Soap-Based Herbicides

Crops

Identification of Petitioned Substance

Chemical Names:
Lauric acid, potassium salt
Myristic acid, potassium salt
Oleic acid, potassium salt
Ricinoleic acid, potassium salt
Nonanoic acid, ammonium salt

Other Name:
Potassium salts of fatty acids
Ammonium salts of fatty acids

Trade Names:
Axxe Broad Spectrum Herbicide
BioSafe Weed Control RTU

CAS Numbers:
67701-09-1 (Potassium salts of fatty acids, C8–18)
10124-65-9 (Potassium laurate)
143-18-0 (Potassium oleate)
63718-65-0 (Ammonium nonanoate)

Other Codes:
Potassium salts of fatty acids, C8–18: 266-933-2 (EINECS), 079021 (EPA PC Code)
Ammonium salts of fatty acids, C8–C18: 031801 (EPA PC Code)

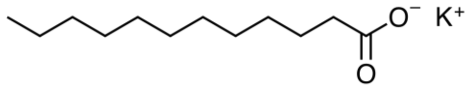
Summary of Petitioned Use

The National Organic Program (NOP) final rule currently permits the use of soaps for a variety of purposes in organic crop production: Soap-based algicides/demossers (7 CFR §205.601(a)(7)), soap-based herbicides (7 CFR §205.601(b)(1)), ammonium soaps as animal repellents (7 CFR §205.601(d)) and insecticidal soaps (7 CFR 205.601(e)(8)). As an approved herbicide, soaps are allowed for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops as a last resort option (USDA, 1996). This technical evaluation report provides updated and targeted technical information to augment the 1996 Technical Advisory Panel Review of soap-based herbicides for the National Organic Standards Board's review of these herbicidal substances under the sunset process.

Characterization of Petitioned Substance

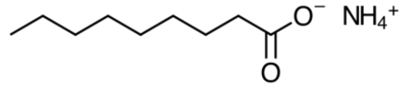
<u>Composition of the Substance:</u>

Soap-based herbicides considered in the current technical review include potassium and ammonium salts of fatty acids. In general, soap salts consist of a fatty acid component with carbon (C), hydrogen (H) and oxygen (O) atoms, as well as potassium (K^+) or ammonium (NH_4^+) counterions. Potassium salts of fatty acids (C_{12}–C_{18} saturated and C_{18} unsaturated) include individual soap salts such as potassium laurate ($C_{12}H_{23}O_2^+$ K^-; Figure 1), potassium myristate ($C_{14}H_{27}O_2^-$ K^+), potassium oleate ($C_{18}H_{33}O_2^+$ K^-) and potassium ricinoleate ($C_{18}H_{33}O_3^+$ K^-). Likewise, ammonium salts of fatty acids include constituent compounds ranging in size from eight to 18 carbons in length (US EPA, 2013). Ammonium nonanoate (pelargonic acid ammonium salt; $C_9H_{17}O_2^-$ NH_4^+) is the most commonly encountered ammoniated fatty acid in commercially available soap-based herbicide products (OMRI, 2014). Commercially available soap-based herbicides are typically formulated as mixtures of potassium or ammonium salts of fatty acids.



Potassium Laurate

($C_{12}H_{23}O_2^- K^+$)



Ammonium Nonanoate

($C_9H_{17}O_2^- NH_4^+$)

Figure 1. Approved soap salts include potassium and ammonium salts of fatty acids. Potassium laurate and ammonium nonanoate are example constituents of soap-based herbicides.

Source or Origin of the Substance:

A variety of preparatory methods are employed depending on the desired soap salt composition of a particular herbicide formulation. Potassium salts of fatty acids are produced through a process known as saponification, whereby aqueous potassium hydroxide (KOH) is added to fatty acids commonly found in animal fats and plant oils (NPIC, 2001; Nora, 2010). Alternatively, ammonium salts of fatty acids, such as ammonium nonanoate, are produced through the room temperature reaction of aqueous ammonia (NH_3) or ammonium hydroxide (NH_4OH) with fatty acids (Reiling, 1962; Dunn, 2010). See Evaluation Question #2 for details regarding the synthesis of potassium and ammonium salts of fatty acids, as well as typical sources of fatty acids used in these syntheses.

