National Organic Standards Board
Crops Subcommittee Petitioned Material Proposal
Allyl Isothiocyanate (AITC)
June 19, 2018

Summary of AITC 2016 Petition; 2013 Petition:
Two petitions for allyl isothiocyanate (AITC) have been submitted to the National Organic Program by Isagro USA, Inc. Both petitions propose to add AITC as an allowed synthetic substance in organic crop production (§205.601) as a pre-plant fumigant. The original petition, dated December 20, 2013, was received by the NOSB on January 24, 2014. After review and discussion by the Crops Subcommittee, the request to add AITC to the National List at §205.601 was not recommended. The petitioner resubmitted a petition, in July 2016, asserted that AITC offers 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.

Summary of Review:
Based on information from the 2018 technical report (TR), AITC is a naturally occurring compound found in plants such as broccoli, brussels sprouts, mustard, wasabi, and horseradish. AITC, commonly referred to as "oil of mustard," was first registered by the U.S. EPA in 1962 for use in pesticides and rodent control products; however, 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 (2018 TR, lines 78-79, 132.

To facilitate review of the re-petition dated July 2016, the Crops Subcommittee requested a limited scope technical report (TR) to address outstanding issues. These issues were as follows and were addressed in the TR dated February 12, 2018:

- Provide a review of allyl isothiocyanate as it pertains to the newly listed additional uses that were not listed in the original petition.
- Review the proposed phytosanitary use for nursery stock and plants which deals with Nursery Stock certification, including potential benefits, all applicable rules and regulations on both a State and Federal level, as well as how that applies to USDA APHIS requirements. Would allyl isothiocyanate work and would it be allowed for this mandatory process as required by law?
    - Clarification: The 2018 petition mentions the use of AITC as a phytosanitary tool for use on organic nursery stock and plants when there is a requirement to meet phytosanitary restrictions. There is currently an exemption that allows treatment of organic nursery stock and plants if that is the only alternative to meet phytosanitary certification processes. This may occur during the intra- and inter-state movement of plant materials (e.g., seed and nursery stock) through inspection and certification programs (e.g., USDA APHIS). Specific soil-borne pathogens and nematodes are targeted pests of the nursery stock registration and certification program and must be treated for presence of such in stock or seeds. Eradication treatments of thermotherapy, fumigation using methyl bromide or Telone II™, other synthetic fumigants, and/or hot water treatments are mandatory. Would this material work, and would it be allowed for this mandatory process, as required by law?
- Provide a comprehensive look at both the short and long-term impacts on soil beneficial life forms compared to existing practices and/or materials being used.

On lines 100-107, the TR states that AITC or AITC-containing plant materials possess good potential to serve as alternative nematicides that are safer and more environmentally benign than traditional synthetic fumigants. However, the effectiveness of AITC can be selective. In a 2005 study, the nematicidal activity of AITC was evaluated using seven different species of nematodes, including six of the most important parasitic nematode species in agriculture world-wide (Yu 2005). The study found that the susceptibility or tolerance of nematode species was highly variable. While AITC was found to be toxic and possess anti-hatching activity against all the species in the study, the required concentrations of AITC for effective nematicidal activity was different across the species studied.

Additionally, the TR notes that one of the degradation products of AITC is carbon disulfide, CS2 (CDS). There are concerns regarding exposure to CDS because it is listed by the State of California on the Proposition 65 list as a developmental toxicant (OEHHA, 2014) and is known to induce neuropathological changes and other toxic effects in rodents exposed through inhalation over an intermediate during of less than one year (OEHHA, 2001). Because CDS is a major degradant of AITC, the human and environmental toxicity of CDS should be considered as part of the evaluation of AITC for use in organic crop production.

According to TR lines 210-211, several international organizations and regulatory bodies do not permit the use of AITC in organic crop production. Additionally, lines 993-994 indicate that in addition to traditional crop rotation, the available information suggests that the variety of available management techniques preclude the application of synthetic biofumigants such as AITC in organic crop production. For example, the TR indicates that some organic growers, including organic strawberry producers, are adopting mustard seed meal as a natural option for soil pest control. Synthetic AITC acts as a broad-spectrum fumigant. This broad-spectrum effect on both beneficial and pest species is not compatible with organic production.

Category 1: Classification

1. For CROP use: Is the substance __ Non-synthetic or _X_ Synthetic?
   Is the substance formulated or manufactured by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources?

