are only in the field for part of the season. Millipedes are sometimes found in association with wireworms and produce similar damage to tubers. Rotations of red or sweet clover of more than one year may promote millipede populations.
Cover crops	Full season cover crops can allow wireworm populations to build. Use shorter season or fall seeded cover crops and cultivate into soil in the spring to avoid buildup.
Resistant varieties	No resistant varieties are available.
Cultivation	Cultivation is effective at reducing wireworm populations.

Management Option	Recommendation for Wireworms
Sanitation	Infestation can be minimized by keeping land free of grassy weeds during the egg-laying period (May through late June).
Notes	Avoid having actively decomposing organic matter during the growing season..

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.8 Pesticides Labeled for Management of Wireworms

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICAL					
PFR-97 20% WDG (Isaria fumosorosea Apopka str. 97)	1-2 lbs/A Soil treatment	-	4	?	
BOTANICAL					
azadirachtin					
Aza-Direct	1-2 pt/A Soil drench	0	4	?	
AzaGuard	8-16 fl oz/A Soil drench	0	4	?	
AzaMax	1.33 fl oz/1000 ft^2 Soil drench	0	4	?	
AzaSol	6 oz/50 gal water/A Soil drench	-	4	?	
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Soil drench	-	12	?	
OIL					
Ecotec - G *(clove, cinnamon and thyme oils)*	22-28 lbs/A Band treatment	0	0	?	

15.9 Symphylan, *Scutigerella immaculata*

Time for concern: May through July

Key characteristics: Garden symphylans, sometimes called garden centipedes, are soil inhabiting arthropods of the Class Symphyla, with 14 body segments and 12 pairs of legs. The quick moving adults are less than ½ inch long, white and slender with prominent antennae. Immature stages only have six pairs of legs. They feed on decaying organic matter and root hairs, stems and tubers. See National Sustainable Agriculture Information Service publication (Reference 119) for photos and more information.

Relative risk: This pest is rare and only occurs sporadically in certain fields and in localized areas within a field.

Management Option	Recommendation for Symphylan
Scouting/thresholds	Record pest history and avoid planting in fields with a history of symphylans. Thresholds have not been established for organic production
Resistant varieties	No resistant varieties are available.

Management Option	Recommendation for Symphylan
Crop rotation	Potato crops are very effective at reducing symphylan populations. A spring oat winter cover crop has been shown to reduce symphylan populations. Mustard and spinach are good hosts for symphylans and may increase populations.
Site selection, Postharvest, and Sanitation	These are currently not viable management options.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.9 Pesticides Labeled for Management of Symphylan

CLASS OF COMPOUNDS Product Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
BIOLOGICALS					
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lbs/A Soil treatment	-	4	?	
BOTANICALS					
azadirachtin					
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Soil drench	-	12	?	
garlic					
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
OILS					
Ecotec - G *(clove, cinnamon and thyme oils)*	22-28 lbs/A Band treatment	0	0	?	25(b) pesticide

15.10 Spider Mites, *Tetranychus spp.*

Time for concern: July through September

Key characteristics: Tiny, spider-like creatures but without narrow waist between head and body. Adults have 4 pairs of legs (3 pairs in immatures). Adults have 2 well-defined reddish-brown spots on top of body. Infested areas on leaves may be somewhat circular in appearance and are often confused with lightning strikes or wet depressions in fields. See life cycle and damage (Reference 120)

Relative risk: Sporadic problem. Some varieties are more prone to spider mite damage.

Management Option	Recommendation for Spider Mites
Scouting/thresholds	Scout fields weekly beginning in early July and pay special attention to edges of fields bordered by field roads, ditches and other grassy areas. Examine at least 20 leaves from each of these areas using 5-10X magnification. Treatment is recommended if spider mite densities reach or exceed an average of 10 adult mites per leaf. Spot or edge treatment of infested areas is encouraged, if practical.
Site selection	Avoid planting susceptible varieties where they will be subject to repeated dusting from field or road traffic.
Resistant varieties	Spider mites are infrequent pests on most varieties. However, during hot and dry conditions, several varieties (Nordonna, Norgold Russet, NY E11-45 and Marcy) have been reported as susceptible to

Management Option	Recommendation for Spider Mites
	spider mite infestations especially in those areas of fields subject to heavy dusting from field roads.
Natural enemies	Naturally occurring predators, parasitoids, and pathogens help suppress infestations. Use Reference 94 or Cornell's Guide to Natural Enemies(Reference 95) to identify natural enemies.
Seed selection/treatment, Postharvest, and Sanitation	These are currently not viable management options.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.10 Pesticides Labeled for Management of Spider Mites

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
BIOLOGICALS					
PFR-97 20% WDG (Isaria fumosorosea Apopkastr. 97)	1-2 lbs/A Foliar treatment	-	4	?	Foliar spray. Repeat at 3-10 day intervals as needed to maintain control.
BOTANICALS					
azadirachtin					
Aza-Direct	1-2 pt/A Foliar treatment	0	4	?	Does not provide immediate mortality. Intoxicated nymphs and larvae die at their next molt. Foliage contact and coverage extremely important.
AzaGuard	10-16 fl oz/A Foliar treatment	0	4	?	
AzaMax	1.33 fl oz/1000 ft^2 Foliar treatment	0	4	?	
Azatrol EC	0.24-0.96 fl oz/1000ft^2 Foliar treatment	0	4	?	
garlic					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
Garlic Barrier *(garlic juice)*	1gal/99 gal water mix, spray at 10 gal mix/A Foliar treatment	-	4	?	25(b) pesticide
pyrethrins					
Pyganic Crop Protection EC 1.4II *(pyrethrins)*	16-64 fl oz/A Foliar treatment	Until spray has dried	12	?	Labeled for the kill of insects.
PyGanic Crop Protection EC 5.0 II *(pyrethrins)*	4.5-17 oz/A Foliar treatment	0	12	?	

Table 15.10 Pesticides Labeled for Management of Spider Mites

CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gal water Foliar treatment	Until spray has dried	12	?	Apply at 1 gal mixed spray/700 ft^2 of plant surface area.
OILS					**Oil based products effective in 1/1 trial.**
Cinnerate *(cinnamon oil)*	13-30 fl oz/100 gal water Foliar treatment	-	-	?	For crops < 20 inches, apply 85-100 gal spray solution/A; for crops 20-50 inches, apply 100-160 gal spray solution/A. Check for phytotoxicity before apply to whole crop.
Ecotec *(rosemary and peppermint oil)*	1-4 pints/A Foliar treatment	0	4	?	25(b) pesticide
GC-Mite *(cottonseed, clove, and garlic oil)*	1gal/100 gal water spray to cover surface Foliar treatment	-	-	1	25(b) pesticide
Glacial Spray Fluid (*mineral oil*)	0.75-1 gal/100g Foliar treatment	Up to day of harvest	4	1	See label for specific application volumes.
Golden Pest Spray Oil (*soybean oil*)	2 gal/A Foliar treatment	-	4	1	
JMS Stylet-Oil *(paraffinic oil)*	3-6 qts/100 gal water Foliar treatment	0	4	1	Foliage contact and coverage extremely important. Do not apply within 10-14 days of a sulfur application.
Oleotrol-I (*soybean oil*)	1 part Oleotrol-I with 300 parts water Foliar treatment	0	-	1	
Organic JMS Stylet-Oil *(paraffinic oil)*	3-6 qts/100 gal water Foliar treatment	0	4	1	Foliage contact and coverage extremely important. Do not apply within 10-14 days of a sulfur application.
Organocide 3-in-1 *(sesame oil)*	1-2 gal/100 gal water Foliar treatment	-	-	1	25(b) pesticide
PureSpray Green *(petroleum oil)*	0.75-1.5 gal/A in 50-100 gal water. Foliar treatment	Up to day of harvest	4	1	
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water Foliar treatment	Up to day of harvest	4	1	Do not mix with sulfur products.
Trilogy *(hydrophobic extract of neem oil)*	1-2% in 25-100 gallons of water/A Foliar treatment	Up to day of harvest	4	2	Neem oil effective in 1/2 trials against mites in the greenhouse. Limited to a maximum of 2 gallons/acre/application.
TriTek *(petroleum oil)*	1-2 gal/100 gal water Foliar treatment	Up to day of harvest	4	1	Apply as needed.
SOAP					
M-Pede *(potassium salts of fatty acids)*	1-2% volume to volume Foliar treatment	0	12	1	Soap based products effective in 2/3 trials.
SULFUR					Elemental sulfur effective in 2/3 trials.
Kumulus DF (*sulfur*)	3-10 lb/A Foliar treatment	-	24	1	Labeled only for use against red spider mites. Do not use within 2 weeks of oil applications.
Micro Sulf *(sulfur)*	5 lbs/A Foliar treatment	-	24	1	Does not provide immediate mortality. Foliage contact and coverage extremely important.

Table 15.10 Pesticides Labeled for Management of Spider Mites					
CLASS OF COMPOUNDS **Product Name** **(*active ingredient*)**	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy**	**Comments**
Microthiol Disperss *(sulfur)*	5-10 lbs/A Foliar treatment	-	24	1	
Thiolux *(sulfur)*	3-5 lbs/A Foliar treatment	-	24	1	Labeled only for use against red spider mites.
OTHER					
Azera *azadirachtin and pyrethrin*	1-3.5 pints/A Foliar treatment	-	12	?	
Nuke Em *(citric acid)*	1 fl oz/31 oz water to 2 fl oz/30 fl oz water. Foliar treatment	0	-	?	
Sil-Matrix (*potassium silicate*)	0.5-1% solution Foliar treatment	0	4	?	Apply 20 gallons finished spray/A.

. PHI = pre-harvest interval, REI = restricted entry interval. - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

15.11 Slugs and Snails

Time of concern: Early spring and fall

Key characteristics: See Rothamsted slug control publication (Reference 121).

Relative risk: Sporadic but wet weather and poorly composted organic matter favor population increase.

Management Option	Recommendation for Slugs and Snails
Slug biology	Slugs and snails are similar in biology except slugs lack an external spiral shell. Pest species have up to 2 generations per year and eggs are laid in the spring and/or fall. Eggs deposited in the fall overwinter and hatch the following spring, usually in April and May. Slugs and snails thrive under the humid canopy of potato crops and can cause significant damage to tubers. Holes and cavities created by feeding of these mollusks are sometimes similar in appearance to (and confused with) that caused by soil arthropods such as millipedes, cutworms and white grubs.
Molluscicide use	For best results, apply in the evening by broadcasting or by row banding to moist soil or after heavy rains. Avoid placing molluscide baits in piles.
Scouting	Low-lying areas and water-filled wheel tracks are excellent places to monitor for the presence of these pests during the period just preceding tuber sizing.
Site selection	Slugs and snails are general organic matter feeders; weedy potato fields and heavy moist soils may favor build-up of these pests. Potato crops following peas may be at greater risk of slug and snail attack in moist years compared to rotations following grains.
Crop rotation	Poorly drained soils, habitually wet areas of fields and weedy fields may be at greatest risk of infestation.
Resistant varieties	No information on North American resistant varieties is available.
Sanitation	Keeping land free of weeds may reduce the potential for infestation.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website (Link 2). ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 15.11 Pesticides Labeled for Management of Slugs and Snails

CLASS OF COMPOUNDS Product Name (active ingredient)	Product Rate	PHI (days)	REI (hours)	Efficacy	Comments
Botanicals					
BioLink *(garlic juice)*	0.5-2 qts/A Foliar treatment	12	-	?	25(b) pesticide
BioLink Insect & Bird Repellant *(garlic juice)*	0.5-4 qts/A Foliar treatment	12 hr	-	?	25(b) pesticide
Envirepel 20 *(garlic juice)*	10-32 fl oz/A Foliar treatment	12 hr	12	?	25(b) pesticide
Garlic Barrier *(garlic juice)*	1gal/99 gal water mix, spray at 10 gal mix/A Foliar treatment	-	4	?	25(b) pesticide
Iron phosphate					
Bug-N-Sluggo® Insect, Slug and Snail Bait *(iron phosphate and spinosad)*	20-44 lbs/A Soil treatment	7	4	?	
Sluggo Slug & Snail Bait (*iron phosphate*)	20-44 lb/A Soil treatment	0	0	?	
Sluggo-AG *(iron phosphate)*	20-44 lb/A Soil treatment	0	0	?	Apply by broadcast or by row band applicator in the evening to moist soil or after heavy rain. Do not place in piles.

PHI = pre-harvest interval, REI = restricted entry interval - = pre-harvest interval isn't specified on label.

Efficacy: 1- effective in half or more of recent university trials, 2- effective in less than half of recent university trials, 3-not effective in any known trials, ?- not reviewed or no research available

16. Pesticides and Abbreviations Mentioned in this Publication

Table 16.1 Fungicides and Nematicides Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
Actinovate AG	*Streptomyces lydicus*	73314-1
Actinovate STP	*Streptomyces lydicus*	73314-4
Badge X2	*copper oxychloride, copper hydroxide*	80289-12
Basic copper 53	*copper sulfate*	45002-8
BIO-TAM	*Trichoderma asperellum, Trichoderma gamsii*	80289-9-69592
Brandt Nema-Q	*(Saponins of Quillaja saponaria)*	82572-1-48813
Champ WG	*copper hydroxide*	55146-1
Clove oil	*clove oil*	Exempt- 25(b) pesticide
Contans WG	*coniothyrium minitans*	72444-1
*Copper Sulfate Crystals	*copper sulfate pentahydrate*	56576-1
CS 2005	*copper sulfate pentahydrate*	66675-3
Cueva Fungicide Concentrate	*copper octanoate*	67702-2-70051

Table 16.1 Fungicides and Nematicides Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
Decco Aerosol 100 For Treatment of Potato in Storage	*clove oil*	Exempt- 25(b) pesticide
DiTera DF	*Myrothecium verrucaria*	73049-67
Double Nickel 55	*Bacillus amyloliquefaciens str. D747*	70051-108
Double Nickel LC	*Bacillus amyloliquefaciens str. D747*	70051-107
EcoMate ARMICARB 0	*potassium bicarbonate*	5905-541
JMS Stylet Oil	*paraffinic oil*	65564-1
MeloCon WG Biological Nematicide	*Paecilomyces lilacinus str. 251*	72444-2
Milstop	*potassium bicarbonate*	70870-1-68539
Mycostop Biofungicide	*Streptomyces griseoviridis str. K61*	64137-5
Mycostop Mix	*Streptomyces griseoviridis str. K61*	64137-9
Nordox 75 WG	*cuprous oxide*	48142-4
NuCop 50DF	*copper hydroxide*	45002-4
Nu-Cop 50 WP	*cupric hydroxide*	45002-7
Nu-Cop HB	*cupric hydroxide*	42750-132
Optiva	*Bacillus subtilis str. QST 713*	69592-26
Organic JMS Stylet Oil	*paraffinic oil*	65564-1
OxiDate 2.0	*hydrogen dioxide, peroxyacetic acid*	70299-12
PERpose Plus	hydrogen peroxide/dioxide	86729-1
Prestop Biofungicide	*Gliocladium catenulatum str. J1446*	64137-11
PureSpray Green	*petroleum oil*	69526-9
*Quimag Quimicos Aguila Copper Sulfate Crystal	*copper sulfate*	73385-1
Regalia Biofungicide	*Reynoutria sachalinensis*	84059-3
RootShield Granules	*Trichoderma harzianum Rifai str. T-22*	68539-3
Rootshield WP	*Trichoderma harzianum*	68539-7
RootShield PLUS+ WP	*Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*	68539-9
Serenade ASO	*Bacillus subtilis*	69592-12 and 264-1152
Serenade MAX	*Bacillus subtilis*	69592-11 and 264-1151
Serenade Optimum	*Bacillus subtilis*	264-1160
Serenade Soil	*Bacillus subtilis*	69592-12 and 264-1152
SoilGard	*Gliocladium virens str. GL-21*	70051-3
Taegro Biofungicide	*Bacillus subtilis var. amyloliquefaciens str. FZB24*	70127-5
TerraClean 5.0	*hydrogen dioxide, peroxyacetic acid*	70299-13
Trilogy	*neem oil*	70051-2
Zonix	*Rhamnolipid Biosurfactant*	72431-1

* Restricted use pesticide. Restricted-use pesticides can be purchased only by certified applicators and used by certified applicators or by those under the direct supervision of a certified applicator.

Table 16.2 Insecticides Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
Aza-Direct	*azadirachtin*	71908-1-10163
AzaGuard	*azadirachtin*	70299-17
AzaMax	*azadirachtin*	71908-1-81268
AzaSol	*azadirachtin*	81899-4
Azatrol EC	*azadirachtin*	2217-836
Azera	*azadirachtin and pyrethrin*	1021-1872
Biobit HP	Bacillus thuringiensis subsp. kurstaki str. ABTS-351	73049-54
BioLink	*garlic juice*	Exempt - 25(b) pesticide
BioLink Insect & Bird Repellant	*garlic juice*	Exempt - 25(b) pesticide

Table 16.2 Insecticides Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
BioRepel	*garlic oil*	Exempt - 25(b) pesticide
Bug-N-Sluggo Insect, Slug and Snail Bait	*iron phosphate and spinosad*	67702-24-70051
Cedar Gard	*cedar oil*	Exempt - 25(b) pesticide
Cinnerate	*cinnamon oil*	Exempt - 25(b) pesticide
Deliver	*Bacillus thuringiensis subsp. kurstaki*	70051-69
Dipel DF	*Bacillus thuringiensis subsp. kurstaki*	73049-39
Ecotec	*rosemary and peppermint oil*	Exempt - 25(b) pesticide
Ecotec - G	*clove, cinnamon and thyme oils*	Exempt - 25(b) pesticide
Ecozin PLUS 1.2% ME	*azadirachtin*	5481-559
Entrust Naturalyte Insect Control	*spinosad*	62719-282
Entrust SC	*spinosad*	62719-621
Envirepel	*garlic juice*	Exempt - 25(b) pesticide
GC-Mite	*cottonseed, clove, and garlic oils*	Exempt - 25(b) pesticide
Garlic Barrier	*garlic juice*	Exempt - 25(b) pesticide
Glacial Spray Fluid	*mineral oil*	34704-849
Golden Pest Spray Oil	*soybean oil*	57538-11
Grandevo	*Chromobacterium subtsugae str. PRAA4-1*	84059-17
Javelin WG	*Bacillus thuringiensis subsp. kurstaki*	70051-66
JMS Stylet Oil	*mineral oil*	65564-1
Kumulus DF	*sulfur*	51036-352-66330
M-Pede	*potassium salts of fatty acids*	10163-324
Micro Sulf	*sulfur*	55146-75
Microthiol Disperss	*sulfur*	70506-187
Molt-X	*azadirachtin*	68539-11
Mycotrol O	*Beauveria bassiana str. GHA*	82074-3
Neemazad 1%EC	*azadirachtin*	70051-104
Neemix 4.5	*azadirachtin*	70051-9
Nuke Em	*citric acid*	Exempt - 25(b) pesticide
Oleotrol-I	*soybean oil*	Exempt - 25(b) pesticide
Organic JMS Stylet Oil	*mineral oil*	65564-1
Organocide 3-in-1	*sesame oil*	Exempt - 25(b) pesticide
PFR-97 20% WDG	*Isaria fumosorosea Apopka str. 97*	70051-19
PureSpray Green	*petroleum oil*	69526-9
Pyganic Crop Protection EC 1.4$_{II}$	*pyrethrins*	1021-1771
PyGanic Crop Protection EC 5.0 $_{II}$	*pyrethrins*	1021-1772
Safer Brand #567	*pyrethrin and soap*	59913-9
Seduce Insect Bait	*spinosad*	67702-25-70051
Sil-Matrix	*potassium silicate*	82100-1
Sluggo-AG	*iron phosphate*	67702-3-54705
Sluggo Slug & Snail Bait	*iron phosphate*	67702-3-70051
SuffOil-X	*petroleum oil*	48813-1-68539
Surround WP	*kaolin*	61842-18
Thiolux	*sulfur*	34704-1079
Trilogy	*neem oil*	70051-2
TriTek	*petroleum oil*	48813-1
Xen Tari	*Bacillus thuringiensis*	73049-40

Table 16.3 Sprout Suppressants Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
Decco 070 EC Potato Sprout Inhibitor	*clove oil*	Exempt - 25(b) pesticide
Decco Aerosol 100 For Treatment of Potato in	*clove oil*	Exempt - 25(b) pesticide

Table 16.3 Sprout Suppressants Mentioned in this Publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
Storage		
Peppermint oil	*peppermint oil*	Exempt - 25(b) pesticide
Clove oil	*clove oil*	Exempt - 25(b) pesticide

Table 16.4 Sanitizers mentioned in this publication

TRADE NAME	ACTIVE INGREDIENT	EPA REG. NO.
CDG Solution 3000	*chlorine dioxide*	75757-2
Enviroguard Sanitizer	*hydrogen peroxide/peroxyacetic acid*	63838-1-527
Oxine	*chlorine dioxide*	9804-1
Oxonia Active	*hydrogen peroxide/peroxyacetic acid*	1677-129
Peraclean 5	*hydrogen peroxide/peroxyacetic acid*	54289-3
Peraclean 15	*hydrogen peroxide/peroxyacetic acid*	54289-4
Perasan 'A'	*hydrogen peroxide/peroxyacetic acid*	63838-1
Per-Ox	*hydrogen peroxide/peroxyacetic acid*	833-4
Pro Oxine	*chlorine dioxide*	9804-9
*SaniDate 5.0	*hydrogen peroxide/peroxyacetic acid*	70299-19
SaniDate 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18
San-I-King No. 451	*sodium hypochlorite*	2686-20001
Shield-Brite PAA 5.0	*Peroxy acetic acid/hydrogen peroxide*	70299-19-64864
Shield-Brite PAA 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18-64864
StorOx 2.0	*hydrogen peroxide/peroxyacetic acid*	70299-7
Tsunami 100	*hydrogen peroxide/peroxyacetic acid*	1677-164
Victory	*hydrogen peroxide/peroxyacetic acid*	1677-186
VigorOx Liquid Sanitizer and Disinfectant OAI	*hydrogen peroxide/peroxyacetic acid*	65402-6
VigorOx 15 F & V	*hydrogen peroxide/peroxyacetic acid*	65402-3
VigorOx LS-15	*hydrogen peroxide/peroxyacetic acid*	65402-3

* Restricted-use pesticide in New York State

Abbreviations and Symbols Used in This Publication

A	Acre	N	Nitrogen
APHIS	Animal and Plant Health Inspection Service	NFT	not frost tolerant
AR	annual rye	P	phosphorus
ASO	aqueous suspension-organic	PHI	pre-harvest interval
AS	aqueous suspension	P_2O_5	phosphorus oxide
DF	dry flowable	PR	perennial rye
EC	emulsifiable concentrate	R	resistant varieties
F	flowable	REI	restricted entry interval
HC	high concentrate	WG	water dispersible granular
K	potassium	WP	wettable powder
K2O	potassium oxide	WPS	Worker Protection Standard

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Integrated Pest Management

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2015 Production Guide for
Organic Strawberries

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Dedication

This publication is dedicated to Cathy Heidenreich who was tragically killed in an automobile accident in December, 2014. Cathy put her heart and soul into her work, which included many hours on this guide.

Funded in part by the New York State Department of Agriculture and Markets.

The guidelines in this bulletin reflect the current authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this bulletin does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

Every effort has been made to provide correct, complete, and up-to-date pest management information for New York State at the time this publication was released for printing (June 2015). Changes in pesticide registrations, regulations, and guidelines occurring after publication are available in county Cornell Cooperative Extension offices or from the Pesticide Management Education Program web site (*pmep.cce.cornell.edu*). Trade names used herein are for convenience only. No endorsement of products is intended, nor is criticism of unnamed products implied.