Properties of the Substance:

Chemical and physical properties are generally available for fatty acids used in the production of soap-based herbicides. Soap salts and their corresponding free fatty acids generally exist as colorless solids or liquids (EFSA, 2013), and are formulated as solutions in water when used as herbicides. Fatty acids are poorly soluble in water in their undissociated (protonated) form; however, they are relatively water-soluble as potassium (K), sodium (Na), or other salts. The actual water solubility of long-chain fatty acids can be difficult to determine since this parameter is largely influenced by pH, and fatty acids commonly associate to form monolayers or micelles (Rustan & Drevon, 2005). Fatty acids are easily extracted using nonpolar solvents from solutions or suspensions by lowering the pH to form the uncharged carboxyl group (COOH) instead of the carboxylate (COO^-) anion. Alternatively, increasing the pH (alkaline conditions) increases the water solubility through formation of the alkali metal salts (i.e., soap). Saturated fatty acids are very stable, whereas unsaturated (C=C bonds) fatty acids are susceptible to oxidation (Rustan & Drevon, 2005).

Nonanoic acid, a low molecular weight constituent fatty acid, is somewhat volatile (vapor pressure = 1.65×10^{-3} mm Hg), but is unlikely to volatilize since its dissociation constant (pKa = 4.9) indicates the substance will exist primarily in its water-soluble (ionized) form under environmental conditions (HSDB, 2008a; EFSA, 2013). Higher molecular weight fatty acids have larger ratios of nonpolar aliphatic regions to the polar carboxylate region, thus making them less water-soluble than low molecular weight acids. Although the vapor pressures of fatty acids generally decrease with increasing molecular weight, higher molecular weight fatty acids have similar dissociation constants as nonanoic acid (e.g., pKa = 5.3 for lauric acid) and should thus behave similarly to nonanoic acid in the environment (HSDB, 2008b).

Specific Uses of the Substance:

Commercially available pesticide products containing potassium, ammonium and sodium salts of fatty acids as the active ingredients are used for a variety of purposes in conventional and organic agriculture. Soap salt products are used as acaricides, algicides, herbicides, insecticides and animal repellents in residential, agricultural and commercial settings. Potassium salts of fatty acids are used as insecticides, acaricides, herbicides and algicides. Specifically, these soap salts control a variety of insects, mosses, algae, lichens, liverworts and other weeds, in or on many crops, ornamental flower beds, house plants, trees, shrubs, walks and driveways, as well as dogs and cats. Ammonium and sodium salts of fatty acids are used as rabbit and deer repellents on forage, grain, vegetable and field crops, in orchards, and on nursery stock, ornamentals, flowers, lawns, turf, vines, shrubs and trees. Ammonium soap salts are also formulated as herbicides to control common annual weeds (US EPA, 2013; US EPA, 1992). The most recent US EPA Environmental Fate and Ecological Risk Assessment for soap salts states that soap salts products may be applied at highly variable rates:

> *Terrestrial application rates are as high as 205 lbs/acre and as low as 1 lb/acre and below. Both potassium and ammonium salts uses have rates greater than 100 lbs/acre. The herbicidal products are generally applied as a spot treatment for weed control and as a broadcast spray or spot treatment for moss control, while the insecticidal products are applied broadcast using ground spray equipment. The high application rates for these products are practical only for spot treatments and usually are not applied to an entire acre but to thoroughly spray all plant (or tree) parts to achieve herbicidal or insecticidal control. Furthermore, the herbicidal products with high rates for moss control are labeled for lawns/turf, exterior building, and paving surfaces; not for agricultural field uses at rates ~10x lower than used for moss control.*

The allowable use patterns for specific soap salt formulations are more restricted in organic agriculture. According to 7 CFR 205.601(a)(7), soap salts may be used as algicides and demossers in organic crop production. Unspecified soap salts are also allowed for use as insecticides, acaricides and for mite control (7 CFR 205.601(e)(8)). In addition, soap salts are permitted as herbicides for farmstead maintenance around roadways, ditches, right of ways and building perimeters, and for application to ornamental crops (7 CFR 205.601(b)(1)). Only ammonium salts of fatty acids may be used in organic crop production as large animal repellents. Although not strictly stated in the final rule, it is generally assumed that soap salts used as algicides, herbicides and insecticides consist of potassium or ammonium salts of fatty acids (US EPA, 2013).