   AITC may be considered synthetic or natural depending on the method utilized for its production. The petitioned substance is produced using chemical synthetic methods (2018 TR lines 337).

2. For CROPS: Reference to appropriate OFPA category:
   Is the substance used in production, and does it contain an active synthetic ingredient in the following categories: copper and sulfur compounds; toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers; or (ii) is used in production and contains synthetic inert ingredients that are not classified by the Administrator of the Environmental Protection Agency as inerts of toxicological concern?

   AITC contains a singular sulfur atom; therefore, AITC may be considered a sulfur compound.

Category 2: Adverse Impacts

1. What is the potential for the substance to have detrimental chemical interactions with other materials used in organic farming systems?

   One possible interaction between the petitioned substance and other materials used in organic crop production involves the reaction of AITC with free amino acids, peptides and proteins contained in organic composts and fertilizers. Specifically, electron deficient AITC can react with the electron rich amino groups of the free amino acids alanine and glycine as well as cysteine, lysine and arginine residues of intact proteins. Diminished enzymatic digestibility was documented for some of the resulting protein-AITC adducts; however, it is uncertain how these chemical transformation products might affect the absorption and metabolism of amino acid building blocks in plants (2018 TR lines 563-569).

2. What is the toxicity and mode of action of the substance and of its breakdown products or any containments, and their persistence and areas of concentration in the environment?

   Overall, as noted in the TR, it can be concluded that the toxicity rating of AITC ranges from toxic to practically non-toxic to the few non-target taxa evaluated in the TR (2018 TR lines 669-670). The TR (lines 603-608) notes that AITC is a broad-spectrum antimicrobial compound that effectively kills both plant pathogens and beneficial soil microorganisms. Additionally, it is known that certain species of soil fungi enhance the bioavailability of organic soil nutrients and mediate the uptake of these nutrients by their mycorrhiza host plants. AITC drift would therefore be problematic for both the beneficial soil fungi and associated plants. The risk of toxicity associated with mammalian exposure to AITC is variable depending on the source and concentration of AITC used in toxicity testing. According to US EPA, oil of mustard containing AITC at a concentration of 4.43% is practically non-toxic via the acute oral and inhalation routes of exposure. In addition, oil of mustard is not an acute dermal irritant or sensitizing agent.

   Also noted in the TR, very few peer-reviewed papers on the ecological toxicity of AITC are available. The aquatic toxicity of AITC was evaluated for Japanese rice fish (Oryzais latipes) using a continuous-flow-mini-diluter system and five concentrations of AITC. Significant mortality was observed in O. latipes exposed to AITC on an acute basis (96-hour LC50 = 0.077 mg/L), and the maximum allowable toxicant concentration (MATC) for chronic (28-day) exposure to AITC was 0.013 mg/L (Holcombe, 1995). Another study found that pure AITC and essential oil extracts containing AITC are completely larvicidal in mosquitoes (A. aegypti) even at the lowest concentration tested (0.1 mg/mL); however, this measurement indicates that AITC is significantly less toxic compared to some synthetic pesticides. In addition, AITC was toxic to the freshwater water flea (Daphnia magna) with a 50% effective concentration value of 0.735 mg/L based on combined mortality and immobility measurements (Park, 2011). As expected, AITC is also highly toxic to soil microorganisms and nematodes, such as the non-parasitic free-living soil nematode Caenorhabditis elegans (Donkin, 1995).

3. Describe the probability of environmental contamination during manufacture, use, misuse or disposal of such substance.

   Considering its moderately high volatility (3.7 mm Hg at 25°C), high application rates (85–340 lbs/acre), and agricultural use as a soil biofumigant, releases of AITC to the environment are

inevitable. AITC is both flammable and potentially toxic to nontarget organisms such as mammals and fish. Aquatic wildlife may be exposed to AITC through spills and/or irrigation runoff. As with conventional fumigants, measures such as the use of plastic tarps on treated fields or application of AITC through a drip system could be taken to further protect humans (bystanders and workers) and nontarget terrestrial organisms from exposure to AITC following soil biofumigation. The rapid breakdown and dissipation of AITC in the environment reduces the probability of contamination of groundwater and surface water due to agricultural applications of the substance (2018 TR lines 523-531).