This guide is not a substitute for pesticide labeling. Always read the product label before applying any pesticide.

Updates and additional information for this guide are available at www.nysipm.cornell.edu/organic_guide. Please submit comments or suggested changes for these guides to organicguides@gmail.com.

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TABLE OF CONTENTS

INTRODUCTION

This guide for organic strawberry production is focused on nutrient and pest management practices and includes topics that have an impact on improving plant health and reducing pest problems. The guide is divided into sections, but the interrelated quality of organic cropping systems makes each section relevant to the others.

Strawberries are moderately amenable to organic production. The greatest challenge, by far, is weeds, particularly in the planting year. Studies have shown that sustained weed pressure in the planting year can negatively affect yield for several subsequent years. It is also difficult to provide a large amount of nitrate nitrogen when the strawberry plant needs it most: early spring and late fall. There are also a few pests that can be difficult to control organically if the weather does not cooperate (e.g. gray mold and anthracnose fruit rots). Use of protected production structures, such as low tunnels, may be needed to adequately manage these diseases. That said, with sufficient attention to weed management, especially in the planting year, and with good soil nitrogen reserves, strawberries can be successfully grown with organic production methods.

Organic strawberry production systems generally share five common characteristics, described in the Strawberry Production Guide for the Northeast, Midwest, and Eastern Canada, NRAES-88:

1. Several years elapse between successive strawberry crops. That is, practice 3- to 5-year-long crop rotations.
2. The production cycle is short, only one or two fruiting years, to avoid the establishment of perennial weeds and depletion of nitrogen reserves.
3. The labor requirements are high because of the need for hand-weeding and frequent light cultivation.
4. Yields tend to be lower in older plantings because weeds and pests tend to build up over time.
5. There is variability in yield due to weather and variable pest pressure.

For a more comprehensive understanding of strawberry production we suggest the following resources: Strawberry Production Guide for the Northeast, Midwest, and Eastern Canada, NRAES-88 available for purchase from Plant and Life Sciences Publishing (PALS, formerly NRAES), and Strawberries: Organic Production, available for purchase from the National Sustainable Agriculture Information Service, ATTRA. For those interested in strawberry production using day neutral strawberries we suggest: Season-long Strawberry Production with Everbearers.

More research on growing perennial crops organically is needed, especially in the area of pest management. This guide attempts to compile the most current information available, but acknowledges that effective means of organic control are not available for some pests. Future revisions to this guide will incorporate new information providing organic growers with a complete set of useful practices to help them achieve success.

This guide uses the term Integrated Pest Management (IPM) which, like organic production, emphasizes the use of cultural practices to minimize pest outbreaks. With the limited pest control products available in many organic production systems, IPM techniques such as keeping accurate pest history records, selecting the proper site, and preventing pest outbreaks through use of sanitation, variety selection and biological controls are essential to producing a high quality crop.

All website addresses and links are listed in Section 11, References and Resources. A glossary of terms used in this guide is included at the end in section 12.

1. GENERAL ORGANIC MANAGEMENT PRACTICES

1.1 Organic Certification

Who needs to be certified?

Operations or portions of operations that produce or handle agricultural products that are intended to be sold, labeled, or represented as "100 percent organic," "organic," or "made with organic ingredients" or food group(s).

Farming operations that gross more than $5,000 per year in organic products and want to use the organic label must be certified by a USDA National Organic Program (NOP) accredited certifying agency. The choice of certifier may be dictated by the processor or by the target market. A list of accredited certifiers operating in New York can be found on the New York State Department of Agriculture and Markets Organic Farming Development/Assistance web page. See more certification details in this guide under Section 3.1, Organic Certification Site Requirements.

Who does NOT need to be certified?

Producers and handling (processing) operations that sell less than $5,000 a year in organic agricultural products do not need to be certified. Although exempt from certification, these producers and handlers must abide by the national standards for organic products and may label their products as organic. Handlers, including final retailers, that: do not process or repackage products; only handle products with less than 70 percent organic ingredients; process or prepare, on the premises of the establishment, raw and ready-to-eat food labeled organic; choose to use the word organic only on the information panel; and handle products that are packaged or otherwise enclosed in a container prior to being received by the operation and remain in the same package do not need to be certified. More information can be found at the USDA Agricultural Marketing Service's National Organic Program (NOP) website.

1.2 Organic Farm Plan

An organic farm plan is central to the certification process and is a good management tool, regardless of whether or not certification is being sought. The farm plan describes production, handling, and record-keeping systems, and demonstrates to certifiers an understanding of organic practices for a specific crop. The process of developing the plan can be very valuable in terms of anticipating potential issues and challenges, and fosters thinking of the farm as a whole system. Soil, nutrient, pest, and weed management are all interrelated on organic farms and must be managed in concert for success. Certifying organizations may be able to provide a template for the farm plan. The following description of the farm plan is from the NOP web site:

> "The Organic Food Production Act of 1990 (OFPA or Act) requires that all crop, wild crop, livestock, and handling operations requiring certification submit an organic system plan to their certifying agent and, where applicable, the State Organic Program (SOP). The organic system plan is a detailed description of how an operation will achieve, document, and sustain compliance with all applicable provisions in the OFPA and these regulations. The certifying agent must concur that the proposed organic system plan fulfills the requirements of subpart C, and any subsequent modification of the organic plan by the producer or handler must receive the approval of the certifying agent."

Find more details at the USDA Agricultural Marketing Service's National Organic Program website. The National Sustainable Agriculture Information Service, (formerly ATTRA), has produced a guide to organic certification that includes templates for developing an organic farm plan. The Rodale Institute has also developed resources for transitioning to organic and developing an organic farm plan.

It is important to note that the USDA National Organic Program requires that applicants for certification must keep accurate post-certification records for 5 years concerning the production, harvesting, and handling of agricultural products that are to be sold as organic. These records must document that the operation is in compliance with the regulations and verify the information provided to the certifying agent. Access to these records must be provided, upon request, to authorized representatives of the USDA, including the certifying agent.

2. SOIL HEALTH

Healthy soil is the basis of organic farming. Regular additions of organic matter in the form of cover crops, compost, or manure create a soil that is biologically active, with good structure and capacity to hold nutrients and water. The minimum acceptable days to harvest interval for raw manure is 120 days (see National Organic Standards); buyers may require a period longer than 120 days between application and harvest however. Always maximize the time between the application of raw manure and harvest; in the case of perennial strawberry plantings, application during the planting year is recommended so that manure is not applied during a bearing year. It is important to never side dress with raw manure or use straw that has been used as animal bedding. Decomposing plant materials will support a diverse pool of microbes, including those that break down organic matter into plant-available nutrients as well as others that compete with plant pathogens in the soil and on the root surface. The practice of crop rotation to promote a healthy soil should be initiated in the one or two years prior to planting establishment. Organic growers must attend to the connection between soil, nutrients, pests, and weeds to succeed. An excellent resource for additional information on soils and soil health is Building Soils for Better Crops, 3rd edition, by Fred Magdoff and Harold Van Es, 2010, available from SARE, Sustainable Agriculture Research and Education, www.sare.org/publications/soils.htm. For more information, refer to the Cornell Soil Health website.

3. SITE SELECTION

For organic strawberry production, the importance of proper site selection and preparation cannot be over-emphasized. June-bearing strawberries are usually grown for two to three years in organic production systems, bearing fruit in the second and third years. Day neutral strawberries are usually grown for 2 years in organic production, bearing fruit in the first and second years. These approaches maximize yields while soil nitrogen content remains at acceptable levels. Consider that an ideal site should be close to your markets, be of sufficient acreage to allow for crop rotation, have available water of acceptable quality for irrigation and frost protection, have well-drained soil, and good air drainage (slopes of 3-4% preferably facing north and away from prevailing winter winds). Sites should not have recently been cropped to plants susceptible to Verticillium wilt.

Conduct needed site improvements prior to planting. Once strawberries are planted it is very difficult to make major changes to improve soil and air drainage, or to modify soil tilth, pH, or nutrient status. Improving soil structure or eliminating soil compaction layers in an established planting rarely prove feasible given the few years the crop is in the ground.

Weather plays a critical role in site selection, as well. The macroclimate, mesoclimate and microclimate of a strawberry site play important roles in variety selection and potential profitability. Of particular importance are the potential for spring frosts, winter minimum temperatures, length of the growing season, and growing season heat accumulation. More detailed information on the site selection information presented here also can be found in Strawberry Production Guide for the Northeast, Midwest and Eastern Canada (NRAES-88) available for purchase from Plant and Life Sciences Publishing (PALS, formerly NRAES).

A web-based, interactive site selection tool, the New York Vineyard Site Evaluation System, uses specific climate information with a 3 kilometer resolution, based on 30 years of weather data, to determine the suitability of your site for different grape varieties. Although the tool was developed for vineyards, the map-based system integrates information on climate, topography, soils, and winter low temperatures much of which may be applicable to site selection for strawberry varieties across the state.

3.1 Organic Certification Site Requirements

The National Organic Program has requirements that affect site selection. Fields must not have been treated with prohibited products for three years prior to harvest of the certified organic crop. Mandated one-year crop rotation out of strawberries must be observed, though a 3-5 year rotation is typical. Adequate buffer zones must exist between certified organic and conventionally grown crops to prevent drift of prohibited materials onto certified organic crops. The buffer zones must be either a barrier (diversion ditch or dense hedgerow) or an area of sufficient size. The buffer zone needed will vary depending on equipment used on adjacent non-certified land. For example, use of high-pressure spray equipment or aerial pesticide applications in adjacent fields will increase the buffer zone size. Check with your certifier for specific buffer requirements. Buffer zone sizes commonly range from 20 to 250 ft, depending on adjacent field practices. Buffers can include windbreaks and living barriers such as a dense hedgerow. A dense hedgerow less than 50 ft wide may offer better protection from contamination than a 50-ft-wide open buffer zone. The National Organic Farmers Association of New York (NOFA NY) organic certification guidance manual states: “If the buffer is planted to the same crop as the field, documentation of what is done with the non-certified buffer crop is required. If harvested, non-certified harvest records and equipment cleanout logs should be maintained. ” Crops grown in the buffer zone may not be marketed as certified organic, or used for feed or bedding for certified organic livestock or dairy cattle.

3.2 Soil and Air Drainage and Soil Depth

Preparations for a strawberry planting should begin at least one year in advance. Selecting a site with good air and water drainage is essential for successful organic production. A nutritionally healthy planting in a well-drained soil with exposure to air movement is least susceptible to damage from pests and frosts.

Strawberries need good internal soil drainage to grow and do best on a well-drained sandy loam. Wet soils restrict root growth and respiration, resulting in weak growth and reduced yields. Coarse-textured soils have excellent soil drainage, but heavier soils, or soils with perched water tables often need drainage tiles to remove excess water and improve internal soil drainage. Drainage tile is best installed before planting. Local soil and water conservation districts and private tiling contractors can provide technical assistance in designing a drainage plan, but keep in mind that many base their designs on annual row crops. Perennial crops often require more intensive drainage than annual row crops. Planting on raised beds or on berms is useful to improve soil drainage in the rooting zone. Strawberries should not be grown on heavy clay soils. Because of the need for frequent light cultivation to manage weeds, stony and gravelly soils can also prove difficult.

Air drainage is an important consideration in choosing a strawberry field site. Cold air, like water, runs downhill, and collects in low areas or areas where trees or hedgerows obstruct airflow. These ‘frost pockets’ increase the risk of both mid-winter cold injury and spring frost damage. Selecting a site with a gentle slope (3-4%) and good air drainage will reduce the risk of cold or frost injury. Good air drainage will also promote faster drying of foliage, flowers and fruit which will reduce the duration and frequency of disease infection periods. Good air drainage is essential to an organic disease management strategy.

Although strawberries can be grown on a wide variety of soils, shallow soils have less water holding capacity and will limit root development, resulting in smaller plants with smaller crops. Rooting depth of 12 inches or more is considered important for adequate plant growth and cropping levels. Digging test soil pits can help you evaluate potential rooting depth and drainage issues and evaluate what measures to take to address soil management issues before planting.

3.3 Soil Testing

Knowing all you can about the soil of a potential strawberry site will allow for better management decisions prior to planting. Soil testing is recommended to provide information on pH, availability of major and minor nutrients, organic matter and cation exchange capacity. A pH of 6.0 to 6.5 is suggested for most strawberry varieties. A Cornell Soil Health Test prior to planting will provide a comprehensive picture of soil condition, and includes nutrient analysis plus physical and biological analyses of the soil. See Table 6.1 for soil and tissue testing laboratories and refer to section 6, Nutrient Management, for more information.

A nematode analysis performed on representative soil samples is a wise step in the year or two prior to planting since it will allow time for using a cover crop to reduce plant parasitic nematode populations, see section 4, Cover Crops, for more information. Samples may be submitted for nematode testing to the Plant Disease Diagnostic Clinic, College of Agriculture and Life Sciences, Ithaca, NY. For more information and fee schedules visit their website at www.plantclinic.cornell.edu/. The best time for collecting samples for nematode testing is during summer, when soils are moist, not dry. A minimum of 6 soil subsamples, approx. 1" diameter and 4" deep should be collected randomly from an area approx. ½ acre in size. Gently mix samples together, transfer about 1 pint of mixed soil to a plastic bag, and ship as soon as possible to the diagnostic lab. Refrigerate sample if it cannot be shipped immediately.

3.4 Previous Cropping History

Another factor to consider when selecting a site is previous cropping history. The Verticillium wilt fungus may persist many years in soil and is devastating to strawberries under conditions favorable for disease development. If possible, avoid sites where potatoes, tomatoes, eggplants, or brambles have recently been grown and, to a lesser extent, squash, cucumber, pepper, or melons. These crops serve as hosts to Verticillium wilt. Many weeds are also hosts of the Verticillium fungus, particularly nightshade, groundcherry, redroot pigweed, lambsquarters, and horsenettle. Weeds should be strictly controlled in current and future planting sites to keep Verticillium inoculum low. Rotating to non-susceptible grasses and cereals (5-8 year rotation) will reduce the amount of Verticillium inoculum in infested soil, but seldom eliminates it. Brassica crop rotations (mustards, broccoli, Brussels sprouts) are recommended where Verticillium wilt is present or has been observed in the past. Brassicas should be grown for a 2-yr period and crop residues incorporated into the soil. Practice long rotations out of strawberry and plant only resistant varieties where Verticillium wilt is a problem.

3.5 Irrigation Water Source

Another important criterion to consider when selecting a strawberry site is irrigation water quantity and quality. The irrigation water source should provide sufficient volume of water to irrigate as needed during the growing season. The irrigation system should be in place prior to planting to insure availability of water to the new transplants and to provide frost protection on cold nights during bloom. Trickle irrigation uses water more efficiently than overhead irrigation, but overhead irrigation can be used for frost protection. With trickle systems, row covers are required for frost protection in the absence of overhead irrigation. June-bearing strawberries, grown in a matted row system, typically require 1 to 2 inches of rainfall per week, or 25 to 30 inches per season. The critical periods when June-bearing strawberries require sufficient water to optimize growth and yield are during the fruiting period and after renovation. Day neutral strawberries have similar water requirements but are likely to require more than twice the inches per season as June-bearing strawberries since they flower and fruit more or less continuously from mid-June to first frost in the fall.

Be sure to have a water test done on irrigation water sources prior to site selection to determine its physical, chemical, and biological constituents. Irrigation water pH should be 7.0 or below, and should also have a low salt content (<2.0 ds/m; preferably <1.0 ds/m) as strawberries are a salt-sensitive fruit crop. Always check with your certifier on the products used for lowering irrigation water pH. Water contaminated with sewage or manure should not be used to irrigate strawberries. Use only potable water to irrigate strawberries during bloom and harvest. For more information on irrigation see the Strawberry Production Guide for the Northeast, Midwest and Eastern Canada, available for purchase from Plant and Life Sciences Publishing (PALS, formerly NRAES).

4. COVER CROPS

Cover crops are grown for their valuable effect on soil properties, such as organic matter, and, in strawberries, on their preplant ability to eliminate or suppress weeds, provide nutrients to the plants, and reduce nematode populations. They can also improve water infiltration into the soil, maintain populations of beneficial fungi, and may help control insects and diseases. To be effective, cover crops should be treated as any other valuable crop on the farm, with their cultural requirements carefully considered and met, including nutrient requirements; susceptibility, tolerance, or antagonism to root pathogens and other pests; life cycle; and mowing/incorporation methods. See Table 4.1.1 for more information on specific cover crops.

4.1 Goals and Timing for Cover Crops

Cover crops play an important role in a strawberry planting, especially during the years prior to planting through improvement of soil organic matter, breaking up of compaction layers, erosion control, and suppression or elimination of weeds. Goals should be established for choosing a cover crop; for example, the crop can add nitrogen, smother weeds, or reduce nematode populations. The cover crop might best achieve some of these goals if it is in place for an entire growing season and incorporated into the soil prior to plant establishment.

Table 4.1.1. Cover Crops for Strawberries: Cultural Requirements and Crop Benefits

Species	Planting Dates	Life Cycle	Soil Type Preference	Seeding (Lb/A)	Comments
Alfalfa [1]	Early April-late May	Perennial	Well-drained, high pH (6.0-7.0)	14	+May be difficult to incorporate if allowed to overwinter
Brassicas e.g. mustards, rapeseed	April OR late Aug.-early Sept.	Annual / biennial	Loam to clay	5-12	+Good dual purpose cover & forage +Establishes quickly in cool weather +Mow or incorporate before seed formation +Biofumigant properties
Buckwheat	Late spring-early summer	Summer annual	Most	35-134	+Rapid grower (warm season) +Good catch or smother crop +Good short-term soil improver for poor soils +Mow or incorporate before seed formation +Will winter kill
Cereal Rye	August-early October	Winter annual	Sandy to clay loams	60-200	+Most cold-tolerant cover crop +Excellent allelopathic weed control +Good catch crop, rapid germination & growth +Mow or incorporate before seed formation +Temporary nitrogen (N) tie-up when turned under
Fescues fine (red, hard) tall	April-May OR late Aug.-Sept.	Long-lived perennial	Most	70-100	+Very good low-maintenance permanent cover, especially in infertile, acid, droughty &/or shady sites +Can be incorporated preplant +Tall fescue has high vigor, requires more frequent mowing, and has moderately high water use +Fine fescues have low vigor, require less frequent mowing, and have moderate water use
Marigold	Late May-June	Annual	Most	5-10	+Will winter kill +Biofumigant properties
Oats	Mid-April OR late Aug.-mid Sept.	Summer annual	Silt & clay loams	60-100	+Incorporate in late June when planted in the spring +Rapid growth +Ideal quick cover crop +When planted in late summer, will winter kill
Ryegrass	August-early Sept.	Winter annual OR short-lived perennial	Most	14-35	+Temporary N tie-up when turned under +Rapid growth +Good catch crop +Heavy N & moisture users
Sorghum-Sudangrass	Late Spring-Summer	Summer annual	NI	50-90	+Tremendous biomass producers in hot weather +Good catch or smother crop +Biofumigant properties
Sweet Clover [1]	Early April-mid May OR early August	Annual / biennial	Most	12-20	+Good dual purpose cover & forage +Does not need added nitrogen +May need to be mowed prior to incorporating +Mow or incorporate before seed formation
Vetch [1]	August	Annual / biennial	Most	30-40	+Does not need added nitrogen +Mow or incorporate before seed formation
Wheat	Early-mid Sept.	Winter annual	Most	80-100	+Mow or incorporate before seed formation

Adapted from M. Sarrantonio. 1994. Northeast Cover Crop Handbook; the Mid-Atlantic Berry Guide for Commercial Growers. 2008. Penn State Univ; the Pest Management Guidelines for Berry Crops. 2009. Cornell Univ.; and M. Pritts and D. Handley, eds. 1998. Strawberry Production Guide, NRAES-88.

[1] Legumes may benefit from inoculation of seed with nitrogen-fixing bacteria when planted in a field for the first time. Check with your certifier for allowable sources of inoculum.

Cover crops planted in late summer will suppress annual weed growth, improve soil texture, provide organic matter, and may increase soil nitrogen. The cover crop can be incorporated in late fall or in early spring before planting. Certain cover crops (marigold, sudangrass) will either suppress or resist nematode populations. In addition to producing large amounts of biomass that out-compete other plant species, some cover crops (annual rye, ryegrass) can inhibit weed growth through allelopathy, the chemical inhibition of one plant species by another. Rye provides allelopathic suppression of weeds when used as a cover crop, and when crop residues are retained as mulch. Rye residues retained on the soil surface release chemicals that inhibit germination and seedling growth of many grass and broadleaf weed species. Retention of residue on the soil surface can be accomplished by mowing before seed head formation.

See Cornell's online cover crop decision tool to match goals, season, and cover crop. Although written for vegetable growers it has comprehensive information on various cover crops. Another resource for determining the best cover crop for your situation is the Northeast Cover Crop Handbook, by Marianne Sarrantonio.

Allowing cover crop residue to remain on the soil surface might make it easier to fit into a crop rotation and will help to conserve soil water. Keep in mind that some of the nitrogen contained in the residue will be lost to the atmosphere, and total organic matter added to the soil will be reduced. Turning under the cover crop will speed up decomposition and nitrogen release from the crop residue. Cover crops such as grasses with low nitrogen content should be plowed under in the fall to allow time for decomposition prior to planting strawberries. Legumes which contain more nitrogen and decompose more quickly can be plowed under within a month of planting.

4.2 Legumes

Legumes are looked to as a potential nitrogen source. Legumes may benefit from inoculation of seed with nitrogen-fixing bacteria when planted in a field for the first time. Check with your certifier for allowable sources of inoculum. Legumes such as red clover and hairy vetch will often benefit from having a nurse crop planted simultaneously, usually a small cereal grain such as wheat or rye. These nurse crops establish faster than legumes and provide soil stability and reduce weed pressure during establishment, and provide support for the newly growing legumes before winter. To receive the full nitrogen benefit from planting legumes, they need to be incorporated into the soil just as they start to bloom, which is usually in late spring. (Source: Bjorkman, T. Cover Crops for Vegetable Growers website.)

5. VARIETY SELECTION

Key considerations in variety selection include the market destination and whether June-bearing or day neutrals will be grown. Consider whether the strawberries will be shipped and, if so, choose varieties with good shelf life and shipping quality. Flavor varies considerably between varieties, too, and may be inversely related to shipping quality. Flavor may fluctuate depending on soil type, plant nutrition, and irrigation. Determine whether flavor or shipping quality are most important to your market and choose varieties accordingly. More information about strawberry varieties is available online, in the Strawberry Production Guide for the Northeast, Midwest and Eastern Canada, available for purchase from Plant and Life Sciences Publishing (PALS, formerly NRAES), and in nursery catalogs.

In organic strawberry production, the variety's relative resistance or susceptibility to diseases is vital because of the limited number of organic fungicides that are available for disease management. June-bearing varieties considered to have the best potential for organic production in New York State include:

Earliglow (early season)	Mesabi (midseason)	Allstar (mid/late season)
L'Amour (early/midseason)	Winona (midseason)	Clancy (late season)

Day neutral strawberry varieties considered to have the best potential for organic production in New York include Albion and Seascape.

Varieties vary widely in their susceptibility to fungal diseases and some may be less susceptible to insects. If susceptible varieties are planted, the importance of site, sanitation and cultural practices will increase in accordance to the variety's susceptibility. Table 5.1 lists the relative disease susceptibility of many of the strawberry varieties grown in the Northeast. This is not an inclusive list and does not represent all varieties that are, or have been, grown organically in New York State.