<u>Approved Legal Uses of the Substance:</u>

Soap salt products are registered with US EPA as acaricides, algicides, herbicides, insecticides and animal repellents. These substances are intended for residential, agricultural and commercial use. Label-mandated application rates for products containing potassium and ammonium salts of fatty acids range from 205 and 104 lb/acre, respectively, on the high end to as low as one lb/acre or less for soap salt active ingredients (US EPA, 2013). According to EPA Regulations, C_{12}–C_{18} fatty acids (saturated and unsaturated) potassium salts and ammonium salts of C_8–C_{18} saturated and C_8–C_{12} unsaturated higher fatty acids are exempt from the requirement of a tolerance for residues in or on all raw agricultural commodities (40 CFR 180.1068, 40 CFR 180.1284). In addition, 40 CFR 180.910 established a tolerance exemption for residues of ammonium salts of fatty acids and fatty acids salts conforming to 21 CFR 172.863, including potassium salts of fatty acids when used as inert ingredients in pesticide formulations applied to crops during or after the growing season (i.e., pre- or post-harvest).

The US Food and Drug Administration (FDA) classifies "salts of fatty acids" as Generally Recognized As Safe (GRAS) when used in food and in the manufacture of food components (7 CFR 172.863). According to the rule, aluminum, calcium, magnesium, potassium and sodium salts of fatty acids conforming with 21 CFR 172.860 and/or oleic acid derived from tall oil fatty acids conforming with 7 CFR 172.862 are additives permitted for direct addition to food for human consumption. The listed salts of fatty acids are intended for use as binders, emulsifiers and anticaking agents in various food products. Ammonium salts of fatty acids are not included in the FDA's description of GRAS fatty acid salts.

<u>Action of the Substance:</u>

According to US EPA, the general herbicidal mode of action for soap salts involves the disruption of photosynthesis through destruction of the cell membrane, thereby resulting in plant death (US EPA, 1992; US EPA, 2013). Formation of the fatty acid salt—potassium, ammonium or sodium—provides water solubility for the fatty acid(s) in the pesticide formulation (NPIC, 2001). The herbicidal mode of action for soap salts is generally considered identical to that of the corresponding free fatty acids. For example, nonanoic acid (C9, saturated) applied to growing plants in sufficient quantities rapidly dessicates green tissue by removing the waxy cuticle of the plant and disrupting the cell membrane, resulting in cell leakage and tissue death. Fatty acids and soap salts—such as nonanoic acid and ammonium nonanoate—are not translocated in treated plants and provide no residual weed control. These substances are only effective as post-emergent herbicides, providing burndown of broadleaf weeds and most mosses (MMWD, 2010).

<u>Combinations of the Substance:</u>

Relevant pesticide formulations contain active ingredient mixtures consisting of soap salts and other substances. Several soap-based herbicide products are co-formulated with the conventional herbicide, glyphosate, and therefore would not be allowed for use in organic production. Other ready-to-use soap salt insecticides are co-formulated with pyrethrins (0.01–0.24%), limonene (1%) and/or neem oil (0.9%). In addition, some fungicidal, insecticidal and miticidal products contain a combination of fatty acid potassium salts and elemental sulfur at 0.4%–6.5% in ready-to-use and concentrated formulations. Naturally occurring pyrethrins, limonene and neem oil are allowed for use in organic crop production for weed control. Aliphatic alcohols, including ethyl alcohol (2–18%) and methanol (1%), as well as propylene glycol (37.8%) are listed as other known ingredients in a small number of soap salt products. Both ethyl alcohol (CAS # 64-17-5) and propylene glycol (CAS # 57-55-6) are US EPA List 4 inert ingredients (US EPA, 2004), and are therefore allowed for use in organic crop production under 7 CFR 205.601(m)(1).

Labels for currently registered soap salt products list potassium laurate, potassium salts of fatty acids, ammonium nonanoate and/or related substances as the active ingredients but do not always include the identity of "other ingredients." Product formulations are considered confidential business information, and manufacturers of soap-based herbicides, algicides and demossers may occasionally reformulate these products. As a result, it is rarely possible to know with certainty the identity of all adjuvants and other inert ingredients used in commercially available products.

Status

Historic Use:

Although soap has been known and used for centuries, industrial-scale soap production did not fully develop in the United States until the second half of the 19th century when personal cleanliness became culturally emphasized (Kostka & McKay, 2002). It is unclear how long soap-based herbicides have been used in conventional agriculture. However, the first pesticide product containing soap salts as an active ingredient was registered in the United States in 1947 (US EPA, 1992). Soap-based herbicides were added to the National List of Allowed and Prohibited Substances for use in organic crop production based on the NOSB's 1996 Technical Advisory Panel (TAP) Review of the active substance (USDA, 1996).