4. Discuss the effect of the substance on human health.

   The TR specifies that natural sources of AITC contained in natural vegetable oils (e.g., mustard oil) are generally non-toxic to humans via oral exposure. This observation is not surprising considering the concentrations of AITC (3 mg/kg to 15 g/kg) generally found in popular food items such as kale, broccoli, mustard and horseradish. However, moderate doses of concentrated AITC are considered toxic to mammals based on laboratory studies in animals. Because AITC is a volatile organic compound and has the potential to cause irritation and systemic toxicity, exposure of and potential adverse effects on non-target receptors (humans and wildlife) is likely considering its proposed use pattern as a pre-plant soil biofumigant at the application rates proposed (85-340 lbs/ac) (TR, lines 378-381).

5. Discuss any effects the substance may have on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms.

   AITC can have a short-term harmful effect on beneficial soil microorganisms and mutualistic fungal interactions. However, data on long-term soil effects is relatively non-existent, as other fumigation agents have not been as widely utilized as methyl bromide and have only received considerable attention since the ban on methyl bromide in 2005.

   In a short-term study (28 days) of the effect of AITC on soil bacterial and fungal communities, the application of AITC significantly decreased soil fungal populations but had negligible impact on soil bacterial numbers. However, AITC did have an influence on certain microbial community composition changes. The results showed increased proportions in bacterial taxa, which include bacteria associated with fungal disease suppression. The increase in these bacteria and decrease in overall fungal populations following application of AITC suggests that the observed efficacy of AITC on fungal suppression was not only due to direct toxicity of AITC to soil fungi, but also to biological interactions and competition with the altered microbial community that existed following fumigation. (2018 TR lines 640-650).

6. Are there any adverse impacts on biodiversity?

   AITC may have an impact on certain fungi that produce mutualistic relationships with plants and prey on insects. Exposure to livestock, birds, freshwater fish, freshwater invertebrates, non-target plants, and non-target insects is not expected based on the application methods proposed and the rapid environmental degradation of AITC (2018 TR lines 605-608, 610-611).

   The 2018 TR (lines 603-608) cites reports that provide direct evidence that AITC does not specifically target soil pests; rather, AITC is a broad-spectrum antimicrobial compound that

effectively kills both plant pathogens and beneficial soil microorganisms. Additionally, it is known that certain species of soil fungi enhance the bioavailability of organic soil nutrients and mediate the uptake of these nutrients by their mycorrhiza host plants AITC drift would therefore be problematic for both the beneficial soil fungi and associated plants. As such, AITC is expected to negatively impact biodiversity.

Category 3: Alternatives/Compatibility

1. Are there alternatives to using the substance? Evaluate alternative practices as well as non-synthetic and synthetic available materials.

   Mustard seed meals, mustard green manures (plowed cover crop), and Regalia (OMRI approved material) are biopesticides that are available. SoilGard, a fungal biocontrol material, Seranade, and Bionematicide Melocon are also feasible alternative materials available for use in organic crop production systems.

   Crop rotation and soil nutrient management are alternative practices, as well as cultural practices that enhance crop health. For pest problems, introduction of predators or parasites of a pest species, lures, traps and/or repellants also can be used. For weed control, mulching, flaming, mowing, hand or mechanical weeding are some examples of practices currently in use. Also, the tilling in of mustard plant cover crops to create a green manure is currently being used and is a viable alternative practice, thus AITC is not essential to organic agriculture.

2. In balancing the responses to the criteria above, is the substance compatible with a system of sustainable agriculture?

   AITC can have a short-term deleterious effect on beneficial soil microorganisms and mutualistic fungal interactions, which is observed for other broad-spectrum fumigants, such as methyl bromide and Telone II (2018 TR, lines 634-636). This broad-spectrum effect is not compatible with a system of sustainable agriculture. In addition, the availability of cultural methods or use of natural mustard plant cover crops precludes AITC from being essential to organic agriculture.

Classification Motion:

Motion to classify allyl isothiocyanate (AITC) as synthetic
Motion by: Jesse Buie
Seconded by: Harriet Behar
Yes: 7 No: 0 Abstain: 0 Absent: 1 Recuse: 0

National List Motion:

Motion to add allyl isothiocyanate (AITC) at §205.601
Motion by: Jesse Buie
Seconded by: Asa Bradman
Yes: 0 No: 7 Abstain: 0 Absent: 1 Recuse: 0

Approved by Steve Ela, Subcommittee Chair to transmit to NOSB, February 9, 2019