Growers must also consider where they obtain their planting stock. According to language in the USDA-NOP regulation §205.202, "the producer must use organically grown seeds, annual seedlings, and planting stock. The producer may use untreated nonorganic seeds and planting stock when equivalent organic varieties are not commercially available. Seed and planting stock treated with substances that appear on the National List may be used when an organically produced or untreated variety is not commercially available. Planting stock used to produce a perennial crop may be sold as organically produced planting stock after it has been maintained under a system of organic management for at least 1 year. Seeds, annual seedlings, and planting stock treated with prohibited substances may be used to produce an organic crop when the application of the substance is a requirement of Federal or State phytosanitary regulations." With the limited availability of organically certified strawberry stock, growers will likely be able to justify the use of non-organic stock to their certifying agency.

Table 5.1. Relative disease susceptibility among some strawberry varieties[1]

	Disease susceptibility [a]						
Variety	**LSc**	**LSp**	**LB**	**RS[b]**	**PM**	**VW**	**AT**
Albion	U	I	U	R	I	R	I
Allstar	T-R	S-T-R	S	R-VR	T-R	I-T-R	VS
Annapolis	S	S	U	T-R	S	S	U
Cavendish	R	R	U	R	U	T-R	U
Chandler	U	S	S	S	R	U	VS
Clancy	T	T	T	R	R	R	R
Darselect	T	S	S	U	S	U	U
Earliglow	R	S-I-R	S	I-R	S-I-R	I-T-R	S
Evie II	U	U	U	T	T	T	U
Honeoye	T-R	S-T-R	U	S	S-I	S	U
Jewel	R	R	U	S	T	S	U
Kent	I-R	S-R	U	S	S	S	U
L'Amour	T	T	T	T	R	R	R
Lateglow	T-R	T_R	S	R	S	R-VR	U
Mesabi	T	T	U	R	U	R	U
Mira	U	U	U	R	U	U	U
Northeaster	T	T	U	R	U	R	U
Ozark Beauty	U	R	U	S	U	S	U
Redchief	R	S-R	VS	R	S-R	I-R	VS
Sparkle	S-I	S-R	U	S-R	R	I-S	U
Tribute	T	T	U	R-VR	R	T-R	U
Tristar	T	T	U	R	R	R	U
AC Wendy	T	S	U	I	T	S	U
Winona	R	R	U	R	U	T	U

Key: VS = very susceptible, S = susceptible, I = intermediate, T = tolerant, R = resistant, VR = very resistant, U =unknown. Where multiple letter designations are given, ratings varied at different research sites.

[1]The relative ratings in this chart apply to an average growing season. Under conditions favorable for disease development, any given variety may be more severely affected.

[a] LSc=Leaf Scorch, LSp=Leaf Spot, LB=Leaf Blight, RS=Red Stele, BRR=Black Root Rot, PM=Powdery Mildew, VW=Verticillium Wilt, AT=Anthracnose.

[b] Varieties are not resistant to all races of the red stele pathogen.

6. NUTRIENT MANAGEMENT

To produce a healthy crop, soluble nutrients must be available from the soil in amounts that meet the minimum requirements for the whole plant. The challenge in organic systems is balancing soil fertility to supply required plant nutrients at a time and at sufficient levels to support healthy plant growth. Restrictions in any one of the needed nutrients will slow growth and can reduce crop quality and yields. In strawberry plantings, the key considerations when managing nutrition organically include preplant soil pH and nutrient adjustments; nutrition in established plantings; and understanding carbon to nitrogen ratios to deliver appropriate amounts of nitrogen to the crop.

Organic growers often speak of feeding the soil rather than feeding the plant. A more accurate statement is that organic growers focus their fertility program on feeding soil microorganisms rather than the plant. Soil microbes decompose organic matter to release nutrients and convert organic matter to more stable forms such as humus. This breakdown of soil organic matter occurs throughout the growing season, depending on soil temperatures, water availability and soil quality. The released nutrients are then held on soil particles or humus making them available to crops or cover crops for plant growth. Amending soils with compost, cover crops, or crop residues also provides a food source for soil microorganisms and when turned into the soil, starts the nutrient cycle again.

One goal of the grower is to heighten resource use efficiency (land, water, nutrients) to optimize plant growth and fruit yield. Plant size and yield can be influenced by water and nutrient supply (i.e. adequate water is needed for adequate nutrient uptake). Weak plants with few, small leaves will intercept insufficient sunlight to produce adequate yields in the current season or to develop flower buds for the next season. Conversely, over-stimulated plants with abundant large, dark green leaves have low water use efficiency, are more prone to winter injury, diseases and insect feeding, and produce fewer fruit. Organic strawberry plantings should strive to balance soil nutrient availability—via irrigation, organic matter content, soil pH, and microbial activity—with plant growth and production goals.

Nutrient demand for June-bearing strawberries is greatest during leaf and fruit development in spring when reserve nutrients carried over from the previous year have been used up and the plant is actively growing. Conversely, day neutral strawberries have a relatively consistent nutrient demand throughout the course of the season. Plant age, vegetative growth, and fruit yield are the deciding factors in determining the need for nutrients during the growing season.

6.1 Soil and Leaf Analysis

Regular soil and leaf analysis helps monitor nutrient levels. Choose a reputable nutrient testing lab (see Table 6.1.1) and use it consistently to avoid discrepancies caused by different extraction methods. It is recommended that annual leaf testing be incorporated into a fertility management program with biennial soil testing to assist in determining the plants' nutrient status and to make sure that what is in the soil is making it into the plants in the proper amounts. It is recommended that soil and leaf tests be completed in each block. Leaf testing is especially crucial in getting the information needed to make management decisions in problem areas of the planting and should be used on a more frequent basis, if needed.

Table 6.1.1. Nutrient Testing Laboratories

Testing Laboratory	Web URL	Soil	Leaf	Compost/Manure	Forage
Dairy One (Cornell Recommendations)	http://dairyone.com/analytical-services/agronomy-services/about-agro-one/	x	x	x	x
Agri Analysis, Inc.	www.agrianalysis.com/		x	x	
A&L Eastern Agricultural Laboratories, Inc.	www.al-labs-eastern.com/	x	x	x	
Cornell Soil Health (Cornell Recommendations)	soilhealth.cals.cornell.edu/	x			
Penn State Agricultural Analytical Services Lab.	www.aasl.psu.edu/	x	x	x	
University of Massachusetts	http://www.umass.edu/soiltest/	x	x	x	
University of Maine	anlab.umesci.maine.edu/	x	x	x	x

Table 6.1.2. Deficient, sufficient, and excessive nutrient concentrations in strawberry leaves.

		Target values (ppm, unless otherwise noted)		
Nutrient	**Symbol**	**Deficient Below**	**Sufficient**	**Excess Above**
Nitrogen	N	1.90%	2.00-2.80%	4.00%
Phosphorus	P	0.20%	0.25-0.40%	0.50%
Potassium	K	1.30%	1.50-2.50%	3.50%
Calcium	Ca	0.50%	0.70-1.70%	2.00%
Magnesium	Mg	0.25%	0.30-0.50%	0.80%
Sulfur	S	0.35%	0.40-0.60%	0.80%
Boron	B	23	30-70	90
Iron	Fe	40	60-250	350
Manganese	Mn	35	50-200	350
Copper	Cu	3	6-20	30
Zinc	Zn	10	20-50	80

Adapted from: Pritts (1998) Soil and Nutrient Management. Chap. 7 In: Strawberry Production Guide. M. Pritts and D. Handley (eds.). NRAES-88. Ithaca, NY.
Note: ppm is parts per million.
% by dry weight of strawberry leaf

Table 6.1.2 gives the target values for strawberry leaf nutrients sampled in late July or early August in the Northeast. Regular soil testing helps monitor nutrient levels, in particular phosphorus (P) and potassium (K). The source of these nutrients depends on soil type and historic soil management. Some soils are naturally high in P and K, or have a history of manure applications that have resulted in elevated levels. Additional plant available nutrients are supplied by decomposed soil organic matter or through specific soluble nutrient amendments applied during the growing season in organically managed systems. Many types of organic fertilizers are available to supplement the nutrients supplied by the soil. ALWAYS check with your certifier before using any product to be sure it is approved.

6.2 Soil pH

Maintaining a soil pH range of 6.0 to 6.5 is recommended for strawberries. Use the soil test results to determine the appropriate amount of lime (raise pH) or sulfur (lower pH) to apply. The lime or sulfur requirement will depend on soil texture, current pH, and organic matter content. Follow the recommendations of the soil test and apply and incorporate sufficient lime or sulfur prior to planting. It typically takes one year for the applied lime or sulfur to raise or lower the soil pH, respectively. The slightly acid soil pH of 6.0 to 6.5 is required to help avoid micronutrient deficiencies.

Prilled sulfur formulations are preferred for soil application because they are easier to work with, provide better coverage, and are cheaper than powdered sulfur. Prilled sulfur takes about one year or more to oxidize and reduce soil pH; powdered sulfur takes 6 to 9 months. Likewise, finely ground lime is more difficult to work with, but it will raise the soil pH faster than coarse particles.

6.3 Managing Nutrients

Table 6.3.1. Available Potassium in Organic Fertilizers

	Pounds of Fertilizer/Acre to Provide given Pounds of K_2O per acre:				
Sources	**20**	**40**	**60**	**80**	**100**
Sul-Po-Mag 22% K_2O also contains 11% Mg	90	180	270	360	450
Wood ash (dry, fine, grey) 5% K_2O, also raises pH	400	800	1200	1600	2000
Alfalfa meal[a] 2% K_2O, also contains 2.5% N and 2% P	1000	2000	3000	4000	5000
Greensand or Granite dust 1% K_2O (x 4)[b]	8000	16000	24000	32000	40000
Potassium sulfate 50% K_2O	40	80	120	160	200

[a]Only non-GMO sources of alfalfa may be used. Check with your certifier.

[b]Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Should be broadcast and incorporated prior to planting.

Table 6.3.2. Available Phosphorous in Organic Fertilizers

	Pounds of Fertilizer/Acre to Provide given Pounds of P_2O_5 Per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Bone meal 15% P_2O_5	130	270	400	530	670
Rock Phosphate 30% total P_2O_5 (x4)[a]	270	530	800	1100	1300
Fish meal 6% P_2O_5 (also 9% N)	330	670	1000	1330	1670

[a] Application rates for some materials are multiplied to adjust for their slow to very slow release rates. Should be broadcast and incorporated prior to planting.

Follow the recommendations of the soil test when adding nutrients to prepare a site for planting. Pay particular attention to the soil test results for potassium, phosphorus, magnesium, calcium, and boron. If interpreting your own soil tests, it is important to know the phosphorus extraction method used by your analytical lab in order to get a proper recommendation. When preplant recommendations are followed, additional potassium and phosphorus likely will not be required unless the soil is very sandy. However, potassium (K) demand by strawberry plants is relatively high, so make certain there is sufficient available potassium in the soil preplant. Boron is frequently low in fruit plantings throughout the Northeast. Note: Boron testing is not included in most standard soil test packages and should be selected as an added test for strawberry soils. Refer to CALCULATING THE AMOUNT OF PESTICIDE TO USE and Tables 9.1.1, 9.1.2, and 9.1.3 in Section 9.1 for converting amounts per acre to amounts needed for smaller areas and for measuring and mixing small amounts.

In established plantings, base fertilizer amounts on leaf analysis. In the event that potassium is required, a reasonable amount of potassium to apply, preferably in the fall, is up to 100 lb/acre. See table 6.3.1 for organic sources of potassium. Pay attention to the K/Mg ratio and if it is above 4, then additional magnesium should be applied with the potassium fertilizer to prevent inducing a magnesium deficiency: the K/Mg ratio should be less than 5.

Magnesium (Mg) deficiency in strawberry is quite common. Factors that influence magnesium availability include soil pH and excess potassium. In established plantings that are low to deficient in magnesium, typical recommendations would be for 10-40 lb/acre actual magnesium, but follow recommendations of the leaf analysis.

Boron is frequently low in fruit plantings throughout the Northeast. If boron is required, then apply no more than 2 lb/acre actual boron in any one year. The best time to apply boron is after leaves are mowed at renovation. Check with your certifier for information on allowable sources of magnesium and boron.

Phosphorus demand by strawberry is relatively low, and phosphorus is usually not required in established plantings. Table 6.3.2 lists some organic fertilizer sources of P.

6.4 Preparing a Nitrogen Budget

The carbon to nitrogen (C/N) ratio in compost can provide a guide for nitrogen release into the soil solution. When a decomposing material has a low C/N ratio (a lot of nitrogen) microbes release the excess nitrogen into the soil solution. When a material undergoing decomposition has an initially high C/N ratio (very little nitrogen), microbes will use whatever nitrogen is available for their own growth, leaving little for plants. This can result in temporary nitrogen deficiency. Once the decomposition process begins to slow and those microbes die off, they will release their nitrogen back into the soil where it will become available to plants. The rule of thumb is that if the C/N ratio is less than 20 or the material's nitrogen content is greater than 2.5%, then there will be enough nitrogen available for both decomposer microbes and plants. If the C/N ratio is above 20, then nitrogen will likely be immobilized until sufficient decomposition has taken place. One reason for applying nitrogen fertilizer at renovation is to help overcome the temporary nitrogen deficiency that will occur when the straw (with a high C/N ratio) is worked into the soil.

Develop a plan for estimating the amount of nutrients that will be released from soil organic matter, cover crops, compost, and manure. Submit soil samples for a Cornell Soil Health Test. This test includes an estimate of nitrogen mineralization rate, which indicates the potential release of N from soil organic matter. Test results will provide feedback on how the soil sample compares to other New York soils. The results can also be useful for monitoring changes in the nitrogen mineralization rate over time and during the transition to organic production.

Management of N, and insuring adequate supply at the times of crop need, requires some planning. Prepare a nitrogen budget for organic production to estimate the amount of N released by various organic amendments as well as native soil organic matter. Examples of manures and their nutrient content are shown in Table 6.4.1. Compost and manure should be tested for nutrient content at an analytical lab, and cover crops can be tested at a forage testing lab (Table 6.1.1). Knowing these values will help evaluate if the budget plan is providing appropriate amounts of N during the season by comparing them to the nitrogen guidelines for strawberries (Table 6.4.2)

Table 6.4.1. Estimated Nutrient Content of Common Animal Manures

	N	P_2O_5	K_2O	N1[a]	N2[b]	P_2O_5	K_2O
	NUTRIENT CONTENT LB/TON			*AVAILABLE NUTRIENTS LB/TON IN FIRST SEASON*			
Dairy (with bedding)	9	4	10	6	2	3	9
Horse (with bedding)	14	4	14	6	3	3	13
Poultry (with litter)	56	45	34	45	16	36	31
Compost (from dairy manure)	12	12	26	3	2	10	23
Composted poultry manure	17	39	23	6	5	31	21
Pelleted poultry manure[c]	80	104	48	40	40	83	43
Swine (no bedding)	10	9	8	8	3	7	7
	NUTRIENT CONTENT LB/1000 GAL.			*AVAILABLE NUTRIENTS LB/1000 GAL FIRST SEASON*			
Swine finishing (liquid)	50	55	25	25*	20+	44	23
Dairy (liquid)	28	13	25	14*	11+	10	23

[a] N1 is the total N available for plant uptake when manure is incorporated within 12 hours of application.
[b] N2 is the total N available for plant uptake when manure is incorporated after 7 days.
[c] Pelletized poultry manure compost. Available in New York from Kreher's.
* injected, + incorporated.
Adapted from *"Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops"* by Carl Rosen and Peter Bierman and Penn State Agronomy Guide 2007-8.

Using the values from your soil test, estimate that 20 lbs. of nitrogen will be released from each percent organic matter in the soil. From the test of total N in any manure applied, estimate that 50% is available in the first year, and then 50% of the remaining is released in each of the next two years. So, for an application rate of 100 lbs. of N as manure, 50 lbs. would be available the first year, 25 lbs. the second, and 12.5 lbs. the third. Remember to check with your certifier on the days-to-harvest interval when using raw manure and allow a minimum of 120 days between application and harvesting. To prevent run-off, do not apply raw manure to bare ground in established strawberry plantings.

Estimate that between 10% and 25% of the N contained in compost will be available the first year. It is important to test each new mix of compost for actual amounts of the different nutrients available. Compost maturity will influence how much N is available. If the material is immature, more of the N may be available to the crop in the first year. A word of caution: Using compost to provide for a crop's nutrient needs is not generally a financially viable strategy. The total volume, trucking, and application can be very expensive for the units of N available to the crop. Most stable composts should be considered as soil conditioners, improving soil health, microbial diversity, tilth, and nutrient retaining capacity.

Add together the various N values from these different organic sources to estimate the N supplying potential of the soil. There is no guarantee that these amounts will actually be available in the season, since soil temperatures, water, and crop physiology all impact the release and uptake of these soil nutrients. If early in the organic transition, a grower may consider increasing the N budget supply by 25%, to help reduce some of the risk of N being limiting to the crop. Remember that with a long-term approach to organic soil fertility, the N mineralization rates of the soil will increase. This means that more N will be available from organic amendments because of increased soil microbial activity and diversity. Feeding these organisms different types of organic matter is essential to help build this type of diverse biological community and ensure long-term organic soil and crop productivity.

Table 6.4.2. Annual Nitrogen Guidelines for June-bearing strawberries.

Planting Age (years)	Amount Actual N (lbs/Acre)	Time of Year to Apply
0	30	early June[a]
	30	early Sept[a]
1+	70	at renovation
	30	early Sept[b]

[a] Be sure plants are growing well prior to application.
[b] Adjust amount based on leaf analysis.

The annual nitrogen guidelines for June-bearing strawberries are outlined in Table 6.4.2. Use leaf analysis for determination of nutrient status in established plantings, and adjust nitrogen fertilization accordingly (see section 6.1). The primary challenge in organic systems is synchronizing nutrient release from organic sources, particularly nitrogen, with crop requirements. In cool soils, microorganisms are less active, and nutrient release may be too slow to meet the crop needs. Once the soil warms, nutrient release may exceed crop needs. In a long-term organic nutrient management approach, most of the required crop nutrients would be in place as organic matter before the growing season starts. Nutrients needed by the crop in the early season can be supplemented by highly soluble organic amendments such as poultry manure composts or organically approved bagged fertilizer products (see Tables 6.4.1 and 6.4.3). These products can be expensive, so are most efficiently used if applied in a 1 foot band over the plant row, splitting applications between May and early June. Be aware that spring applications of nitrogen can greatly increase the risk of gray mold fruit rot infections.

Day neutral strawberries generally require 3 lb actual nitrogen per week during active spring growth. This rate should be increased to 5 lb actual N per week when fruiting begins. During the fruiting period, plants may require additional potassium; alternate a nitrogen fertilizer every other week with a nitrogen fertilizer product that supplies both N and K.

Table 6.4.3 lists some commonly available fertilizers, their nutrient content, and the amount needed to provide different amounts of available nitrogen, adapted by Vern Grubinger from the University of Maine soil testing lab.

Table 6.4.3. Available Nitrogen in Organic Fertilizers

	Pounds of Fertilizer/Acre to Provide given Pounds of N per Acre				
Sources	**20**	**40**	**60**	**80**	**100**
Blood meal 13% N	150	310	460	620	770
Soy meal 6% N (x 1.5)[a], also contains 2% P and 3% K_2O	500	1000	1500	2000	2500
Fish meal 9% N, also contains 6% P_2O_5	220	440	670	890	1100
Alfalfa meal 2.5% N also contains 2% P and 2% K_2O	800	1600	2400	3200	4000
Feather meal 15% N (x 1.5)[a]	200	400	600	800	1000

[a] Application rates for some materials are multiplied to adjust for their slow to very slow release rates.

7. ORGANIC STRAWBERRY IPM

Organic production of strawberries is challenging in New York State given the abundant rainfall during the growing season leading to increased pressure from diseases, insects and weeds. However, growers in New York and the eastern United States, through proper variety and site selection, strict attention to cultural practices and sanitation, and increased attention paid to scouting plantings on a weekly basis to catch pest outbreaks early, have succeeded in producing quality organic strawberries. In contrast, a failure to appreciate the risk of disease, insect and weed development, and failure to devise and implement a season-long (and multiyear) management strategy, can lead to serious crop and even plant losses in particular years. Successful IPM is essential to the sustainable production of organic strawberries.

7.1 Developing a Strawberry IPM Strategy

1. Examine your strawberry operation closely. Break it down into specific plantings, or "strawberry blocks."
2. Produce a map of each planting (or block) to record weeds, pest outbreaks, nutrient deficiencies, drainage problems, missing plants, and any other abnormalities you find.
3. Develop a record-keeping system for each planting or block.
4. Develop a scouting plan for each block and record results.
5. Monitor and record weather factors and understand basic weather patterns of the area.
6. Keep accurate records of spray applications, tools, or tactics used to manage pests.
7. Properly maintain your spray equipment, calibrate the sprayer, select appropriate nozzles, and reduce spray drift. Consult the Pesticide Application Technology website at Cornell University or the Strawberry Production Guide for the Northeast, Midwest, and Eastern Canada (NRAES-88) available for purchase from PALS Publishing.
8. Develop a thorough knowledge of the strawberry pests you are likely to encounter during the year. This includes basic pest biology, symptoms or damage, whether they are a primary or secondary pest, scouting thresholds, and the best time to implement management practices.
9. Choose a pest management strategy for the planting (or block) that is based on all of the information you've gathered. Use the options that make the most sense for your operation.
10. Continue your pest management education.

Other resources available online, include:
New York State IPM website: nysipm.cornell.edu/fruits/
Cornell Fruit Resources: www.fruit.cornell.edu/berry/
New York State berry IPM insect and disease fact sheet index: nysipm.cornell.edu/factsheets/berries/
Cornell University Pesticide Management Education Program: pmep.cce.cornell.edu/
Pesticide Application Technology at Cornell University: web.entomology.cornell.edu/landers/pestapp/
Elements of IPM for Strawberries in New York State www.nysipm.cornell.edu/elements/strawb.asp
Network for Environment and Weather Applications (NEWA) newa.cornell.edu
Berry Diagnostic Tool www.fruit.cornell.edu/berrytool/

7.2 Weed Management

Weed management is a major challenge for strawberry growers. Weeds are part of the strawberry planting ecosystem and can compete for water and nutrients; provide alternate hosts for pests; and interfere with planting operations. Weed growth can also alter the microclimate around plants, leading to higher disease pressure. In organic production, site preparation prior to planting spanning 2- to 3-years to eliminate weeds through cover cropping and cultivation will provide lasting benefits in weed control for the short-term perennial production cycle of strawberries. Table 7.2.1 outlines weed management practices in strawberry plantings.

Table 7.2.1. Weed management without herbicides in a strawberry planting.

Year	Month	Non-herbicidal options
Planting year [1]	**April - May**	Till to prepare for planting.
	May	Cultivate.
[1]CRITICAL TIME FOR REDUCING WEEDS.	**Mid-June after planting**	Cultivate.
	Mid-July	Cultivate.
	Mid-August	Cultivate.
	October	Cultivate.
	Late November	Mulch for winter protection.
Fruiting years	**March - April**	Remove mulch.
	Early May	Hand weed only.
	Late July after harvest	Mow leaves, narrow rows with a tiller.
	September	Cultivate.
	November	Mulch for winter protection.

Excellent preplant preparation with the goal of eliminating perennial weeds from the site before planting is essential. Good preplant preparation, use of cover crops, and crop rotation help reduce weed pressure considerably. Eliminating perennial weeds can be achieved with repeated cultivation and using "green manure" cover crops that are plowed under prior to planting. For more information on cover crops see section 4. Keep in mind that excessive cultivation can lead to undesirable consequences such as soil erosion, reduced soil organic matter, and breakdown in soil structure resulting in compaction and reduced permeability.

Minimizing weed competition during plant establishment is critical to achieve optimal plant growth and yields. Once plants are set, regular hand weeding, hoeing, and cultivation are required throughout the first year. Do not let weeds go to seed, and keep the surrounding area mowed to prevent weed seeds from migrating into the planting site. If a first year planting is healthy, dense, and weed free prior to winter, weed problems will be much less in subsequent years. Some growers are planting in late May or early June at a higher density to reduce weed pressure.

Managing weeds within the row may be one of the most difficult tasks in the production of organic strawberries. Inorganic mulches like plastic can only be used in organic production if they are removed from the soil annually. There has been some recent research in Italy with the use of biodegradable mulch films (starch-based) that do not need to be removed from the soil. These materials have shown promise in New York strawberry plantings.

Organic mulches can also be used as tools for weed management. They are most effective where soil moisture and fertility are low and where low plant size restricts crop productivity. To provide adequate weed control, organic mulches must be at least 4 inches thick. Potential organic mulches include straw, hay, sawdust, and wood chips. Mulch matted row plantings with straw (wheat or rye works best) for winter protection, then rake the straw into the alleyways for additional weed suppression. Straw mulch may serve as a major source of weed seed; be sure to inspect straw before purchase. Use of straw or hay mulch between the rows for suppression of weed growth is also an excellent method of water conservation and increasing the soil organic matter. Financial assistance to help pay for mulch may be available from your county's Soil and Water Conservation District office.

There are a number of mechanical, thermal and animal measures that can be used to limit the effects of weeds in a strawberry planting. Mechanical and thermal options include fixed hoes, rotary cultivators, flamers, steamers, and hot water applicators. Animal weeders have also been used with some success in organic plantings across the United States. The use of weeder geese, guinea fowl, and sheep have some effectiveness, but due to food safety concerns regarding microbial contamination of food crops from manure they should be used during the planting (non-bearing) year only. The mechanical brush hoe, in particular, showed promise for use in matted row strawberry production. Just two well-timed passes provided excellent seasonal weed control. The brushes moved runners back into the row, allowing cultivation to occur later in the season compared with other implements. The resulting layer of dust created by the implement "mulched" the field and suppressed weed seed germination.

Herbicides are applied on the basis of the sprayed area. Use the formula below to calculate rates needed. For example, if plants are set in rows 8 feet apart and there is to be a 4-foot grass aisle between the rows and a 4-foot weed-free strip within the row, only 50 percent of the given rate of herbicide will be required per planted acre.

$$\frac{\textbf{Width of weed-free strip}}{\textbf{Distance between rows}} \times \textbf{Recommended rate of herbicide} = \textbf{Rate per planted acre}$$

Note: An organic herbicide strategy alone cannot provide satisfactory weed control for organic strawberry growers.

At the time this guide was produced, the following materials were available in New York State for managing weeds and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Organic Herbicides Labeled for Management of Weeds in Strawberry

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
AXXE Broad Spectrum Herbicide *(ammonium nonanoate)*	6-15% solution	-	24	?	

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?- not reviewed or no research available.
PHI - pre-harvest interval, REI - re-entry interval, - = pre-harvest interval isn't specified on label.

7.3 Principles of Insect and Disease Management

While strawberry production may be severely limited by insect pests and plant diseases, an understanding of the factors involved in their development can ensure effective management. The development of disease and insect damage is highly dependent on characteristics and conditions of the crop (host), the pathogen/pest population, and the environment. These factors all must be conducive before disease development and/or considerable insect damage will occur.

Characteristics of the host that influence disease and pest susceptibility include the host's vigor, physiology, and variety (genetics). Aggressiveness or virulence, abundance, and physiology are characteristics of the pest or pathogen populations that influence their ability to cause disease or damage. At the same time, abiotic environmental conditions such as temperature, moisture, light, and soil chemistry can affect both the host and pest and may promote or prevent disease. Moreover, the presence, abundance and activity of natural enemies can play an important role in determining pest status. The most successful disease pathogens and insect pests have coevolved with their hosts over many years to incite disease and damage at the most opportune times. To successfully minimize disease and pest damage, the relevant aspects of the host, pathogen/pest, and environment must all be managed within specific timeframes.

Although insect pests and plant disease pathogens are vastly different in their biology, they often have enough similarity in life history strategies to allow successful management under a single set of underlying principles. These principles include avoidance/exclusion, eradication, and protection. They are defined below.

Avoidance/exclusion

This principle focuses on preventing pathogen introduction and minimizing factors that favor the establishment of pests and pathogens. Several practices that exclude or limit pathogen and pest presence include the following:

- Select sites with good soil drainage. Install tile in plantings with less than optimal drainage and/or incorporate raised beds or berms to further promote soil drainage.
- Choose sites with good air drainage. Promote air circulation by selecting an open site, removing dead or senescent plant material and reducing weeds; these practices allow fruit and leaves in berry plantings to dry more quickly.
- Plant only disease free and insect free planting stock.
- Prevent rain-splash dispersal of soil particles by applying a thick layer of mulch under and around plants.
- Practice weed management as weeds can be hosts for strawberry pathogens and arthropod (insect and mite) pests.
- Avoid planting strawberries in proximity to other crops or habitats that harbor large pathogen and/or pest populations.

Eradication

This principle is concerned with the destruction of pathogen/pest populations. These practices include:

- Sanitation of plantings by removal of infected/infested plant material including overripe fruit, leaf litter, and plants to eradicate pathogen and pest populations. Destruction of this material is accomplished through burning, chipping, burying, and composting.
- Several biological control alternatives are available for insect suppression for strawberry crops including products based on formulated *Bacillus thuringiensis* and insectary-reared predatory mites. Currently, no reliable biological control tactics have been developed for strawberry diseases, although biopesticides, such as Serenade, are available.
- Chemical application of fungicides, insecticides, and miticides may reduce pathogen and pest populations below damage thresholds, but will rarely eradicate them.

Protection

This principle is founded on protection of plants from pathogen infection and pest damage. Practices that protect plants by minimizing factors favoring infection and damage include the following:

- Plant strawberry varieties that are disease resistant or less susceptible to diseases of concern.
- Consider the use of protected production structures such as low tunnels, to reduce occurrence of fruit rots.
- Avoid excessive nitrogen fertilization as many pathogens, insects and mites thrive on succulent tissues.
- Keep fruit from contacting soil by use of mulch under and around the plants.
- Harvest fruit promptly and cool it to protect from fruit rots and insect infestations on overripe fruit.
- Applications of fungicides, insecticides, or miticides may protect susceptible tissues from disease and insect damage.

7.4 DISEASES OF PRIMARY CONCERN

Several important diseases that occur in the temperate climate of the northeastern U.S. are described below to help growers manage them with appropriate organic practices.

7.4.1 Leaf Blight (*Phomopsis obscurans*)

Leaf lesions begin as small, circular to irregular, reddish, or purplish spots. As they expand, lesion centers become necrotic and turn light brown with a dark purple halo. Older lesions along major leaf veins develop into large V-shaped lesions that eventually kill the leaf. Heavy leaf infections can inhibit the production of flower buds for the following year, predispose a plant to winter injury, and provide inoculum for infection of the fruit caps. Fruit may also be infected in some instances.

Leaf Blight Management Options	
Scouting/thresholds	None established.
Variety susceptibility	There are no reports of cultivar resistance to leaf blight.
Cultural management	Destroying infected leaves at renovation (e.g., mowing and burying) will reduce the amount of carry-over inoculum. Promoting air circulation (plant spacing and weed control) will reduce foliage drying time and limit infection periods.
Chemical treatment	An early season fungicide application is recommended when carry-over inoculum from the previous year is high or conditions are favorable for disease development.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.4.1 Pesticides Labeled for Management of Leaf Blight

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Badge X2 (*copper oxychloride, copper hydroxide)*	0.75-1.25 lb/A	-	48	?	Apply in at least 20 gal water.
Champ WG (*copper hydroxide*)	2-3 lb/A	-	48	?	May cause crop injury under some conditions.
CS 2005 *(copper sulfate pentahydrate)*	19.2-25.6 oz/A	-	48	?	
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.
Milstop *(potassium bicarbonate)*	2-5 lb/A	0	1	?	Do not mix with other pesticides or fertilizers. Not compatible with alkaline solutions.
Nu-Cop 50 DF *(copper hydroxide)*	2-3 lb/A	1	24	?	Use higher rate when conditions favor disease. Discontinue use if signs of phytotoxicity appear. Copper may cause blue spotting on fruit.
Nu-Cop 50 WP *(copper hydroxide)*	2-3 lb/A	1	24	?	Use higher rate when conditions favor disease. Discontinue use if signs of phytotoxicity appear. Copper may cause blue spotting on fruit.
Nu-Cop HB *(cupric hydroxide)*	1-1.5 lb/A	1	24	?	Discontinue applications if signs of phytotoxicity appear.
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	32 fl oz – 1 gal/100 gal water	0	Until spray has dried	?	Typical applications use 30-100 gals of spray solution per acre. At planting and in existing planting, foliar application.

Table 7.4.1 Pesticides Labeled for Management of Leaf Blight					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
PERpose Plus (*hydrogen peroxide/dioxide*)	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/ preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Regalia (*Reynoutria sachalinensis)*	1-3 qts/ A	0	4	?	Initiate at first sign of disease then every 7-14 days
Trilogy (*neem oil)*	1% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/acre.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.2 Leaf Scorch (*Diplocarpon earliana*)

Dark purple leaf spots about one eighth to one quarter inch in diameter appear scattered over the upper leaf surfaces or petioles. These spots differ from those of leaf spot in that they are purple throughout (no light centers). Numerous infections can cause a leaf to appear red or light purple and eventually to dry up and appear scorched. Heavy leaf infections can inhibit the production of flower buds for the following year, predispose a plant to winter injury, and provide inoculum for infection of the fruit caps.

Leaf Scorch Management Options	
Scouting/thresholds	None established.
Variety susceptibility	Resistance and tolerance has been reported for several varieties. However, reports from different states often conflict; hence resistance/tolerance may be variable and/or region dependent. A consensus of reports suggests that 'Allstar', 'Jewel', 'Canoga', 'Cardinal', 'Cavendish', 'Earliglow', 'Lester', and 'Redchief' have some resistance. 'Tristar' and 'Tribute' are susceptible but tolerant of infection.
Cultural management	Destroying infected leaves at renovation (e.g., mowing and burying) will reduce the amount of carry-over inoculum. Promoting air circulation (plant spacing and weed control) will reduce foliage drying time and limit infection periods.
Chemical treatment	Check with your organic certifier about allowable copper formulations.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.4.2 Pesticides Labeled for Management of Leaf Scorch					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Badge X2 (*copper oxychloride, copper hydroxide)*	0.75-1.25 lb/A	-	48	?	Apply in at least 20 gal water.
CS 2005 (*copper sulfate pentahydrate)*	19.2-25.6 oz/A	-	48	?	

Table 7.4.2 Pesticides Labeled for Management of Leaf Scorch					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.3 Leaf Spot (*Mycosphaerella fragariae*)

Initial lesions on leaves begin as small, irregularly shaped purple spots. Mature lesions become approximately one eighth to one quarter inch in diameter; remain relatively round, and the centers of lesions turn from a purplish brown to grayish white. The pathogen primarily infects young, expanding leaves and petioles, and occasionally fruit (black seed). Heavy leaf infections can inhibit the production of flower buds for the following year, predispose a plant to winter injury, and provide inoculum for infection of the fruit caps.

Leaf Spot Management Options	
Scouting/thresholds	None established.
Variety susceptibility	Resistance and tolerance has been reported for several varieties. However, reports from different states are often in conflict with one another; hence resistance/tolerance may be variable and/or region dependent. A consensus of reports suggests that 'Jewel', 'Canoga', 'Cardinal', and 'Lester', have some resistance. 'Tristar' and 'Tribute' are susceptible but tolerant of infection.
Cultural management	Destroying infected leaves at renovation (e.g., mowing and burying) will reduce the amount of carry-over inoculum. Promoting air circulation (plant spacing and weed control) will decrease foliage drying time and limit infection periods.
Chemical treatment	An early season fungicide application is recommended when carry-over inoculum from the previous year is high or conditions are favorable for disease development.

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Table 7.4.3 Pesticides Labeled for Management of Leaf Spot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Badge X2 *(copper oxychloride, copper hydroxide)*	0.75-1.25 lb/A	-	48	?	Apply in at least 20 gal water.
Basic Copper 53 *(copper sulfate)*	2-3 lb/100 gal/A	Up to day of harvest	24	?	Copper may cause blue spotting on fruit.
Champ WG (*copper hydroxide*)	2-3 lb/A	-	48	?	May cause crop injury under some conditions.
CS 2005 *(copper sulfate pentahydrate)*	19.2-25.6 oz/A	-	48	?	
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.

Table 7.4.3 Pesticides Labeled for Management of Leaf Spot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Nordox 75 WP *(cuprous oxide)*	3-5 lb/A	0	12	?	Begin application when plants are established and then on a weekly basis.
Nu-Cop 50 DF *(copper hydroxide)*	2-3 lb/A	1	24	?	Use higher rate when conditions favor disease. Discontinue use if signs of phytotoxicity appear. Copper may cause blue spotting on fruit.
Nu-Cop 50 WP *(copper hydroxide)*	2-3 lb/A	1	24	?	Use higher rate when conditions favor disease. Discontinue use if signs of phytotoxicity appear. Copper may cause blue spotting on fruit.
Nu-Cop HB *(cupric hydroxide)*	1-1.5 lb/acre	1	24	?	Discontinue applications if signs of phytotoxicity appear.
PERpose Plus (*hydrogen peroxide/dioxide*)	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Regalia *(Reynoutria sachalinensis)*	1-3 qts/A	0	4	?	Initiate at first sign of disease then every 7-14 days.
Trilogy (*neem oil*)	1% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/acre/application.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.4 Powdery Mildew (*Podosphaera aphanis*)

The edges of infected leaves roll up, sometimes revealing a white, powdery layer of mycelium and spores on the lower leaf surfaces. Purple to reddish blotches also occur frequently on the lower leaf surfaces. Symptoms are usually not evident until middle or late summer. Numerous pepper-like black flecks (overwintering spore-producing structures – cleistothecia) may appear on infected leaf surfaces in fall.

Powdery Mildew Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties. If possible, **avoid** varieties commonly infected in New York which include: 'Earliglow', 'Darselect', 'Evangeline', 'Annapolis', and to a lesser extent, 'Raritan'.
Cultural management	Manage weeds and regulate planting density to promote good air circulation. Avoid excessive nitrogen and sites with poor air drainage.
Chemical treatment	See table below.

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Table 7.4.4 Pesticides Labeled for Management of Powdery Mildew

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Acoidal *(sulfur)*	5-10 lb/A	-	24	1	Begin applications when disease first appears. Repeat as necessary. Do not use on sulfur sensitive varieties.
Actinovate-AG *(Streptomyces lydicus WYEC 108)*	3-12 oz/A	0	1 (or until spray has dried)	3	Foliar application. For best results apply with a spreader/sticker prior to onset of disease. Re-apply at 7-14 day intervals depending on disease pressure and environmental conditions.
Cinnerate *(cinnamon oil)*	13-30 fl oz/100 gal water	-	-	?	25(b) pesticide. Apply 85-125 gal diluted spray/A.
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.
Defend DF *(sulfur)*	5-10 lb/A	-	24	1	Begin applications when disease first appears. Repeat as necessary. Do not use on sulfur sensitive varieties.
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.25-3 lb/A	0	4	?	Foliar application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-6 qt/A	0	4	?	Foliar application.
Glacial Spray Fluid (*mineral oil*)	0.75 gal/100gal	Up to day of harvest	4	?	See label for specific application volumes and equipment.
Golden Pest Spray Oil (*soybean oil*)	0.5-1% solution	-	4	?	
JMS Stylet Oil Organic JMS Stylet Oil *(paraffinic oil)*	3 qt/100 gal water	0	4	2	A high volume of water is needed for through coverage. Many common pesticides are phytotoxic when applied with or close to oil sprays (e.g., sulfur). Check label for restrictions.
Kaligreen *(potassium bicarbonate)*	2.5-3.0 lb/A	1	4	3	Do not mix with highly acidic products or nutrients.
Kumulus DF *(sulfur)*	5-10 lb/A	-	24	1	Begin applications when disease first appears. Repeat as necessary. Do not use on sulfur sensitive varieties.
Micro Sulf (*sulfur*)	5-10 lb/A	-	24	1	Some varieties may be sensitive to sulfur.
Microthiol Disperss (*sulfur*)	5-10 lb/A	-	24	1	Not recommended within 2 weeks of an oil application nor if temperatures are expected to exceed 90 degrees within 3 days following the application.
Mildew Cure (*cottonseed, corn, and garlic oils*)	1 gal/100 gal water/A	-	-	?	25(b) pesticide. Conduct phytotoxicity test prior application.
Milstop *(potassium bicarbonate)*	2-5 lb/A	0	1	3	Do not mix with other pesticides or fertilizers. Not compatible with alkaline solutions.
M-Pede *(potassium salts of fatty acids)*	1-2% vol/vol	0	12	?	Curative control.
Organocide 3-in-1 (*sesame oil*)	1-2 gal/100 gal water/A	-	-	?	25(b) pesticide.

Table 7.4.4 Pesticides Labeled for Management of Powdery Mildew					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	64 fl oz/100 gal water (pre-plant dip) 32 fl oz – 1 gal/100 gal water (foliar spray)	0	Until spray has dried	?	Pre-plant dip. At-planting foliar application and foliar and crown disease control for existing plantings.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	3	For curative uses, apply the curative rate For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
PureSpray Green (*petroleum oil*)	0.75-1.5 gal/100 gal at 100-200 gals water/A	Up to day of harvest	4	?	Spray at no less than 400 PSI using ceramic nozzles.
Sil-Matrix (*potassium silicate*)	0.5-1% solution	0	4	?	Apply at 50-250 gal/A finished spray.
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water/A	Up to day of harvest	4	?	Do not mix with sulfur products.
Thiolux *(sulfur)*	5-10 lb/A	-	24	1	Not recommended within 2 weeks of an oil application nor if temperatures are expected to exceed 90 degrees within 3 days following application.
Trilogy (*neem oil*)	1%solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/acre/application.
TriTek *(petroleum oil)*	1-2 gal/100 gal water	Up to day of harvest	4	?	Apply as needed.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.5 Gray Mold/Botrytis Fruit Rot (*Botrytis cinerea*)

Botrytis fruit rot usually begins as a small lesion at the blossom end or where a berry is touching another infected berry. The infected portion is firm and brown while the berry is still green, but it expands and softens as the fruit ripens. A powdery gray mass of spores covers infected berries if the weather remains humid and/or air circulation is poor.

IPM fact sheet on Gray Mold (Botrytis Fruit Rot) nysipm.cornell.edu/factsheets/berries/botrytis.pdf

Gray Mold (Botrytis Fruit Rot) Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties. Less severely impacted varieties are ‘Earliglow’, ‘Jewel’ and ‘Clancy’. ‘Allstar’ and ‘Sable’ are very susceptible.

Gray Mold (Botrytis Fruit Rot) Management Options	
Cultural management	Disease control is greatly aided by managing weeds and by using other practices that promote good air circulation and rapid drying of the fruit such as regulating plant density. Use of protected production structures, such as low tunnels, reduces gray mold occurrence by limiting fruit wetness. Spring applications of nitrogen can dramatically increase the potential for infection. Prompt harvest of ripe fruit helps reduce disease development and spread. It may be beneficial to employ an hourly picker to remove only overripe and diseased fruit to prevent infection of clean fruit by other pickers. Overripe fruit should not be consumed. Cull piles should be buried or otherwise physically removed from fields during harvest.
Chemical treatment	Protection of blossoms is critical in gray mold management. Research in New York has consistently shown that excellent gray mold control can be obtained with just two fungicide sprays applied at early bloom and 10 days later. Continued protection of fruit prior to harvest may be necessary during prolonged periods of wet, foggy, or humid weather.

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Table 7.4.5 Pesticides Labeled for Management of Gray Mold (Botrytis Fruit Rot)

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Actinovate-AG (*Streptomyces lydicus WYEC 108s*)	3-12 oz/A	0	1 (or until spray has dried)	2	Foliar application. For best results apply with a spreader/sticker prior to onset of disease.
Cinnerate *(cinnamon oil)*	13-30 fl oz/100 gal water	-	-	?	25(b) pesticide. Apply 85-125 gal diluted spray/A.
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.25-3 lb/A	0	4	?	Foliar application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-6 qt/A	0	4	?	Foliar application.
EcoMate ARMICARB 0 *(potassium bicarbonate)*	2.5-5.0 lb/100 gal water	0	4	3	
JMS Stylet Oil Organic JMS Stylet Oil *(paraffinic oil)*	3 qt/100 gal water	0	4	2	A high volume of water is needed for through coverage. Many common pesticides are phytotoxic when applied with or close to oil sprays (e.g., sulfur). Check label for restrictions.
Milstop (*potassium bicarbonate*)	2-5 lb/A	0	1	3	
Optiva *(Bacillus subtilis)*	14-24 oz/A	0	4	3	Repeat on 7-10 day intervals.

Table 7.4.5 Pesticides Labeled for Management of Gray Mold (Botrytis Fruit Rot)					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	64 fl oz/100 gal water (pre-plant dip) 32 fl oz – 1 gal/100 gal water (foliar spray)	0	Until spray has dried	?	Pre-plant dip. Foliar application, at-planting and for existing plantings. See label for additional instructions.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	3	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop (*Gliocladium catenulatum str. J1446*)	3.5 oz/5 gal	-	0	?	Foliar spray. Apply at 0.5 gallon of mixed spray per 100 sq. ft. Apply only when no above-ground harvestable food commodities are present
PureSpray Green *(petroleum oil)*	0.75-1.5 gals oil/100 gals water	Up to day of harvest	4	?	Apply 100-200 gals water per acre. Spray at no less than 400 PSI using ceramic nozzles.
Regalia *(Reynoutria sachalinensis)*	1-3 qt/A	0	4	?	Initiate at first sign of disease then every 7-14 days
Serenade ASO *(Bacillus subtilis str. QST 713)*	2-6 qt/A	0	4	3	Begin application at or before flowering repeat every 7-10 days.
Serenade MAX *(Bacillus subtilis str. QST 713)*	1-3 lb/A	0	4	3	Begin application at or before flowering repeat every 7-10 days.
Serenade Optimum *(Bacillus subtilis str. QST 713)*	14-20 oz/A	0	4	3	Begin application at or before flowering repeat every 7-10 days.
Trilogy (*neem oil*)	1% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/acre/application.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.6 Anthracnose (*Colletotrichum acutatum*)

One or more circular spots occur on the fruit. Spots originally are tan or light brown but become darker and sunken. Sunken spots are usually about one eighth to one quarter inch in diameter and may be covered with pink slimy spore masses during wet or very humid periods. The disease may occur on both green and ripe fruit, but is most common on ripe fruit following periods of warm, wet weather. In New York, anthracnose occurs only sporadically and is a more common problem on day-neutral varieties in the summer than it is on June-bearing varieties. However, the disease can be serious on June-bearing varieties if warm, wet weather conditions occur between fruit set and harvest.

Anthracnose Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties.

Anthracnose Management Options	
Cultural management	Provide good air circulation by controlling weeds and reducing planting density. Use of protected production structures, such as low tunnels, reduces anthracnose occurrence by limiting fruit wetness. The anthracnose fungus is spread throughout a planting by splashing raindrops or sprinkler irrigation. Straw mulch may reduce the rate of disease spread relative to bare ground (less rain splash).
Chemical treatment	See table below.

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Table 7.4.6 Pesticides Labeled for Management of Anthracnose

Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Actinovate-AG (*Streptomyces lydicus WYEC 108*)	3-12 oz/A	0	1 (or until spray has dried)	2	Foliar application. For best results apply with a spreader/sticker prior to onset of disease. Re-apply as necessary.
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.25-3 lb/A	0	4	?	Foliar application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-6 qt/A	0	4	?	Foliar application.
EcoMate ARMICARB 0 *(potassium bicarbonate)*	2.5-5.0 lb/100 gal water	0	4	3	
Milstop *(potassium bicarbonate)*	2-5 lb/A	0	1	?	Do not mix with other pesticides or fertilizers. Not compatible with alkaline solutions.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	2	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Regalia *(Reynoutria sachalinensis)*	1-3 qt/A	0	4	?	Apply preventatively in 50-100 gal water/acre and repeat on a 7-10 day interval or as needed.
Serenade ASO *(Bacillus subtilis str. QST 713)*	2-6 qt/A	0	4	?	Begin application at or before disease development then repeat every 7-10 days.
Serenade MAX (*Bacillus subtilis str. QST 713*)	1-3 lb/A	0	4	2	Apply on a 7-10 schedule following disease onset.
Serenade Optimum *(Bacillus subtilis str. QST 713)*	14-20 oz/A	0	4	3	Begin application at or before flowering repeat every 7-10 days.

Table 7.4.6 Pesticides Labeled for Management of Anthracnose					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Trilogy (*neem oil*)	1% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/A/application.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.7 Leather Rot (*Phytophthora cactorum*)

Infected areas on immature fruit are brown, whereas those on maturing fruit appear bleached out. On all fruit, the infected areas are tough, leathery, and discolored on the inside as well as the outside of the fruit. Diseased fruits have a pungent smell and bitter taste. Leather rot is most severe during periods of abundant warm rains during the fruiting period and in flooded soils. The cultural practices listed in the table below are the most effective control procedures.

IPM fact sheet Leather Rot nysipm.cornell.edu/factsheets/berries/leather_rot.pdf

Leather Rot Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties.
Cultural management	Plant only on a well-drained site or provide supplemental drainage. Growing strawberries on raised beds will also reduce disease severity. Minimize soil flooding through site selection; by avoiding planting in ruts; and by preventing or reducing soil compaction. Provide an extra layer of straw mulch between rows throughout the fruiting season. The mulch provides a physical barrier between the soilborne pathogen and the susceptible fruit.
Chemical treatment	See below.

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Table 7.4.7 Pesticides Labeled for Management of Leather Rot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Actinovate-AG (*Streptomyces lydicus WYEC 108*)	3-12 oz/A	0	1 (or until spray dries)	?	Apply as a soil drench. Since Actinovate AG contains live spores of a microbe, best results will be obtained if used prior to disease onset.
BIO-TAM BIO-TAM 2.0 (*Trichoderma asperellum, Trichoderma gamsii)*	0.25-2 lb /gal water; bare root dip 1.5-3 oz/1000 row feet; in furrow 2.5-3 lb/A; banded	-	1	?	
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A	0	4	?	Soil application.

Table 7.4.7 Pesticides Labeled for Management of Leather Rot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pt/A	0	4	?	Soil application.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water (soil drench)	-	0	?	Treat only the growth substrate when above-ground harvestable food commodities are present.
RootShield PLUS+ Granules *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	2.5-6 lb/half acre	-	0	?	In-furrow.
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-5 lb/20 gal water (dip) 16-32 oz/acre (in-furrow)	0	4	?	Do not apply when above-ground harvestable food commodities are present.
TerraClean 5.0 (*hydrogen dioxide, peroxyacetic acid)*	25 fl oz/ 200 gal water/ 1,000 sq ft of soil treated. (soil drench)	Up to day of harvest	0	?	See label for rate information for specific soil treatments.
Zonix Biofungicide (*Rhamnolipid Biosurfactant)*	0.5-0.8 fl oz/gal water	-	4	?	Prepare enough solution based on plant density and soil conditions to insure thorough coverage,

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.8 Red Stele (*Phytophthora fragariae*)

Red stele is caused by a soilborne aquatic pathogen (Phytophthora) that may persist in the soil for many years even when strawberries are no longer grown. Symptoms of infection often appear just before harvest. Diseased plants appear stunted and off-color, and will often wilt and collapse if the weather becomes warm and dry. Because these same symptoms may be caused by other factors that destroy roots (such as root-feeding insects), the diagnosis depends on an examination of the plant's root system. In a diseased plant, the roots have a "rat-tail" appearance caused by loss of the fine branched feeder roots from the main fleshy roots. The main fleshy roots are rotted from the tips back toward the crown. Cutting or scraping away the white outer portion (epidermis and cortex) just above the rotten areas in early infections sometimes reveals a reddish root core (stele). Infected plants usually appear in groups and are frequently found in the lowest or wettest parts of a field.

IPM fact sheet Red Stele nysipm.cornell.edu/factsheets/berries/red_stele.pdf

Red Stele Management Options	
Scouting/thresholds	None established.
Variety susceptibility	Resistant varieties include 'Earliglow', 'Northeaster',' Mohawk', 'Redchief', 'Guardian', 'Allstar', 'Tribute', 'Tristar', 'Surecrop', and 'Sparkle'. However, these varieties are not resistant to all races of the red stele pathogen (*P. fragariae*), and as such, the disease could still develop if a race to which they are not resistant is present.

Red Stele Management Options	
Cultural management	Because the red stele fungus is particularly active in extremely wet soil, plant only on a well-drained site or provide supplemental drainage. Growing strawberries on raised beds will also reduce disease severity.
Chemical treatment	The red stele fungus is not present in every field, thus treatments should be confined to fields and areas within fields where the disease has occurred previously or is suspected.

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Table 7.4.8 Pesticides Labeled for Management of Red Stele

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Actinovate-AG *(Streptomyces lydicus WYEC 108)*	3-12 oz/A	0	1 (or until spray has dried)	?	Apply as a soil drench. Since Actinovate AG contains live spores of a microbe, best results will be obtained if used prior to disease onset.
BIO-TAM BIO-TAM 2.0 (*Trichoderma asperellum, Trichoderma gamsii)*	0.25-2 lb/gal water; bare root dip 1.5-3 oz/1000 row feet; in furrow 2.5-3 lb/A; banded	-	1	?	
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A	0	4	?	Soil application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pt/A	0	4	?	Soil application.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water (soil drench - treat only growth substrate)	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are present.
Regalia *(Reynoutria sachalinensis)*	1-4 qt/100 gals	0	4	?	Apply as a pre-plant dip.
RootShield PLUS+ Granules *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	2.5-6 lb/half acre	-	0	?	In-furrow application.
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-5 lb/20 gal water (dip) 16-32 oz/acre (in-furrow)	0	4	?	Do not apply when above ground harvestable food commodities are present.

Table 7.4.8 Pesticides Labeled for Management of Red Stele					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
TerraClean 5.0 (*hydrogen dioxide, peroxyacetic acid)*	25 fl oz/ 200 gal water/ 1,000 sq ft of soil treated (soil drench)	Up to day of harvest	0	?	See label for rate information for specific soil treatments.
Zonix Biofungicide (*Rhamnolipid Biosurfactant)*	0.5-0.8 fl oz/gal water	-	4	?	Prepare enough solution based on plant density and soil conditions to insure thorough coverage,

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.

PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.4.9 Black Root Rot

Black root rot constitutes a complex set of symptoms caused by one or more of the following organisms: nematodes, root rot fungi (*Pythium spp., Rhizoctonia spp.)*. Black root rot is most commonly observed in older plantings or on heavy compacted soils. Over time, plant vigor and productivity declines. Feeder rootlets die, and fleshy structural roots deteriorate and become blackened. The blackening starts as patches along the length of the root, rather than from the tip back. This disease is often associated with fields having a long history of strawberry production. Because no single cause of black root rot has been defined, there is no single control.

Black Root Rot Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties. Particularly susceptible varieties are ‘Honeoye’ and ‘Jewel’. These varieties should be avoided in fields without adequate rotation.
Cultural management	Fields with high nematode populations may be more prone to black root rot development. Check nematode populations prior to planting. If high, consider incorporating a cover crop with biofumigant properties. See Section 4, Cover Crops. Cultural practices that reduce soil compaction, improve aeration, and promote good drainage are beneficial for reducing disease. Rotating a field out of strawberries for at least 2 - 3 years is strongly recommended. Measures to control red stele will also help alleviate black root rot. Cover crops such as brown mustard and indiangrass and incorporation of compost can also provide disease suppression.
Chemical treatment	Chemical treatment with a nematicide is not suggested for black root rot. See below for fungicides.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.4.9 Pesticides Labeled for Management of Black Root Rot

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Actinovate-AG *(Streptomyces lydicus WYEC 108)*	3-12 oz/A	0	1 (or until spray has dried)	?	Apply as a soil drench. Since Actinovate AG contains live spores of a microbe, best results will be obtained if used prior to disease onset.
BIO-TAM BIO-TAM 2.0 (*Trichoderma asperellum, Trichoderma gamsii)*	0.25-2 lb /gal water; bare root dip 1.5-3 oz/1000 row feet; in furrow 2.5-3 lb/A; banded	-	1	?	
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A	0	4	?	Soil application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pt/A	0	4	?	Soil application.
PERpose Plus (*hydrogen peroxide/dioxide)*	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water (soil drench - treat only growth substrate)	-	0	?	Treat only the growth substrate when above-ground harvestable food commodities are present.
Regalia *(Reynoutria sachalinensis)*	1-4 qt/100 gal (pre-plant dip) 1-3 qt/100 gal (soil drench)	0	4	?	
RootShield Granules *(Trichoderma harzianum Rifai str. T-22)*	5-12 lb/A	-	0	?	In-furrow.
RootShield PLUS+ Granules *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	2.5-6 lb/half A	-	0	?	In-furrow.

Table 7.4.9 Pesticides Labeled for Management of Black Root Rot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
RootShield WP (*Trichoderma harzianum Rifai str. KRL-AG2)*	3-5 oz/100 gal (greenhouse /nursery drench) 0.5-2.5 lb/5 gal (root dip) 16-32 oz/A (In-furrow or transplant starter solution)	-	Until spray has dried	?	No PHI specified on the label for any of the product rates.
RootShield PLUS+ WP *(Trichoderma harzianum str. T-22, Trichoderma virens str. G-41)*	0.25-5 lb/20 gal water (root dip) 16-32 oz/acre (in-furrow)	0	4	?	
SoilGard *(Gliocladium virens str. GL-21)*	2-10 lb/acre	-	0	?	
TerraClean 5.0 (*hydrogen dioxide, peroxyacetic acid)*	25 fl oz/ 200 gal water/ 1,000 sq ft of soil treated. (soil drench)	Up to day of harvest	0	?	See label for rate information for specific soil treatments.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.5 OTHER DISEASES OF NOTE

7.5.1 Angular Leaf Spot (*Xanthomonas fragariae*)

Tiny water-soaked lesions appear first on lower leaf surfaces. These enlarge to form angular spots usually bordered by small veins. When held up to the light spots appear translucent, but are dark green under reflected light. Spots may ooze bacteria under moist conditions, which dry to form a whitish scaly skin. Lesions eventually become visible on upper leaf surfaces as irregular reddish brown spots. Calyxes may also become infected. The disease is favored by daytime temperatures around 68°F, low to near freezing night temperatures, and precipitation events such as rain, overhead irrigation or heavy dews.

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Table 7.5.1 Pesticides Labeled for Management of Angular Leaf Spot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Badge X2 *(copper oxychloride, copper hydroxide)*	0.75-1.25 lb/A	-	48	?	Apply in at least 20 gal water.
Champ WG (*copper hydroxide*)	2-3 lb/A	-	48	?	May cause crop injury under some conditions.
CS 2005 *(copper sulfate pentahydrate)*	19.2-25.6 oz/A	-	48	?	
Cueva Fungicide Concentrate (*copper octanoate*)	0.5-2.0 gal/100gal	Up to day of harvest	4	?	Product is applied as a diluted spray at 50-100 gallons per acre.
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.25-3 lb/A	0	4	?	Foliar application.
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-6 qt/A	0	4	?	Foliar application.

Table 7.5.1 Pesticides Labeled for Management of Angular Leaf Spot					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
OxiDate 2.0 *(hydrogen dioxide, peroxyacetic acid)*	32 fl oz – 1 gal/100 gal water	0	Until spray has dried	?	30-100 gals spray per acre is typical.
PERpose Plus (*hydrogen peroxide/dioxide*)	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	3	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Trilogy (*neem oil*)	1% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/A/application.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.5.2 Verticillium Wilt (*Verticillium albo-atrum*)

Plants are affected most severely during their first year of growth. Outer leaves turn brown and eventually collapse, but inner leaves remain green until the plant dies. This symptom distinguishes Verticillium wilt from other root and crown disorders. Affected plants may occur uniformly, but more typically, they appear scattered throughout a field. In problem areas or after the last crop of tomatoes, potatoes, or eggplant, plant only varieties resistant to Verticillium wilt for at least 3 years. Resistant varieties include 'Earliglow', 'Guardian', 'Allstar', 'Tribute', and 'Tristar'. Many weeds are hosts of the Verticillium fungus, particularly nightshade, groundcherry, redroot pigweed, lambsquarters, and horsenettle. These weeds should be strictly controlled in current and future planting sites to keep *Verticillium* inoculum low.

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Table 7.5.2 Pesticides Labeled for Management of Verticillium Wilt					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Actinovate-AG *(Streptomyces lydicus WYEC 108)*	3-12 oz/A	0	1 (or until spray has dried)	?	Apply as a soil drench. Since Actinovate AG contains live spores of a microbe, best results will be obtained if used prior to disease onset.
BIO-TAM BIO-TAM 2.0 *(Trichoderma asperellum, Trichoderma gamsii)*	0.25-2 lb /gal water (bare root dip) 1.5-3 oz/1000 row feet (in furrow) 2.5-3 lb/A (banded)	-	1	?	
Double Nickel 55 (*Bacillus amyloliquefaciens str. D747)*	0.125-1 lb/A	0	4	?	Soil application.

Table 7.5.2 Pesticides Labeled for Management of Verticillium Wilt					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Double Nickel LC (*Bacillus amyloliquefaciens str. D747)*	0.5-4.5 pt/A	0	4	?	Soil application.
PERpose Plus (*hydrogen peroxide/dioxide*)	1 fl oz/gal (initial/curative) 0.25-0.33 fl oz/gal (weekly/preventative)	-	Until spray has dried	?	For initial or curative use, apply higher rate for 1 to 3 consecutive days. Then follow with weekly/preventative treatment. For weekly or preventative treatments, apply lower rate every five to seven days. At first signs of disease, use curative rate then resume weekly preventative treatment.
Prestop *(Gliocladium catenulatum str. J1446)*	1.4-3.5 oz/2.5 gal water (soil drench)	-	0	?	Apply only to growth substrate when above-ground harvestable food commodities are present.
Regalia *(Reynoutria sachalinensis)*	1-4 qts/100 gal	0	4	?	Pre-plant dip.
Serenade Soil (*Bacillus subtilis str. QST 713*)	2-6 qt/A	0	4	?	Soil drench or in-furrow treatment.
TerraClean 5.0 (*hydrogen dioxide, peroxyacetic acid)*	25 fl oz/ 200 gal water/ 1,000 sq ft of soil treated. (soil drench)	Up to day of harvest	0	?	See label for rate information for specific soil treatments.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.

PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.6 INSECTS AND MITES OF PRIMARY CONCERN

The insects and mites that are considered major pests in strawberries can vary in occurrence both from year to year and from site to site. For these reasons it is important to be familiar with the life cycle of the pest to assist in developing a scouting program that will ensure a pest problem can be discovered and dealt with before it becomes an outbreak. Alternatively, it is important to know when a potential pest is not causing significant economic damage so that unnecessary controls can be avoided. Applying an organically approved broad-spectrum insecticide such as PyGanic EC (a pyrethrum) when not necessary, for example, is not only a waste of money but also has the potential to disrupt biological control by beneficial organisms. This illustrates the need to take potential biological control agents (predators, parasitoids, parasites, microbes) into account when making management decisions. Following are descriptions of the most commonly found insect pests in strawberry plantings.

7.6.1 Root Weevil *(various species)*

Different species, but most commonly the strawberry root weevil, the black vine weevil, and the rough strawberry root weevil. These pests attack the roots or crowns of plants while in the grub stage. All have a one-year life cycle, although some are known to live two seasons. Adults emerge about late June. Beds with heavy infestations show distinct patches or spots that appear stunted and have substantially reduced yields. The roots of injured plants are badly eaten away, and continued infestation may destroy infested plants.

IPM fact sheet Root Weevil nysipm.cornell.edu/factsheets/berries/root_weevils.pdf

Root Weevil Management Options	
Scouting/thresholds	None established.
Variety susceptibility	None adapted to the Northeastern region.
Cultural management	Rotate out of strawberries for a least 1 year to reduce root weevil density. A barrier (plastic fence) can prevent adults from moving from an infested field to a new field to be planted. See Exclusion Barriers for Management of Black Vine Weevil for details.
Biological control	Two species of *Heterorhabditis*, insect parasitic nematodes, *H. bacteriophora* and *H. marelatus*, can provide control of larvae. Release nematodes either in spring when soils warm (>50 F) or in late summer - early fall. Provide sufficient water to move nematodes into the root zone.
Chemical treatment	See below.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.6.1 Pesticides Labeled for Management of Root Weevil

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct (*azadirachtin*)	1-2 pt/A	0	4	?	
AzaGuard (*azadirachtin*)	10-16 fl oz/A	0	4	?	Apply with OMRI approved spray oil.
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2	0	4	?	
AzaSol (*azadirachtin*)	6 oz/50 gal water/A	-	4	?	
Azatrol EC (*azadirachtin*)	0.29-0.96 fl oz/1000 ft^2	0	4	?	
Azera (*azadirachtin, pyrethrins*)	1-3.5 pt/A	-	12	?	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Ecozin Plus 1.2% ME (*azadirachtin*)	15-30 oz/A	0	4	?	
Envirepel (*garlic juice*)	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X (*azadirachtin*)	10 oz/A	0	4	?	
Mycotrol O (*Beauveria bassiana str. GHA*)	0.25-1 qt/A	Up to day of harvest	4	?	

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.6.2 STRAWBERRY SAP BEETLE *(Stelidota geminata)* & PICNIC BEETLE *(Glischrochilus fasciatus)*

Sap beetle adults make cavities in ripe and overripe fruit as well as spread spores of decay organisms. The larvae also feed on ripe and overripe fruit and are a source of contamination in harvested fruit. Until a few years ago, sap beetles were uncommon in strawberries. Now, sap beetles are occasionally found in high numbers in later ripening strawberry plantings throughout the state. Two species feed on strawberry fruits: the common picnic beetle, one quarter inch long with four yellow spots on the back, and the smaller, brown strawberry sap beetle without distinctive markings. Strawberry sap beetle is the more serious pest because it does not limit its activity to over-ripe fruit. Beetles overwinter at the edge of woodlots and possibly under other perennial fruit crops, such as brambles and blueberries, but they do not appear to overwinter in strawberry fields. As strawberries ripen, beetles move into the field and begin feeding and laying eggs. Fruit touching the ground or straw mulch appears particularly vulnerable.

IPM fact sheet Sap Beetle nysipm.cornell.edu/factsheets/berries/ssb.pdf

Sap Beetle Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties, although cultivars that tend to hold fruit off the ground may be less vulnerable to adult feeding and larval contamination.
Cultural management	Keep the field free of ripe and over-ripe fruit.
Chemical treatment	None known to be effective.

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Table 7.6.2 Pesticides Labeled for Management of Sap Beetle

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	3	
AzaGuard *(azadirachtin)*	8-16 fl oz/A	0	4	3	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	3	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	
Azatrol EC *(azadirachtin)*	0.29-0.96 fl oz/1000 ft^2	0	4	3	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	3	
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	3	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X *(azadirachtin)*	8 oz/A	0	4	3	
PyGanic EC 1.4 II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	
PyGanic EC 5.0 II (*pyrethrin*)	4.5-17 fl oz/A	0	12	?	

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.6.3 TARNISHED PLANT BUG *(Lygus lineolaris)*

This pest causes "cat faced" or "button" berries. It damages the fruit by feeding on the developing fruit. The fruit tissue in the immediate area of damaged seeds stops developing. Little information is available on cultivar differences in susceptibility to tarnished plant bug, but early maturity is correlated with freedom from injury; later cultivars may suffer more damage. Also, highly productive cultivars appear to tolerate feeding damage better than less productive ones. Tarnished plant bug feeds on many crop and non-crop plants as they flower and fruit. Hence, weedy fields can promote higher populations.

IPM fact sheet Tarnished Plant Bug nysipm.cornell.edu/factsheets/berries/tpb.pdf

Tarnished Plant Bug Management Options	
Scouting/thresholds	Anytime from just before the blossoms open until harvest, check for tarnished plant bug nymphs by striking the plant over a flat, low-sided, light-colored dish. Suggested action threshold: 0.5 nymphs per cluster, or 4 out of 15 clusters with 1 or more nymphs.
Variety susceptibility	'Honeoye' and other highly productive cultivars appear less susceptible to feeding injury. Early-flowering cultivars may be less susceptible to injury also. Day-neutral varieties are particularly vulnerable later in the season.
Cultural management	Row covers accelerate plant development and help avoid injury. Pressure is often highest in weedy fields or in fields bordered by woody shrubs.
Chemical treatment	See below.

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Table 7.6.3 Pesticides Labeled for Management of Tarnished Plant Bug

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	1	
AzaGuard *(azadirachtin)*	10-16 oz/A	0	4	1	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	1	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	For control of nymphs.
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	1	
Azera *(azadirachtin,pyrethrins)*	1-3.5 pt/A	-	12	1	
Ecotec *(rosemary and peppermint oil)*	1-4 pt/A	0	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	1	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide
Molt-X *(azadirachtin)*	10 oz/A	0	4	1	
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	2-3 lb/A	0	4	?	
Mycotrol O (*Beauveria bassiana str. GHA*)	0.25-1 qt/A	Up to day of harvest	4	2	
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lb/A	-	4	?	
PyGanic EC 1.4$_{II}$ *(pyrethrin)*	16-64 fl oz/A	Until spray has dried.	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0$_{II}$ *(pyrethrin)*	4.5-17 fl oz/A	0	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.6.4 TWO-SPOTTED SPIDER MITE *(Tetranychus urticae)*

In early spring, mites begin feeding on the undersides of new leaves, sometimes resulting in small yellow spots on the upper leaf surfaces. These symptoms do not occur in all cases, however, and are not seen later in the year. Brownish dry areas on the lower leaf surfaces are more characteristic of damage. Later, the entire lower leaf may become dry and brown, giving it a bronzed appearance. Heavily infested plants look dry and stunted, and their sparse new growth is yellowish and distorted. Damage is first seen and is most prevalent in dry areas of a field. Mild growing areas in New York (Hudson Valley and Long Island) experience problems with mites most frequently.

Two-spotted Spider Mite Management Options	
Scouting/thresholds	Five mites/leaf or 15 out of 60 mature (fully expanded) leaflets infested with 1 or more mites. Regular leaf monitoring is necessary for assessing population growth.
Variety susceptibility	No known resistant varieties.
Cultural management	Ensure plots are not over fertilized. Provide adequate irrigation. Cool, moist conditions are unfavorable to mites. Do not use other insecticides that kill predatory mites. Mow and incorporate leaves at renovation.
Biological Control	Species of predatory mites can be purchased from biological control supply companies and released into strawberry fields to provide some control of spider mites. Effectiveness has not been carefully assessed under NY conditions. Note that predatory mites should be released before significant feeding damage is observed. *Neoseiulus californicus* and *Amblysyeius fallacis* are two predatory mite species used in strawberries for biological control of two-spotted spider mite.
Chemical treatment	Chemical control of spider mites is often not completely effective because of their high mobility, tendency to reside on the underside of leaves where it is difficult to reach with miticides, high reproductive rate, and resistance to some pesticides. Good coverage of the plants, particularly the undersides of the leaves, is critical for adequate protection. Use adequate water (200 - 300 gal/A) for maximum effectiveness of the miticide. Repeat at 7- to 10-day intervals as necessary unless otherwise noted on label. Soap sprays may provide some control but excellent coverage is essential, especially on lower leaf surfaces.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.6.4 Pesticides Labeled for Management of Two-spotted Spider Mite

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Acoidal *(sulfur)*	5-10 lb/A	-	24	1	Do not use on sulfur sensitive varieties.
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	1	
AzaGuard *(azadirachtin)*	10-16 oz/A	0	4	1	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	1	
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	1	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	1	

Table 7.6.4 Pesticides Labeled for Management of Two-spotted Spider Mite					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide.
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Cinnerate *(cinnamon oil)*	13-30 fl oz/100 gal water	-	-	?	25(b) pesticide. Apply 85-125 gal diluted spray/A.
Defend DF *(sulfur)*	5-10 lb/A	-	24	1	Do not use on sulfur sensitive varieties.
Ecotec *(rosemary and peppermint oil)*	1-4 pints/A	0	-	3	25(b) pesticide. Essential oils effective against spider mites in 0/1 trial.
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
GC-Mite (*cottonseed, clove, and garlic oils*)	1 gal/100 gal/A	-	-	1	25(b) pesticide. Conduct compatibility test prior to application.
Glacial Spray Fluid (*mineral oil*)	0.75 gal/100gal	Up to day of harvest	4	1	See label for specific application volumes and equipment.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	2-3 lb/A	0	4	?	
JMS Stylet Oil Organic JMS Stylet Oil *(paraffinic oil)*	3 qt/100 gal water	0	4	1	Apply for optimum coverage of leaf surfaces. Use high pressure, small droplet size, and adequate gallonage to ensure good coverage. Can cause phytotoxicity if applied too close to a sulfur application.
Micro Sulf (*sulfur*)	5-10 lb/A	-	24	?	Some varieties may be sensitive to sulfur.
Microthiol Disperss (*sulfur*)	5-10 lb/A	-	24	?	Not recommended within 2 weeks of an oil application nor if temperatures are expected to exceed 90 degrees within 3 days following the application.
M-Pede *(potassium salts of fatty acids)*	1-2% vol/vol	0	12	1	Works by contact. Good coverage is important.
Nuke Em *(citric acid)*	Normal: 1 fl oz/31 fl oz water	-	-	?	Use the normal strength mix first. See label for stronger dilutions if needed.
Oleotrol-I (*soybean oil)*	43-45 fl oz/100 gal water	0.5	12	?	Minimum spray volume of 50 gal/A.
Omni Supreme Spray (*mineral oil*)	1-2% vol/vol	-	12	1	See label for specific precautions. Applied at 60 gallons of finished spray per acre when using air-assisted, low-volume ground application equipment or 200 gallons of water per acre with standard ground spray equipment.
Organocide 3-in-1 (*sesame oil*)	1-2 gal/100 gal/A	-	-	1	25(b) pesticide.
PFR-97 30% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lb/A	-	4	?	
PureSpray Green (*petroleum oil*)	0.75-1.5 gal/100 gal water at 10-200 gal water/acre	Up to day of harvest	4	1	Spray at no less than 400 PSI using ceramic nozzles.

Table 7.6.4 Pesticides Labeled for Management of Two-spotted Spider Mite					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
PyGanic EC 1.4 II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	
PyGanic EC 5.0 II *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.
Sil-Matrix (*potassium silicate*)	0.5-1 % solution	0	4	?	Apply 50-250 gallons of finished spray/A.
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water/A	Up to day of harvest	4	1	Do not mix with sulfur products.
Trilogy (*neem oil*)	1-2% solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/acre/application
TriTek *(petroleum oil)*	1-2 gal/100 gal water	Up to day of harvest	4	1	Apply as needed.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.6.5 SPOTTED WING DROSOPHILA *(Drosophila suzukii)*

Spotted Wing Drosophila (SWD) is an invasive vinegar or fruit fly that was first detected in NY in 2011 and spread across NY in 2012. June-bearing strawberries and day neutral strawberries fruiting early in the growing season have thus far escaped injury from this pest. There is however, potential for significant impact from this pest for day neutral strawberries which continue fruiting when populations tend to increase. Adult flies are 2-3 mm in length, with red eyes and a tan-colored body with darker bands on the abdomen. Males have characteristic single spots at the leading edge of the tip of the wing and two dark spots on their front legs. Females lack wing spots and leg spots, but are distinguished by a saw-toothed ovipositor (visible under magnification). Larvae are white, nondescript and legless. Female SWD can lay eggs in ripening and marketable fruit.

Monitoring is very important for this pest. Talk to your local extension educator about a monitoring program. Traps baited with apple cider vinegar have proven successful in capturing adult SWD. Traps should be checked weekly, adding fresh vinegar. Traps and synthetic lures are commercially available for monitoring SWD.

Fruit destined for a processing market may be at risk of rejection due to presence of larvae. Home canning and processing may generate complaints from customers that notice SWD larvae. Display farm market fruit in a cooler— refrigeration slows or stops SWD development in fruit. Regular fruit sampling will help identify problems in the field. Fruit can be inspected for evidence of larval feeding. On strawberries, sunken areas appearing on the fruit surface may indicate SWD infestation. If late season day-neutral strawberries are grown, at least 100 fruit per block per harvest should be observed for infestation. Immersing fruit in a salt solution (1 Tbsp. table salt/cup water (14.8 cc/236.6 ml)) will cause larvae to float out where they can be observed with the aid of magnification.

For more information, consult the Spotted Wing Drosophila website on Cornell Fruit Resources.

Spotted Wing Drosophila Management Options	
Scouting/thresholds	Not specifically established but customer tolerance for infested fruit is likely to be very low.
Variety susceptibility	No known resistant varieties.

Spotted Wing Drosophila Management Options	
Cultural management	Canopy and water management will make the environment less favorable. Use adequate plant and row spacing at planting to increase sunlight and reduce humidity. Similarly, at renovation, narrow June-bearing strawberry matted rows to an 8" to 10" width. These practices will make plantings less attractive to SWD and will improve spray coverage. Repair leaking drip lines and avoid overhead irrigation when possible. Allow the ground and mulch surfaces to dry before irrigating. Excellent sanitation will reduce SWD populations. Fruit should be harvested frequently and completely to prevent the buildup of ripe and over-ripe fruit. Unmarketable fruit should be removed from the field and either frozen, "baked" in clear plastic bags placed in the sun, or disposed of in bags off-site. This will kill larvae, remove them from your crop, and prevent them from emerging as adults. Cool berries immediately. Chilling berries immediately after harvest to 32-33F will slow or stop the development of larvae and eggs in the fruit. U-Pick customers should be encouraged to follow this strategy to improve fruit quality at home. If the planting includes day neutral varieties; consider using insect exclusion netting on these to protect fruit; if establishing a new planting, focus on June-bearing varieties to minimize the need for SWD management.
Chemical treatment	A few insecticides have recently been granted 2ee label exemptions for control of SWD. SWD adults appear sensitive to several different chemistries, although their high reproductive rate, short generation time, and mobility may necessitate multiple applications for control.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.6.5 Pesticides Labeled for Management of Spotted Wing Drosophila

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct (*azadirachtin)*	1-2 pt/A	0	4	2	
AzaGuard (*azadirachtin)*	10-16 oz/A	0	4	2	
AzaMax (*azadirachtin)*	1.33 fl oz/1000 ft²	0	4	2	
AzaSol (*azadirachtin)*	6 oz/50 gal water/A	-	4	?	For larvae control.
Azatrol EC (*azadirachtin)*	0.24-0.96 fl oz/1000 ft²	0	4	2	
Azera (*azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	1	
Entrust Naturalyte Insect Control *(spinosad)*	1.25-2 oz/A	1	4	1	2(ee) recommendation. User must have a copy of the recommendation in their possession at the time of application. http://pims.psur.cornell.edu/LabelResults.php?ProductId=154869&SearchPage=ProductName.php
Entrust SC (*spinosad)*	4-6 fl oz/A	1	4	1	2(ee) recommendation. User must have a copy of the recommendation in their possession at the time of application. http://pims.psur.cornell.edu/LabelResults.php?ProductId=176736&SearchPage=ProductName.php
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.

Table 7.6.5 Pesticides Labeled for Management of Spotted Wing Drosophila					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Molt-X *(azadirachtin)*	10 oz/A	0	4	2	
Neemazad 1% EC *(azadirachtin)*	18-72 fl oz/A	-	4	2	
PyGanic EC 1.4$_{II}$ *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0$_{II}$ *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7 MINOR AND SPORADIC INSECT AND MITE PESTS

Many insects found in strawberry plantings of New York, while having the capacity to cause economic damage, do not occur on a yearly basis at damaging levels and therefore are considered minor or sporadic pests. For these reasons it is important to be familiar with the life cycle of the pest to assist in developing a scouting program that will ensure a pest problem can be discovered and dealt with before it becomes an outbreak. And again, it is important to know when a potential pest is not causing significant economic damage so that unnecessary controls can be avoided.

7.7.1 BUD WEEVIL (CLIPPER) *(Anthonomus signatus)*

Adults puncture blossom buds while feeding in the spring, deposit eggs in the nearly mature buds, and then girdle the bud so that it hangs by a mere thread or falls to the ground. Injury is most likely along edges of fields or when strawberries are grown next to woodlots or other sites suitable for adult hibernation. Frequent scouting for bud cutting is important in areas where weevil pressure is expected to be high. In the past, a treatment threshold of 1 cut bud per linear foot has been recommended. Research conducted in the last few years, however, suggests that plants can sustain many times this pressure without a measurable reduction in yield if clipping occurs on tertiary flower buds. The new threshold is more than one primary or secondary flower bud or more than two tertiary flower buds per truss, or more than one injured truss per foot of row. Mulches and full-canopy beds may encourage newly emerged adults to remain in the planting so that damage increases in succeeding years. Using cropping systems shorter than 3 years, plowing under all old beds immediately after final harvest, and removing foliage and mulch to reduce the suitability of overwintering sites help lessen the chances of clipper injury.

IPM fact sheet Bud Weevil (Clipper) nysipm.cornell.edu/factsheets/berries/strawberry_clipper.pdf

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Table 7.7.1 Pesticides Labeled for Management of Bud Weevil					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct (*azadirachtin*)	1-2 pt/A	0	4	?	
AzaGuard (*azadirachtin*)	10-16 oz/A	0	4	?	Apply with OMRI approved spray oil
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2	0	4	?	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	
Azatrol EC *(azadirachtin)*	0.29-0.96 fl oz/1000 ft^2	0	4	?	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	?	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	?	

Table 7.7.1 Pesticides Labeled for Management of Bud Weevil					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X *(azadirachtin)*	10 oz/A	0	4	?	
PyGanic EC 1.4 II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	
PyGanic EC 5.0 II *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Short residual activity may require multiple applications. Caution: do not use when bees are active in the planting.
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrins & potassium salts of fatty acids*)	6.4 oz/gallon of water	When spray is dry	12	?	Apply one gallon of mixed spray per 700 sq. ft. of plant surface area.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.2 SPITTLEBUG *(Philaenus spumaris)*

White frothy masses on the stems and leaves around the time of bloom harbor the nymphs, which pierce the stems and suck plant juices. Their feeding, if extensive, can stunt the plants and reduce berry size. Leaves appear crinkled and darker green than undamaged leaves. The spittle masses are a great nuisance to pickers. Threshold is one mass per square ft. of row. Good weed control may help to reduce numbers. Populations are usually largest in weedy fields. Only one generation is produced per year. The leaves recover after the insects are gone.

IPM fact sheet Spittlebug nysipm.cornell.edu/factsheets/berries/meadow_spittlebug.pdf

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Table 7.7.2 Pesticides Labeled for Management of Spittlebug					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct (*azadirachtin*)	1-2 pt/A	0	4	?	
AzaGuard (*azadirachtin*)	10-16 oz/A	0	4	?	Apply with OMRI approved spray oil.
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2	0	4	?	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	For control of nymphs.
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	?	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	?	
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	?	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X *(azadirachtin)*	10 oz/A	0	4	?	
Neemazad 1% EC (*azadirachtin*)	18 -72 fl oz/A	-	4	?	
Neemix 4.5 *(azadirachtin)*	7-16 fl oz/A	0	4	?	
PyGanic EC 1.4 II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	1	

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.3 STRAWBERRY ROOTWORM *(Paria fragaria-complex)*

Grubs feed on roots in late spring to early summer. Adults feed on leaves in May and again in late July, at night.

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Table 7.7.3 Pesticides Labeled for Management of Strawberry Rootworm

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	3	
AzaGuard *(azadirachtin)*	8-16 oz/A	0	4	3	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	3	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	For control of larvae.
Azatrol EC *(azadirachtin)*	0.29-0.96 fl oz/1000 ft^2	0	4	3	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pt/A	-	12	3	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Molt-X *(azadirachtin)*	8 oz/A	0	4	3	
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
PyGanic EC 1.4$_{II}$ *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0$_{II}$ *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.4 GREENHOUSE WHITEFLY *(Trialeurodes vaporariorum)*

Whiteflies are small, white insects that resemble flies but are actually more closely related to aphids. Whiteflies feed on young plants, causing stunting.

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Table 7.7.4 Pesticides Labeled for Management of Greenhouse Whitefly

Trade Name (*active ingredient*)	Product Rate	PHI (days)	REI (hours)	Efficacy[1]	Comments
Aza-Direct (*azadirachtin*)	1-2 pt/A	0	4	?	
AzaGuard (*azadirachtin*)	8-21 oz/A	0	4	?	Apply with OMRI approved spray oil
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2	0	4	?	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	?	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pt/A	-	12	?	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
BioRepel (*garlic oil*)	1 part BioRepel to 100 parts water/A	-	-	?	25(b) pesticide

Table 7.7.4 Pesticides Labeled for Management of Greenhouse Whitefly

Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Cedar Gard (*cedar oil*)	1 qt/A	-	-	?	25(b) pesticide
Ecotec *(rosemary and peppermint oil)*	1-4 pints/A	0	-	?	25(b) pesticide
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	?	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide See label for specific information.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	2-3 lb/A	0	4	?	
Molt-X *(azadirachtin)*	8 oz/A	0	4	?	
M-Pede *(potassium salts of fatty acids)*	1-2% vol/vol	0	12	?	Works by contact. Good coverage is important. Use in combination with another pesticide for enhanced and residual effect.
Mycotrol O (*Beauveria bassiana str. GHA*)	0. 5-1 qt/100 gal spray volume/A	Up to day of harvest	4	?	
Neemazad 1% EC (*azadirachtin*)	18 -72 fl oz/A	-	4	?	
Neemix 4.5 *(azadirachtin)*	4-16 fl oz/A	0	4	?	Rate and frequency of application vary based on pest pressure. See label for guidance.
Nuke Em *(citric acid)*	Normal: 1 fl oz/31 fl oz water	-	-	?	Use the normal strength mix first. See label for stronger dilutions if needed.
PFR-97 20% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lb/A	-	4	?	
PyGanic EC 1.4$_{II}$ *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0$_{II}$ *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
Oleotrol-I (*soybean oil)*	43-45 fl oz/100 gal water	0.5	12	?	Minimum spray volume of 50 gal/A.
Organocide 3-in-1 (*sesame oil*)	1-2 gal/100 gal/A	-	-	?	25(b) pesticide.
PureSpray Green *(petroleum oil)*	0.75-1.5 gal oil/100 gal water at 100-200 gal water/A	Up to day of harvest	4	?	Spray at no less than 400 PSI using ceramic nozzles.
Sil-Matrix (*potassium silicate*)	0.5-1% solution	0	4	?	Apply at 50-250 gal/A finished spray
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water/A	Up to day of harvest	4	?	Can cause phytotoxicity if applied too close to a sulfur application

Table 7.7.4 Pesticides Labeled for Management of Greenhouse Whitefly					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Trilogy (*neem oil*)	1-2% solution	Up to day of harvest	4	?	Apply in sufficient water to achieve complete coverage. Maximum labeled use of 2 gal/acre/application. Provides suppression only.
TriTek *(petroleum oil)*	1-2 gal/100 gal water	Up to day of harvest	4	?	Apply as needed.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.5 CYCLAMEN MITE *(Stenotarsonemus pallidus)*

This tiny (one one-hundredth-inch) mite is pinkish orange and shiny when mature. Its translucent eggs are often so abundant that they appear as a white mass along the mid-veins of folded, newly emerging leaves. The mites feed on the young leaves in plant crowns; when the leaves emerge, they are stunted, crinkled, and malformed. Blossom feeding later results in misshapen fruit. The mites are most troublesome in strawberry beds that are kept for long periods. They increase in number during bloom and peak during fruit development. Avoid infested planting stock. 'Cabot' is particularly susceptible.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.7.5 Pesticides Labeled for Management of Cyclamen Mite					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	1	
AzaGuard *(azadirachtin)*	10-16 oz/A	0	4	1	Apply with OMRI approved spray oil
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	1	
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft2	0	4	1	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide.
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
GC-Mite (*cottonseed, clove, and garlic oils*)	1 gal/100 gal/A	-	-	1	25(b) pesticide. Conduct compatibility test prior to application
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	2-3 lb/A	0	4	?	
JMS Stylet Oil *(paraffinic oil)*	3 qt/100 gal water	0	4	2	A high volume of water is needed for through coverage. Many common pesticides are phytotoxic when applied with or close to oil sprays (e.g., sulfur). Check label for restrictions.
Nuke Em *(citric acid)*	Normal: 1 fl oz/31 fl oz water	-	-	?	Use the normal strength mix first. See label for stronger dilutions if needed.
Oleotrol-I (*soybean oil)*	43-45 fl oz/100 gal water	0.5	12	?	Minimum spray volume of 50 gal/A.

Table 7.7.5 Pesticides Labeled for Management of Cyclamen Mite					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Organic JMS Stylet Oil (*paraffinic oil)*	3 qt/100 gal	0	4	1	Apply for optimum coverage of leaf surfaces. Use high pressure, small droplet size, and adequate gallonage to ensure good coverage. Can cause phytotoxicity if applied too close to a sulfur application
PureSpray Green (*petroleum oil*)	0.75-1.5 gal/100 gal at 100-200 gal water/A	Up to day of harvest	4	1	Spray at no less than 400 PSI using ceramic nozzles.
PyGanic EC 1.4II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	
PyGanic EC 5.0II *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	
Sil-Matrix (*potassium silicate*)	0.5-1% solution	0	4	?	Apply 50-250 gallons of finished spray/A.
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water/A	Up to day of harvest	4	1	Can cause phytotoxicity if applied too close to a sulfur application
Trilogy (*neem oil*)	1-2%solution	Up to day of harvest	4	?	Apply in 25-100 gal water/A. Maximum labeled use of 2 gal/acre/application.
TriTek *(petroleum oil)*	1-2 gal/100 gal water	Up to day of harvest	4	1	Apply as needed.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.6 LEAFROLLER *(various species)*

Several species of moth larvae roll or fold strawberry leaves with silk. Leaf injury can be seen throughout the season, but an extremely large population is required before noticeable crop damage occurs.

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Table 7.7.6 Pesticides Labeled for Management of Leafrollers					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct (*azadirachtin*)	1-2 pt/A	0	4	?	
AzaGuard (*azadirachtin*)	8-16 oz/A	0	4	?	Apply with OMRI approved spray oil.
AzaMax (*azadirachtin*)	1.33 fl oz/1000 ft^2	0	4	?	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	?	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	?	See label for specific leafroller species.
Biobit HP *(Bacillus thuringiensis subsp. kurstaki)*	0.5-1 lb/A	0	4	1	See label for specific leafroller species product can be used against.
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide.
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Cedar Gard (*cedar oil*)	1 qt/A	-	-	?	25(b) pesticide.

Table 7.7.6 Pesticides Labeled for Management of Leafrollers					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Deliver *(Bacillus thuringiensis subsp. kurstaki)*	0.25-1.50 lb/A	0	4	1	See label for specific leafroller species product can be used against.
Dipel DF *(Bacillus thuringiensis subsp. kurstaki)*	0.5-1.0 lb/A	0	4	1	See label for specific leafroller species product can be used against.
Ecotec *(rosemary and peppermint oil)*	1-4 pt/A	0	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	?	
Entrust Naturalyte Insect Control *(spinosad)*	1.25-2.0 oz/A	1	4	1	Treat when pests appear, targeting eggs at hatch or small larvae.
Entrust SC *(spinosad)*	4-6 fl oz/A	1	4	1	Treat when pests appear, targeting eggs at hatch or small larvae.
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	1-3 lb/A	0	4	?	
Javelin *(Bacillus thuringiensis subsp. kurstaki)*	0.25-1.5 lbs/A	0	4	?	See label for specific leafroller species product can be used against.
Molt-X *(azadirachtin)*	8 oz/A	0	4	?	
Neemix 4.5 *(azadirachtin)*	7-16 fl oz/A	0	4	?	See label for specific leafroller species.
Organocide 3-in-1 (*sesame oil*)	1-2 gal/100 gal/A	-	-	?	25(b) pesticide.
PyGanic EC 1.4$_{II}$ *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0$_{II}$ *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	?	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
Xentari *(Bacillus thuringiensis subsp. Aizawai, str. ABTS-1857)*	0.5-1.5 lbs/A	0	4	?	See label for specific leafroller species product can be used against.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.7 APHIDS *(various species)*

These soft-bodied insects usually occur on new shoots and buds in the crown of the plant and along the veins on the undersides of the leaves. When present in large numbers, they weaken the plant. Their honeydew promotes the growth of a black sooty mold, which makes the fruit and leaves sticky, hindering harvest and reducing marketability. More important, aphids are vectors for several serious virus diseases. Aphid populations often are controlled by natural enemies and do not require insecticide control.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.7.7 Pesticides Labeled for Management of Aphids					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	1	
AzaGuard *(azadirachtin)*	10-16 oz/A	0	4	1	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	1	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	

Table 7.7.7 Pesticides Labeled for Management of Aphids					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Azatrol EC *(azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	1	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pt/A	-	12	1	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide.
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
BioRepel (*garlic oil*)	1 part BioRepel to 100 parts water/A	-	-	?	25(b) pesticide.
Ecotec *(rosemary and peppermint oil)*	1-4 pt/A	0	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	1	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
GC-Mite (*cottonseed, clove, and garlic oils*)	1 gal/100 gal water/A	-	-	1	25(b) pesticide. Conduct compatibility test prior to application.
Grandevo (*Chromobacterium subtsugae str. PRAA4-1)*	2-3 lb/A	0	4	?	
Molt-X *(azadirachtin)*	10 oz/A	0	4	1	
Mycotrol O (*Beauveria bassiana str. GHA*)	0.25-1 qt/A	Up to day of harvest	4	?	
M-Pede *(potassium salts of fatty acids)*	1-2% vol/vol	0	12	1	Works by contact. Good coverage is important.
Neemazad 1% EC *(azadirachtin)*	22.5-31.5 fl oz/A	-	4	1	Product suppresses and deters adult feeding.
Neemix 4.5 *(azadirachtin)*	5-7 fl oz/A	0	4	1	
Nuke Em *(citric acid)*	Normal: 1 fl oz/31 fl oz water	-	-	?	Use the normal strength mix first. See label for stronger dilutions if needed.
Oleotrol-I (*soybean oil)*	43-45 fl oz/100 gal water	0.5	12	?	Minimum spray volume of 50 gal/A.
Organocide 3-in-1 (*sesame oil*)	1-2 gal/100 gal water/A	-	-	1	25(b) pesticide.
PFR-97 30% WDG *(Isaria fumosorosea Apopka str. 97)*	1-2 lb/A	-	4	?	
PureSpray Green *(petroleum oil)*	0.75-1.5 gals oil/100 gal water at 100-200 gal water/A	Up to day of harvest	4	1	Spray at no less than 400 PSI using ceramic nozzles.
PyGanic 1.4 EC_{II} *(pyrethrin)*	16-64 fl oz/A	0	12	2	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic 5.0 EC_{II} *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	2	
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrins & potassium salts of fatty acids*)	6.4 oz/gallon of water	When spray is dry	12	?	Apply one gallon of mixed spray per 700 sq. ft. of plant surface area.
Sil-Matrix (*potassium silicate*)	0.5-1% solution	0	4	?	Apply at 50-250 gal/A finished spray.
SuffOil-X (*petroleum oil*)	1-2 gal/100 gal water/A	Up to day of harvest	4	1	Can cause phytotoxicity if applied too close to a sulfur application.

Table 7.7.7 Pesticides Labeled for Management of Aphids					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Trilogy (*neem oil*)	1-2% solution	Up to day of harvest	4	?	Apply in sufficient water to achieve complete coverage. Maximum labeled use of 2 gal/A/application.
TriTek (*petroleum oil)*	1-2 gal/100 gal water	Up to day of harvest	4	1	Apply as needed.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.8 POTATO LEAFHOPPER *(Empoasca fabae)*

Adults migrate into New York State in early to mid-June, carried by summer weather fronts. The adults and nymphs feed along the veins on the undersides of leaves by sucking plant juices, and in the process, inject a toxic substance with their saliva. Affected plants have shortened petioles and small distorted leaves that bend down at right angles. Leaf yellowing is also seen, starting at the margins and progressing toward the mid-vein. Avoid proximity to alfalfa plantings, which provide a major source of potato leafhopper population build-up.

At the time this guide was produced, the following materials were available in New York State for managing this pest and were allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 7.7.8 Pesticides Labeled for Management of Potato Leafhopper					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct (*azadirachtin)*	1-2 pt/A	0	4	1	
AzaGuard (*azadirachtin)*	10-16 fl oz/A	0	4	1	Apply with OMRI approved spray oil.
AzaMax (*azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	1	
Azatrol EC (*azadirachtin)*	0.24-0.96 fl oz/1000 ft^2	0	4	1	
Azera (*azadirachtin, pyrethrins)*	1-3.5 pt/A	-	12	1	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide.
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
BioRepel (*garlic oil*)	1 part BioRepel to 100 parts water/A	-	-	?	25(b) pesticide.
Cedar Gard (*cedar oil*)	1 qt/A	-	-	?	25(b) pesticide.
Ecotec (*rosemary and peppermint oil)*	1-4 pt/A	0	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME (*azadirachtin)*	15-30 oz/A	0	4	1	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X (*azadirachtin)*	10 oz/A	0	4	1	
M-Pede (*potassium salts of fatty acids)*	1-2% vol/vol	0	12	3	Works by contact. Good coverage is important. Early growth stages and eggs only.
Mycotrol O (*Beauveria bassiana str. GHA*)	0.25-1 qt/A	Up to day of harvest	4	?	
Neemazad 1% EC (*azadirachtin)*	31.5-72 fl oz/A	-	4	1	Target nymphs.
Neemix 4.5 (*azadirachtin)*	7-16 fl oz/A	0	4	1	

Table 7.7.8 Pesticides Labeled for Management of Potato Leafhopper					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
PyGanic EC 1.4II *(pyrethrin)*	16-64 fl oz/A	Until spray has dried	12	1	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0II *(pyrethrin)*	4.5-17.0 fl oz/A	0	12	1	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gallon of water	When spray is dry	12	?	Apply 1 gallon of mixed spray pre 700 sq. ft. of plant surface area.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.7.9 JAPANESE BEETLE *(Popillia japonica)*

Beetles emerge in early July and feed on leaves. Although there are Japanese beetle traps, research has shown that the traps may attract more beetles into a planting than they eliminate in the traps.

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Table 7.7.9 Pesticides Labeled for Management of Japanese Beetle					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Aza-Direct *(azadirachtin)*	1-2 pt/A	0	4	3	
AzaGuard *(azadirachtin)*	8-16 oz/A	0	4	3	Apply with OMRI approved spray oil.
AzaMax *(azadirachtin)*	1.33 fl oz/1000 ft^2	0	4	3	
AzaSol *(azadirachtin)*	6 oz/50 gal water/A	-	4	?	For control of larvae.
Azatrol EC *(azadirachtin)*	0.29-0.96 fl oz/1000 ft^2	0	4	3	
Azera *(azadirachtin, pyrethrins)*	1-3.5 pints/A	-	12	3	
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide.
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Cedar Gard (*cedar oil*)	1 qt/A	-	-	?	25(b) pesticide.
Ecozin Plus 1.2% ME *(azadirachtin)*	15-30 oz/A	0	4	3	
Envirepel *(garlic juice)*	10-32 oz/A	0.5	12	?	25(b) pesticide. Repellant.
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Molt-X *(azadirachtin)*	8 oz/A	0	4	3	
PyGanic EC 1.4II (*pyrethrin*)	16-64 fl oz/A	Until spray has dried	12	3	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.
PyGanic EC 5.0II (*pyrethrin*)	4.5-17.0 fl oz/A	0	12	3	Spraying should begin when the insects first appear. Repeat as required. Caution: do not use when bees are active in the planting.

Table 7.7.9 Pesticides Labeled for Management of Japanese Beetle					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentration II (*pyrethrin & potassium salts of fatty acids*)	6.4 oz/gallon of water	When spray is dry	12	?	Apply 1 gallon of finished spray per 700 sq. ft. of plant surface area.

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.8 Slug Management *(various species)*

These soft-bodied mollusks resemble snails without a shell. Slugs feed on ripening fruit, leaving holes in the berries. They are most active at night and during cool, wet weather. Populations are greatest when the weather is damp and the planting is mulched. Translucent silver to whitish slime trails are visible on damaged plant parts.

IPM fact sheet Banded Slug nysipm.cornell.edu/factsheets/fieldcrops/b_slug.pdf
IPM fact sheet Gray Garden Slug nysipm.cornell.edu/factsheets/fieldcrops/gg_slug.pdf
IPM fact sheet Marsh Slug nysipm.cornell.edu/factsheets/fieldcrops/m_slug.pdf
IPM fact sheet Spotted Garden Slug nysipm.cornell.edu/factsheets/fieldcrops/sg_slug.pdf

Slug Management Options	
Scouting/thresholds	None established.
Variety susceptibility	No known resistant varieties.
Cultural management	Eliminating mulch will reduce slug populations, but will cause other problems, so this is not recommended. Good sanitation and weed control helps to reduce slug populations. In areas where slugs are a problem, avoid perennial clovers as cover crops and rotate out of alfalfa or other perennial legumes 1 year prior to planting establishment. Overhead irrigation creates conditions especially favorable to slugs. If overhead irrigation must be used, irrigate during morning hours to allow foliage to dry before evening.
Chemical treatment	See below.

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Table 7.8.1 Pesticides Labeled for Management of Slugs					
Trade Name (*active ingredient*)	**Product Rate**	**PHI (days)**	**REI (hours)**	**Efficacy[1]**	**Comments**
BioLink (*garlic juice*)	0.5-2 qt/A	0.5	-	?	25(b) pesticide
BioLink Insect & Bird Repellant (*garlic juice*)	0.5-4 qt/A	0.5	-	?	25(b) pesticide
Bug-N-Sluggo (*iron phosphate and spinosad)*	20-44 lb/A	1	4	?	
Garlic Barrier AG+ (*garlic juice*)	See comments	-	4	?	25(b) pesticide. See label for specific information.
Sluggo-AG (*iron phosphate)*	20-44 lb/A	0	0	?	Spread bait around perimeter to intercept slugs migrating toward berries.
Sluggo Slug & Snail Bait (*iron phosphate*)	20-44 lb/A	0	0	?	

[1] Efficacy: 1-effective in some research studies, 2- inconsistent efficacy results, 3-not effective, ?-not reviewed or no research available.
PHI-Pre-harvest interval. REI-Restricted Entry Interval. - = pre-harvest interval isn't specified on label.

7.9 Wildlife Management

Various rodents can damage a strawberry planting, especially as they feed under mulch in the winter. Closely mowing the area around the planting in early November will reduce the habitat for voles and mice. The habitats (woodlots) of predators that feed on rodents (hawks, owls, foxes) should be protected around the area. A number of poisonous baits are labeled for use in agricultural areas. To be most effective, baits should be placed in feeding stations that exclude large animals and are replenished throughout the winter.

Deer browsing can devastate berry plantings. Multiple strategies are required to discourage deer from feeding on berry plantings. Refer to Reducing Deer Damage to Home Gardens and Landscape Plantings by P. Curtis and M. Richmond for recommended methods.

When using dogs and invisible fence to manage vertebrate pests in a planting, there is food safety risk associated with the dog excrement. If the dog consistently uses an area away from the field, the risk is somewhat reduced. Also, if the dog prevents other vertebrate animals from using the field, that also reduces the risk to food safety. Using dogs primarily in the winter and early spring when deer browsing is greatest (and avoiding use during harvest) will also minimize food safety risk.

Table 7.9.1. Vertebrate Damage Mitigation Practices

Animal Pest	Management Practices[1]
Mice and voles	Removal of dropped fruit; habitat manipulations including elimination of unmowable areas surrounding plantings; monitor to determine the need for management. Mow closely in late fall around the planting and apply winter mulch only after mowing. Population control through trapping by landowner.
Raccoons	Avoid sites with woods along the edge(s) because these will support raccoon populations. Electrified exclusion fencing. Population reduction through shooting by licensed hunters or landowners in appropriate seasons; through trapping by landowner, by licensed trapper, or by licensed nuisance wildlife control agent.
Red and gray foxes	Tend to chew on irrigation lines. Manipulation including elimination of protective cover around plantings. Population reduction through shooting by licensed hunters or landowners in appropriate seasons; through trapping by landowner, by licensed trapper, or by licensed nuisance wildlife control agent.
White-tailed deer	Exclusion fencing (8 ft. [250 cm] high-tensile woven wire or 5 to 6 ft. [150 to 200 cm] electric exclusion fencing; peanut-butter baited electric fences; invisible fencing with dogs); habitat manipulation including elimination of protective cover around plantings. Population reduction through shooting by licensed hunters, landowners or their agents with DMAP or nuisance deer permits. Unlike with other vertebrate pests, landowners cannot kill nuisance deer without a permit.
Woodchucks	Exclusion fencing (electrified exclusion fencing); habitat manipulation including removal of brush piles. Population reduction through shooting by licensed hunters or landowners; through trapping by landowner or by licensed nuisance wildlife control agent.

[1] Conduct shooting and trapping only as defined by New York State Department of Environmental Conservation regulations. Shooting for nuisance wildlife control is allowed only when neighboring occupied buildings are >500 ft. distant; shooting when neighboring buildings are less than 500 ft. distant requires neighbor permission. Shooting also may require a permit, depending on animal and season. Also check local ordinances, as shooting and trapping are prohibited in some areas. Note: It is illegal to trap a nuisance animal and release it onto public lands or someone else's property. It must be released on the landowner's property or killed.

7.10 Considerations During Harvest and Renovation

During harvest operations some pests can become a nuisance, e.g. wasps and yellow jackets, particularly in U-pick operations. Wasp and yellow jacket nests can be destroyed during the growing season as they are found in the planting and surrounding areas. Some species are ground-nesting and such nests can be destroyed by drenching with hot water. Traps baited with sugary liquids, such as Hi-C, provide a means of reducing the population of wasps and yellow jackets, but the effectiveness of this tactic on a large scale is unknown. For more information see "Bee and Wasp Management, A Common Sense Approach" (2011) by Jody Gangloff-Kaufman.

During harvest much can be done to reduce disease and insect pressure by eliminating infested and infected fruit from the planting. Separate damaged fruit from healthy fruit as it is being picked. Designate pickers to cull such fruit from the field at harvest time. Then bury or burn the diseased and infested fruit. This is helpful to combat gray mold, leather rot and anthracnose (through the removal of overripe and infected fruit), spotted wing drosophila, strawberry sap beetle (through the removal of overripe or infested fruit), and slugs (through the removal of overripe and dropped fruit).

After harvest, a post-harvest grading table will provide an excellent opportunity to grade out damaged, diseased and infected fruit which will lower quality and market value. All culled fruit should be destroyed by burning or burying. Cleanliness or sanitation in the planting is very important, removing dropped berries during harvest will reduce risk from gray mold, leather rot and anthracnose, spotted wing drosophila, strawberry sap beetle and slugs, as described above. At this time also make note of trouble spots in the field, or the presence of unthrifty plants, foliar diseases, leaf damage, etc. and plan steps to maintain a healthy planting.

At renovation do a thorough job of mowing the leaves off June-bearing strawberry plants, chopping mulch, and turning under infected and infested plant parts. Application of a thick mat of straw in early winter will provide protection from cold weather for the winter and assist in protecting plants from rain splashed inoculum from buried plant debris.

Keep in mind your production goals and recognize that it should be possible to obtain good yields in organic strawberry production. Therefore, maintain good records of the planting condition, pest pressure, the amount of fruit harvested, and your markets.

8. FOOD SAFETY

Attention to microbial food safety is important for crops that are eaten raw. Continuing produce-associated foodborne illness outbreaks have resulted in many buyers requiring the implementation of food safety practices on the farm and the development of the first ever produce safety regulations as part of the Food Safety Modernization Act (FSMA). Pathogens can contaminate food during all phases of production, harvesting, and packing. Wild and domesticated animals, manure, irrigation water, inadequate worker hygiene, unclean picking containers, unsanitized post-harvest water, and unclean packaging materials are all potential vectors of microbiological contaminants. Growers should conduct a risk assessment to identify microbial hazards and then implement appropriate practices to reduce risks. There are many resources available to help including those at the National GAPs Program or the Produce Safety Alliance. Regardless of farm size, commodities or cultural practices, Good Agricultural Practices can be used to identify and possibly reduce microbial risks.

Implementing just a few simple practices can reduce risks significantly. One of these is to wash hands using potable water and sanitizer prior to any contact with the crop, particularly after using the restroom or eating. Do not allow workers who are ill to handle produce. If they are able to work, assign jobs that do not involve contact with produce or customers. Prevent animals or animal manure from contacting produce, by discouraging animals (including pets) from entering production fields and by not using irrigation water that may have been contaminated with manure. Manure should only be applied before planting so it can be incorporated into the soil. For fall-fruiting berries, composted manure can be applied to the soil in spring if it has been composted prior to application. Ensure that picking containers are clean and free from mouse droppings. Do not allow fruit to become wet after harvest. Following these steps can dramatically reduce risks of pathogen contamination. Conduct a full assessment of your farm to identify other high risk practices.

The Food Safety Modernization Act (FSMA) will apply to farms that grow, harvest, pack or hold most fruits and vegetables when those fruits and vegetables are in an unprocessed state, and will govern practices affecting: water, worker hygiene, manure and other soil additions, animals in the growing area, and equipment, tools and buildings When the FSMA is finalized, the Food and Drug Administration (FDA) will be mandated to enforce preventive control measures, and to conduct inspections across the food supply system. Updates and information on this proposed rule are available at the United States Food and Drug Administration's Food Safety Modernization Act website.

At the time this guide was produced, the following materials were available in New York State as sanitizers allowable for organic production. Listing a pest on a pesticide label does not assure the pesticide's effectiveness. The registration status of pesticides can and does change. Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. However, pesticides meeting the federal requirements for minimum-risk (25(b)) pesticides do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) website. ALWAYS CHECK WITH YOUR CERTIFIER before using a new product.

Table 8.1 Rates for Sanitizers Labeled for Postharvest Strawberries and/or Postharvest Facilities

Active ingredient **Product name**	***Uses***		
	Food contact surfaces[1]	**Hard surface, non-food contact[1]**	**Fruit surface (spray or drench)**
chlorine dioxide			
CDG Solution 3000	50 ppm solution	500 ppm solution	5 ppm solution
Oxine[2]	100 ppm solution	500 ppm solution	In tanks, use a 5 ppm solution; for process waters use a chemical feed

Table 8.1 Rates for Sanitizers Labeled for Postharvest Strawberries and/or Postharvest Facilities			
Active ingredient	***Uses***		
Product name	**Food contact surfaces**[1]	**Hard surface, non-food contact**[1]	**Fruit surface (spray or drench)**
			pump or other injector system at 3 ¼ fl oz per 10 gal water.[3]
Pro Oxine[2]	50-200 ppm solution	500 ppm solution	-
hydrogen peroxide/peroxyacetic acid			
Enviroguard Sanitizer	-	2.5-20 fl oz/5 gal water	1 fl oz/20 gal water
Oxonia Active	1-1.4 oz/4 gal water	1 oz/8 gal water.	-
Peraclean 5	1-1.5 fl oz/5 gal water	-	-
Peraclean 15	0.33 fl oz/5 gal water	-	-
Perasan 'A'	1-2.4 fl oz/6 gal water	-	1 fl oz/20 gal water
Per-Ox	1-2.25 fl oz/5 gal water	1-10 fl oz/15 gal water	1 fl oz/5 gal water
*SaniDate 5.0	1.6 fl oz/ 5 gal water	1.6 fl oz/ 5 gal water	59.1 to 209.5 fl oz/ 1,000 gal water
SaniDate 12.0	-	-	25.6 to 89.6 fl oz / 1,000 gal water
Shield-Brite PAA 5.0	1.6fl oz/5 gal water	1.6fl oz/5 gal water	59.1 to 209.5 fl. oz./1,000 gal water
Shield-Brite PAA 12.0	-	-	25.6 to 89.6 fl.oz/1,000 gal water
StorOx 2.0	0.5 fl oz/1 gal water	0.5 fl oz/1 gal water	-
Tsunami 100	-	-	2.5-6.7 fl oz/100 gal water
Victory	-	-	1 fl oz/16.4 gal water
VigorOx Liquid Sanitizer and Disinfectant OA I	1-1.7 fl oz/5 gal water	1-11 fl oz/16 gal water	-
VigorOx 15 F & V	0.31-0.45 fl oz/5 gal water	1.1-9.5 fl oz/5 gal water	0.54 fl oz/ 16 gal water
VigorOx LS-15	0.31-0.45 fl oz/5 gal water	1.1-9.5 fl oz/5 gal water	-
sodium hypochlorite			
San-I-King No. 451	100 ppm chlorine in solution	-	-

[1] Thoroughly clean all surfaces and rinse with potable water prior to treatment.
[2] Requires acid activator.
[3] After treatment, rinse with potable water.
*Restricted-use pesticide in New York State

9. SMALL-SCALE SPRAYER TECHNOLOGY

9.1 Spraying Small Strawberry Plantings

On many small-scale strawberry plantings, spraying often requires special attention to calibration, calculating amounts of pesticide to use, and measuring pesticide products.

To ensure even distribution throughout the canopy, a systematic approach to spraying the whole canopy is essential. Take particular care to cover the top of the canopy as well as ensuring adequate penetration into the inside and middle of the canopy and the fruiting zone. Water sensitive cards (Syngenta) or Surround, kaolin clay, (Engelhard) may be used as tracers to monitor spray distribution.

PRIOR TO SPRAYING—CALIBRATING SPRAYERS

Calibration of backpack sprayers

Use clean water

DYNAMIC CALIBRATION

1. Select correct nozzle and pressure.
2. Measure and mark off an area 10 feet x 10 feet on concrete.
3. Fill sprayer to a known level, mark the fill level.
4. Spray the area on the concrete.
5. Refill sprayer to the fill mark.
6. Compare quantity collected with nozzle chart and desired amount.

STATIC CALIBRATION

1. Select correct nozzle and pressure.
2. Measure and mark off an area 10 feet x 10 feet on concrete.
3. Spray the area and record time taken.
4. Carry out stationary run of same time duration, catching liquid in a graduated measuring jug.
5. Compare quantity collected with nozzle chart and desired amount.

CALCULATING THE AMOUNT OF PESTICIDE TO USE

Some organically approved pesticides are typically sold for large-scale plantings and give application rates on a per acre basis. When converting a known quantity per acre to spray a smaller area, the first step is to measure the area to be sprayed using a tape measure. Divide the number of square feet you have measured by 43,560 to obtain the acreage (in decimal form).

Example:

1. If you are going to spray 20,000 sq. ft,
   20,000 divided by 43,560 = 0.459 acre
2. The label states 3 pints of product per acre
   Multiply the label rate per acre by the decimal for you area
   3 pints multiplied by 0.459 = 1.38 pints
3. Remember there are 16 fl oz in 1 pint.

MEASURING SMALL AMOUNTS OF PESTICIDE

The following tables and examples provide information on converting pesticide rate amounts for smaller areas.

Table 9.1.1. How much powder or granules should I use?

Volume of liquid	*100 gallons*	*25 gallons*	*5 gallons*	*1 gallon*
Amount of powder or granules to use	4 oz	1 oz	$^3/_{16}$ oz	½ tsp
	8 oz	2 oz	$^3/_8$ oz	1 tsp
	1 lb	4 oz	$^7/_8$ oz	2 tsp
	2 lb	8 oz	1 ¾ oz	4 tsp
	3 lb	12 oz	2 $^3/_8$ oz	2 Tbsp
	4 lb	1 lb	3 ¼ oz	2 Tbsp + 2 tsp

Table 9.1.2. How much liquid should I use?

Volume of liquid	*100 gallons*	*25 gallons*	*5 gallons*	*1 gallon*
Amount of liquid to use	1 gal	2 pts	6 ½ oz	1 ¼ oz
	4 pts	1 pt	3 ¼ oz	$^5/_8$ oz
	2 pts	½ pt	1 $^9/_{16}$ oz	$^5/_{16}$ oz
	1 ½ pt	6 oz	1 ¼ oz	¼ oz
	1 pt	4 oz	$^7/_8$ oz	$^3/_{16}$ oz
	8 oz	2 oz	$^7/_{16}$ oz	½ tsp
	4 oz	1 oz	¼ oz	¼ tsp

Table 9.1.3. Dilution of liquid products to various concentrations

Dilution rate	*1 gallon*	*3 gallon*	*5 gallon*
1 in 100	2 Tbsp + 2 tsp	½ cup	¾ cup + 5 tsp
1 in 200	4 tsp	¼ cup	6 ½ Tbsp
1 in 800	1 tsp	1 Tbsp	1 Tbsp + 2 tsp
1 in 1000	¾ tsp	2 ½ tsp	1 Tbsp + 1 tsp

Powders and granules

Example: The label states 3 lb of powdered product per 100 gallons but you only wish to use a backpack sprayer with a 5-gallon tank. Table 8.1 shows you need to mix in 2 $^3/_8$ oz of powder. Use clean weighing scales to provide the correct amount of powder, NEVER use a volumetric measure, e.g. a measuring cup, because the bulk density of different products varies.

Liquids

Example: The label states 4 pts of a liquid product per 100 gallons of spray but you only wish to use a backpack sprayer with a 5-gallon tank. Table 8.2, below, shows you need to mix in 3¼ fl oz of liquid product. Use a clean measuring cylinder or vessel to provide the correct amount of liquid.

Measuring equipment.

Always use measuring equipment that is dedicated only for pesticide use. For very small quantities of liquids, a syringe can be useful. For powder or granular products use weighing scales, do not rely on a measuring cup as the bulk density of products varies.

Safety.

Be sure to wear the proper protective clothing and equipment as required on the pesticide label. Always be aware of watercourses, neighboring properties and changes in the weather.

9.2 Selecting a Small Sprayer for the Small, Organic Strawberry Planting

There are many important points to consider before purchasing a sprayer, not the least of which is the area to spray, the proximity of the local supplier, standard of manufacture, etc. There are many growers with small plantings who need spraying equipment ranging from backpack sprayers to small truck- or ATV-mounted machines.

CANOPY SPRAYERS

Backpack sprayers

Small capacity (4-5 gallon) sprayers will produce up to approximately 100 psi pressure. Weight is an important consideration and growers should select a sprayer with good, wide, padded straps to ease the load on your shoulders. Correct nozzle selection according to the target is very important to ensure even coverage. A good-sized filling hole at the top is also important.

There are three factors affecting application rate - forward speed, pressure, and nozzle tip size. Unfortunately most inexpensive backpack sprayers have no pressure gauge. Pay more money and purchase a backpack sprayer with a pressure gauge or, better still, purchase a spray management valve as standard or as an option. Normally output increases or decreases according to the pressure in the system, (which is dependent upon how vigorous you are in pumping the handle up and down). A spray management valve, such as a CF valve, will ensure a constant output irrespective of hand pump action. The CF valve evens out fluctuations in pressure, e.g. will only allow a maximum and minimum pressure thus ensuring even flow. The Fountainhead Group sells a backpack sprayer with a simple valve which ensures the correct pressure is not exceeded.

An alternative to the hand-operated backpack sprayer is an electrically-operated backpack sprayer, which utilizes a small rechargeable battery. Maximum pressure is relatively low and it is easier than using a traditional hand pump system, particularly if you have many rows of plants to spray. Similarly a small back pack sprayer fitted with a small gas engine is available. The electric version is quieter to use, but you must remember to recharge the batteries otherwise spraying will be delayed.

Portable mist and air blower backpacks

These are ideal where canopy penetration is required, e.g. denser, vigorous plantings. A small gas engine drives a fan blower which creates an airstream which passes along a hand-held tube (similar to a leaf blower). The tube has a nozzle situated at the end so that liquid spray can be squirted into the airstream. The operator directs the spray cloud towards the canopy by pointing the hand-held tube. It is preferable to point the tube backwards to avoid walking into the spray cloud. Engine speed can be reduced which enables a slower airspeed to match a smaller canopy in early season. They are very good at rustling the canopy and getting good penetration and deposition. They are heavy! Noise is a problem, so ear protection must be worn.

Portable engine-driven gas sprayers

If weight is a problem, and ground conditions are relatively smooth, a number of manufacturers offer a sprayer with a small gas engine and a 10 to 12 gallon tank. Larger capacity tanks (14 to 100 gallons) are often trailed and can be pulled by a lawn tractor, ATV, Gator, or small tractor.

Small, mounted sprayers

Ideal for mounting onto the carrier rack of an ATV, 15 to 25 gallons, they use a small electric pump to provide up to 70 psi. When used with a hand wand and a hose, they can be used to spray short rows. The same system is ideal for weed control and spot spraying of weeds.

Large, skid mounted sprayers

Ideal for fitting into the back of a pick-up truck, these sprayers have a tank capacity of 35 to 200 gallons, and an electric-start gas engine.

HERBICIDE OR GROUND APPLICATION SPRAYERS

Backpack, small ATV-mounted tank, and hand-lance sprayers

These sprayers can be used for herbicide application **BUT** be very careful that there is no carry-over from herbicide residues in the sprayer, therefore wash them out very thoroughly before using them to apply materials other than herbicides. Alternatively, have dedicated herbicide-only equipment.

Controlled Droplet Applicators (CDA)

The use of CDA's will considerably reduce the need to carry vast amounts of water. A spinning disc (battery powered) will produce 95% of the same-size droplets, thus reducing herbicide rates by at least 50% and water rates by 75%. Herbi and Mantis (trade names) are both hand-held CDA sprayers. ATV- or tractor-mounted shielded CDA sprayers such as the Environmist also reduce spray rates while shielding the plants from the spray.

Wick wipers

Where occasional weeds and access over wet land are a problem, the use of a hand-held wick wiper is an easy-to use, effective option. A small tank, usually contained in the handle, holds the liquid, which soaks a rope wick or a sponge. The rope or sponge can then be wiped against the weeds.

For further information on pesticide application technology visit Cornell's Pesticide Application Technology website.

10. PESTICIDES MENTIONED IN THIS PUBLICATION

Table 10.1 Fungicides, and Bactericides		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
Acoidal	*sulfur*	62562-4
Actinovate-AG	*Streptomyces lydicus WYEC 108*	73314-1
Badge X2	*copper oxychloride, copper hydroxide*	80289-12
Basic Copper 53	*copper sulfate*	45002-8
BIO-TAM	*Trichoderma asperellum, Trichoderma gamsii*	80289-9-69592
BIO-TAM 2.0	*Trichoderma asperellum, Trichoderma gamsii*	80289-9
Champ WG	*copper hydroxide*	55146-1
Cinnerate	*cinnamon oil*	exempt 25(b) pesticide
CS 2005	*copper sulfate pentahydrate*	66675-3
Cueva Fungicide Concentrate	*copper octanoate*	67702-2-70051
Defend DF	*sulfur*	62562-8
Double Nickel 55	*Bacillus amyloliquefaciens str. D747*	70051-108
Double Nickel LC	*Bacillus amyloliquefaciens str. D747*	70051-107
EcoMate ARMICARB 0	*potassium bicarbonate*	5905-541
Glacial Spray Fluid	*mineral oil*	34704-849
Golden Pest Spray Oil	*soybean oil*	57538-11
JMS Stylet Oil	*paraffinic oil*	65564-1
Kaligreen	*potassium bicarbonate*	11581-2
Kumulus DF	*sulfur*	51036-352-66330
M-Pede	*potassium salts of fatty acids*	10163-324
Microthiol Disperss	*sulfur*	70506-187
Micro Sulf	*sulfur*	55146-75
Mildew Cure	*cottonseed, corn and garlic oils*	exempt 25(b) pesticide
Milstop	*potassium bicarbonate*	70870-1-68539
Nordox 75 WG	*cuprous oxide*	48142-4
Nu-Cop 50 WP	*copper hydroxide*	45002-7
Nu-Cop 50 DF	*copper hydroxide*	45002-4
Nu-Cop HB	*cupric hydroxide*	42750-132
Nuke Em	*citric acid*	exempt 25(b) pesticide
Optiva	*Bacillus subtilis*	69592-26
Organic JMS Stylet Oil	*paraffinic oil*	65564-1
Organocide 3-in-1	*sesame oil*	exempt 25(b) pesticide
OxiDate 2.0	*hydrogen dioxide, peroxyacetic acid*	70299-12
PERpose Plus	*hydrogen peroxide/dioxide*	86729-1
Prestop	*Gliocladium catenulatum*	64137-11
PureSpray Green	*petroleum oil*	69526-9
Regalia	*Reynoutria sachalinensis*	84059-3
RootShield Granules	*Trichoderma harzianum Rifai str. T-22*	68539-3
RootShield PLUS+ Granules	*Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*	68539-10

Table 10.1 Fungicides, and Bactericides		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
RootShield PLUS+ WP	*Trichoderma harzianum str. T-22, Trichoderma virens str. G-41*	68539-9
RootShield WP	*Trichoderma harzianum Rifai str. KRL-AG2*	68539-7
Serenade ASO	*Bacillus subtilis str. QST 713*	69592-12 and 264-1152
Serenade MAX	*Bacillus subtilis str. QST 713*	69592-11 and 264-1151
Serenade Optimum	*Bacillus subtilis str. QST 713*	264-1160
Serenade Soil	*Bacillus subtilis str. QST 713*	69592-12
Sil-Matrix	*potassium silicate*	82100-1
SoilGard	*Gliocladium virens str. GL-21*	70051-3
SuffOil-X	*petroleum oil*	48813-1-68539
TerraClean 5.0	*hydrogen dioxide, peroxyacetic acid*	70299-13
Thiolux	*sulfur*	34704-1079
Trilogy	*neem oil*	70051-2
TriTek	*mineral oil*	48813-1
Zonix Biofungicide	*Rhamnolipid Biosurfactant*	72431-1

Table 10.2. Insecticides and Miticides		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
Acoidal	*sulfur*	62562-4
Aza-Direct	*azadirachtin*	71908-1-10163
AzaGuard	*azadirachtin*	70299-17
AzaMax	*azadirachtin*	71908-1-81268
AzaSol	*azadirachtin*	81899-4
Azatrol EC	*azadirachtin*	2217-836
Azera	*azadirachtin, pyrethrins*	1021-1872
Biobit HP	*Bacillus thuringiensis subsp. kurstaki*	73049-54
BioLink	*garlic juice*	exempt 25(b) pesticide
BioLink Insect & Bird Repellant	*garlic juice*	exempt 25(b) pesticide
BioRepel	*garlic oil*	exempt 25(b) pesticide
Cedar Gard	*cedar oil*	exempt 25(b) pesticide
Cinnerate	*cinnamon oil*	exempt 25(b) pesticide
Defend DF	*sulfur*	62562-8
Deliver	*Bacillus thuringiensis subsp. kurstaki*	70051-69
Dipel DF	*Bacillus thuringiensis subsp. kurstaki*	73049-39
Ecotec	*rosemary and peppermint oil*	exempt 25(b) pesticide
Ecozin Plus 1.2% ME	*azadirachtin*	5481-559
Entrust Naturalyte Insect Control	*spinosad*	62719-282
Entrust SC	*spinosad*	62719-621
Envirepel 20	*garlic juice*	exempt 25(b) pesticide
Garlic Barrier AG+	*garlic juice*	exempt 25(b) pesticide
GC-Mite	*cottonseed, clove and garlic oils*	exempt 25(b) pesticide
Glacial Spray Fluid	*mineral oil*	34704-849
Grandevo	*Chromobacterium subtsugae str. PRAA4-1*	84059-17
Javelin WG	*Bacillus thuringiensis subsp. kurstaki*	70051-66
JMS Stylet Oil	*paraffinic oil*	65564-1
M-Pede	*potassium salts of fatty acids*	10163-324
Micro Sulf	*sulfur*	55146-75

Table 10.2. Insecticides and Miticides		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
Microthiol Disperss	*sulfur*	70506-187
Molt-X	*azadirachtin*	68539-11
Mycotrol O	*Beauveria bassiana*	82074-3
Neemazad 1% EC	*azadirachtin*	70051-104
Neemix 4.5	*azadirachtin*	70051-9
Nuke Em	*citric acid*	exempt 25(b) pesticide
Oleotrol-I	*soybean oil*	exempt 25(b) pesticide
Omni Supreme Spray	*mineral oil*	5905-368
Organic JMS Stylet Oil	*paraffinic oil*	65564-1
Organocide 3-in-1	*sesame oil*	exempt 25(b) pesticide
PFR-97 20% WDG	*Isaria fumosorosea Apopka str. 97*	70051-19
PureSpray Green	*petroleum oil*	69526-9
PyGanic EC 1.4 II	*pyrethrins*	1021-1771
PyGanic EC 5.0 II	*pyrethrins*	1021-1772
Safer Brand #567 Pyrethrin & Insecticidal Soap Concentrate II	*pyrethrins & potassium salts of fatty acids*	59913-9
Sil-Matrix	*potassium silicate*	82100-1
SuffOil-X	*petroleum oil*	48813-1-68539
Trilogy	*neem oil*	70051-2
TriTek	*petroleum oil*	48813-1
Xentari	*(Bacillus thuringiensis subsp. Aizawai, str. ABTS-1857)*	73049-40

Table 10.3. Herbicides		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
AXXE Broad Spectrum Herbicide	*ammonium nonanoate*	70299-23

Table 10.4. Mollusk Control Chemicals		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
Bug-N-Sluggo	*iron phosphate and spinosad*	67702-24-70051
Sluggo-AG	*iron phosphate*	67702-3-54705
Sluggo Slug & Snail Bait	*iron phosphate*	67702-3-70051

Table 10.5 Sanitizers mentioned in this publication		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
CDG Solution 3000	*chlorine dioxide*	75757-2
Enviroguard Sanitizer	*hydrogen peroxide/peroxyacetic acid*	63838-1-527
Oxine	*chlorine dioxide*	9804-1
Oxonia Active	*hydrogen peroxide/peroxyacetic acid*	1677-129
Peraclean 5	*hydrogen peroxide/peroxyacetic acid*	54289-3
Peraclean 15	*hydrogen peroxide/peroxyacetic acid*	54289-4
Perasan 'A'	*hydrogen peroxide/peroxyacetic acid*	63838-1
Per-Ox	*hydrogen peroxide/peroxyacetic acid*	833-4
Pro Oxine	*chlorine dioxide*	9804-9
*SaniDate 5.0	*hydrogen peroxide/peroxyacetic acid*	70299-19

Table 10.5 Sanitizers mentioned in this publication		
Trade Name	**Active Ingredient**	**EPA Reg. No.**
SaniDate 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18
San-I-King No. 451	*sodium hypochlorite*	2686-20001
Shield-Brite PAA 5.0	*Peroxy acetic acid/hydrogen peroxide*	70299-19-64864
Shield-Brite PAA 12.0	*hydrogen peroxide/peroxyacetic acid*	70299-18-64864
StorOx 2.0	*hydrogen peroxide/peroxyacetic acid*	70299-7
Tsunami 100	*hydrogen peroxide/peroxyacetic acid*	1677-164
Victory	*hydrogen peroxide/peroxyacetic acid*	1677-186
VigorOx Liquid Sanitizer and Disinfectant OAI	*hydrogen peroxide/peroxyacetic acid*	65402-6
VigorOx 15 F & V	*hydrogen peroxide/peroxyacetic acid*	65402-3
VigorOx LS-15	*hydrogen peroxide/peroxyacetic acid*	65402-3

* Restricted-use pesticide in New York State

10.1 Pesticides Labeled for use in Organic Strawberry Production

At the time the guide was released, the pesticides listed in this guide were allowable for organic production under the National Organic Program (NOP) regulations as set forth in 7 CFR Part 205, sections 600-606 and registered for use in New York. The authors relied mainly on the Organic Materials Review Institute (OMRI) list for pesticides to include. Always check with your certifier before using any new pesticide.

Given the high cost of many pesticides and the limited efficacy data available for many of them, the importance of developing an integrated approach based on cultural practices for disease and insect management, as described in the previous section, cannot be emphasized strongly enough. **Pesticides should not be relied on as a primary method of pest control**. Scouting, forecasting, or trapping pests are important for detecting infestations at an early stage. When conditions do warrant an application, proper choice of materials, proper timing, and excellent spray coverage are essential.

10.2 Pesticide Regulatory Considerations

Organic production focuses on cultural, biological, and mechanical techniques to manage pests on the farm, but in some cases pesticides, which include repellents, allowed for organic production are needed. Pesticides mentioned in this organic production guide are registered by the United States Environmental Protection Agency (EPA) or meet the EPA requirements for a "minimum risk" pesticide. The pesticides mentioned in this guide are also registered by the New York State Department of Environmental Conservation (NYS DEC) for use in New York State. See Cornell's Product, Ingredient, and Manufacturer System website for pesticides currently registered for use in NYS. Additional products may be available for use in other states.

To maintain organic certification, products applied must also comply with the National Organic Program (NOP) regulations as set forth in 7 CFR Part 205, sections 600-606. The Organic Materials Review Institute (OMRI) is one organization that reviews products for compliance with the NOP regulations and publishes lists of compliant products, but other entities also make product assessments. Organic growers are not required to use only OMRI listed materials, but the list is a good starting point when searching for allowed pesticides.

Finally, farms grossing more than $5,000 per year and labeling products as organic must be certified by a NOP accredited certifier who must approve any material applied for pest management. ALWAYS check with the certifier before applying any pest control products. Some certifiers will review products for NOP compliance.

Note that "home remedies" may not be used. Home remedies are products that may have properties that reduce the impact of pests. Examples of home remedies include the use of beer as bait to reduce slug damage in strawberries or dish detergent to reduce aphids on plants. These materials are not regulated as pesticides, are not exempt from registration, and are therefore not legal to use.

Do you need to be a certified pesticide applicator? The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines two categories of pesticides: general-use and restricted-use. NYS DEC also defines additional restricted-use pesticides. Pesticide applicator certification is required to purchase and use restricted-use pesticides. Restricted-use pesticides mentioned in this guide are marked with an asterisk (*). Farmers who purchase and use only general-use pesticides on property they own or rent do not need to be certified pesticide applicators. However, we do encourage anyone who applies pesticides to become certified.

Worker Protection Standard training. If the farm has employees who will be working in fields treated with a pesticide, they must be trained as workers or handlers as required by the federal Worker Protection Standard (WPS). Having a pesticide applicator certification is one of the qualifications needed to be a WPS trainer. Certified pesticide applicators meet the WPS training requirements. For more information on the Worker Protection Standard see: How To Comply with the Worker Protection Standard. Find more information on pesticide applicator certification from the list of State Pesticide Regulatory Agencies or, in New York State, see the Cornell Pesticide Management Education Program website at http://psep.cce.cornell.edu.

10.3 Optimizing Pesticide Effectiveness

Information on the effectiveness of a particular pesticide against a given pest can sometimes be difficult to find. Some university researchers include pesticides approved for organic production in their trials; some manufacturers provide trial results on their web sites; some farmers have conducted trials on their own. Efficacy ratings for pesticides listed in this guide were summarized from university trials and are only provided for some products.

In general, pesticides allowed for organic production may kill a smaller percentage of the pest population, could have a shorter residual, and may be more quickly broken down in the environment than synthetic pesticides. Read the pesticide label carefully to determine if water pH or hardness will negatively impact the pesticide's effectiveness. Use of a surfactant may improve organic pesticide performance. OMRI lists adjuvants in OMRI Products List, Web Edition, http://www.omri.org/simple-opl-search/results/adjuvants.

Regular scouting and accurate pest identification are essential for effective pest management. Thresholds used for conventional production may not be useful for organic systems because of the typically lower percent mortality and shorter residual of pesticides allowed for organic production. When pesticides are needed, it is important to target the most vulnerable stages of the pest. Thoroughly cover plant surfaces, especially in the case of insecticides, since many must be ingested to be effective. The use of pheromone traps or other monitoring or prediction techniques can provide an early warning for pest problems, and help effectively focus scouting efforts.

Pesticide resistance may develop in pathogens, insects, mites, etc. following repeated exposure to the same or similar mode-of-action materials and result in reduced or complete loss of pesticide efficacy against the resistant pest. During the growing season and across growing seasons, pesticides of one mode-of-action should be alternated with those of different modes-of-action to lower the risk of pests developing resistance to the pesticides. See the product label for more information.

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11. GLOSSARY

(Adapted from: Wikipedia, www.wikipedia.org/, the free online encyclopedia)

Adjuvant – any substance added to the spray tank, (separate from the pesticide) that will improve the performance of the pesticides, (herbicides, insecticides, miticides, fungicides, bactericides), fertilizers etc. by reducing the surface tension of the water and improving spread and coverage.

Agroecosystem – all of the living and non-living components, including inputs and outputs, that comprise a spatial and functional coherent unit of agricultural activity.

Allelopathy – condition in which one plant emits substances that affect germination, development or growth of other plants in contact with the substance.

Annual – a plant that completes its life cycle within one year (germination, flowering, seed production, death).

Biennial – a flowering plant that takes two years to complete its biological life cycle.

Buffer zone – a physical space of sufficient size that separates two or more areas of activity so that these areas do not affect each other.

Cation exchange capacity – (CEC) is the capacity of a soil to retain and substitute cations (positively charged ions, e.g. potassium) between the soil and the soil solution. CEC is a measure of nutrient retention capacity.

Compost – a combination of plant, animal and other organic materials that have been decomposed largely through aerobic processes into a substance rich in carbon, nutrients, and biological activity.

Crop rotation – the practice of growing, in the same area, in sequential seasons, a series of dissimilar types of crops to avoid the buildup of pathogens and pests that often occurs when one species is continuously cropped.

Frost pocket – an area where still air, cooled by ground-level radiation, travels downhill, replaces warm air, and accumulates to form pockets of very cold air in depressions, valleys, and hollows.

Green manure – a type of cover crop grown for a specific period of time, then incorporated into the soil to add nutrients and organic matter for soil improvement.

Humus – organic matter that is well-decomposed, stable, and contributes to soil tilth and cation exchange.

Immobilization – is when organic matter decomposes and is absorbed by micro-organisms, therefore preventing it being accessible to plants for periods of time. Immobilization is the opposite of mineralization.

Integrated Pest Management (IPM) – a management strategy aimed at insects, mites, plant diseases, weeds, and other pests that uses a variety of planned, complementary tactics including: mechanical devices, physical devices, genetic resistance, biological control, cultural practices, and chemical treatment. It is an ecological approach with a main goal of significantly reducing or eliminating the use of pesticides while at the same time managing pest populations at an acceptable level.

Macroclimate – refers to the regional climate of a broad agricultural area. It can include an area on the scale of tens to hundreds of kilometers.

Mesoclimate – refers to the climate of a particular planting site and is generally restricted to a space of tens or hundreds of meters.

Microclimate – refers to the specific environment in a small restricted space such as a row of plants or corner of a field.

Mineralization – refers to the process where an organic substance is converted to an inorganic substance that can be taken up by the plant.

Nitrogen assimilation – process by which plants expend energy to take up nitrate and ammonium ions and incorporate them into organic molecules required for growth.

Nitrogen budget – accounting that quantifies the nutrients entering the farm (e.g. fertilizers, manure, legumes crops, soil residual nitrogen) and the nutrients leaving the farm (crop harvest, runoff, leaching, and volatilization) for the purpose of balancing inputs and exports.

Nitrogen fixation – the biological process by which nitrogen gas (N_2) in the atmosphere is converted into ammonium compounds that are used by plants.

Organic certification – a certification process for producers of organic food and products that requires strict adherence to production standards for growing, storing, processing, packaging and shipping.

Perched water table – accumulated water above the level of the local water table because impermeable rock or sediment prevents downward movement of water into the local water table.

Perennial –a plant that completes its life cycle (germination, flowering, seed production) over more than one year.

Summer annual – an annual plant that germinates, flowers, produces seed and dies within the same growing season.

Surfactant – (or wetting agent) a soap-like adjuvant added to water or some other liquid to increase wetting properties by reducing the surface tension of the droplets.

Threshold – the density of a pest (insect, mite, plant disease, weed, etc.) at which a control treatment will provide an economic return.

Tilth – a term describing soil that is friable, crumbly, and not compacted which allows rainfall to penetrate and roots to grow without obstruction.

Wind break – (or shelterbelt) is a planting around the edge of a field consisting of one or more rows of trees or shrubs planted in such a manner as to provide shelter from the wind and to protect soil from erosion.

Winter annual – a plant that germinates in the fall or winter, then flowers, produces seed and dies within one year.