The NOSB recommended against the explicit use of ammonium salts of fatty acids as herbicides in organic crop production in 2007 and 2008 (USDA, 2007; USDA, 2008). During both reviews, the NOSB voted to reject the use of ammonium soap salts due to the availability of numerous alternative weed management practices and incompatibility of the substance with the provisions of the Organic Foods Production Act (OFPA) for general use on crops or cropland. These rulings stand in contrast to the allowed use of generic soap-based herbicides—including potassium and ammonium salts of fatty acids—for use in organic farmstead maintenance under 7 CFR 205.601(b)(1).

Organic Foods Production Act, USDA Final Rule:

Synthetically produced soap-based herbicides are eligible for use in organic production due to their listing in Section 2118 of the Organic Foods Production Act of 1990 (OFPA). Specifically, the OFPA states that the National List may allow the use of substances that would otherwise be prohibited under organic regulations (i.e., synthetics) if the substance contains an active 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" (OFPA 2118(c)(B)(i)).

The National Organic Program (NOP) final rule currently permits the use of soaps for a variety of purposes in organic crop production: Soap-based algicides/demossers (7 CFR §205.601(a)(7)), soap-based herbicides (7 CFR §205.601(b)(a)), ammonium soaps as animal repellents (7 CFR §205.601(d)) and insecticidal soaps (7 CFR 205.601(e)(8)). As an approved herbicide, soaps are only allowed for nonfood uses—in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops. The NOP final rule indicates that ammonium soaps are permitted as large animal repellents but may not come into contact with soil or the edible portion of crops. Several OMRI-approved herbicides are formulated with ammonium soaps, such as ammonium nonanoate (OMRI, 2014).

International

Several of the international organizations surveyed have provided guidance on the use of soap-based pesticide products in organic production. Among these are regulatory agencies (Canada, Japan and the EU) and independent organic standards organizations (Codex and IFOAM). International organic regulations and standards concerning soap salts are described in the following subsections.

Canadian General Standards Board

The Canadian Organic Production Systems Permitted Substances List provides several use patterns for soaps in organic crop and livestock production, as well as organic processing. Section 4.3—Crop Production Aids and Materials—lists "soaps (including insecticidal soaps) consisting of fatty acids derived from animal or vegetable oils" as allowed substances. Ammonium soaps are listed in this section for "large animal control only; no contact with soil or edible portion of crop allowed." This listing for ammonium soaps is also reproduced in Section 6.6—Processing Aids. Finally, soap-based algicides (demossers) are included for use in Section 7.4—Cleaners, disinfectants and sanitizers allowed on food contract surfaces including equipment provided that substances are removed from food contact surfaces prior to organic production (CAN, 2011).

European Union

European organic regulations allow the use of soap salts in crop and livestock production as insecticides and disinfecting agents. Article 5(1) of Commission Regulation (EC) No 889/2008 states that products referred to in Annex II of this regulation may be used in organic production when plants cannot be adequately protected from pests and diseases by the prescribed measures in Article 12 (a)(a), (b), (c), and (g) of Regulation (EC) 834/2007. Fatty acid potassium salts (soft soap) are allowed for use only as insecticides in organic crop production. In addition, Article 23 (4) of 889/2008 states that products listed in Annex VI of the regulation—including potassium and sodium soap—may be used for cleaning and disinfection of livestock building installations and utensils (EC, 2008).

Codex Alimentarius Commission

The Codex Alimentarius Commission Guidelines for the Production, Processing, Labeling and Marketing of Organically Produced Foods only allows the use of soaps in organic crop production. Specifically, the guidelines indicate that only "potassium soap (soft soap)" is an allowed synthetic substance for plant pest and disease control (Codex, 2013).

Japanese Ministry of Agriculture, Forestry and Fisheries

Similar to the Codex guidelines described above, the Japanese Ministry for Agriculture, Forestry and Fisheries permits the use of "potash soap (soft soap)"—which correspond to potassium salts of fatty acids—for the control of pests in organic crop production (JMAFF, 2012).

International Federation of Organic Agriculture Movements

The IFOAM Norms include a number of allowed use patterns for soaps in organic production. Appendix 3 of the Norms lists soft soap (i.e., potassium salts of fatty acids) as an allowed crop protectant and growth regulator. Appendix 4, Table 2 states that potassium and sodium soaps may be used as equipment cleansers and equipment disinfectants in food processing if "an intervening event or action" is taken to eliminate the risk of food contamination with the substance. Potassium and sodium soaps are similarly allowed as substances for pest and disease control and disinfection in livestock housing and equipment according to Appendix 5 of the IFOAM Norms (IFOAM, 2014).

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

<u>Evaluation Question #1: Indicate which category in OFPA that the substance falls under:</u> (A) Does the substance contain an active ingredient in any of 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? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

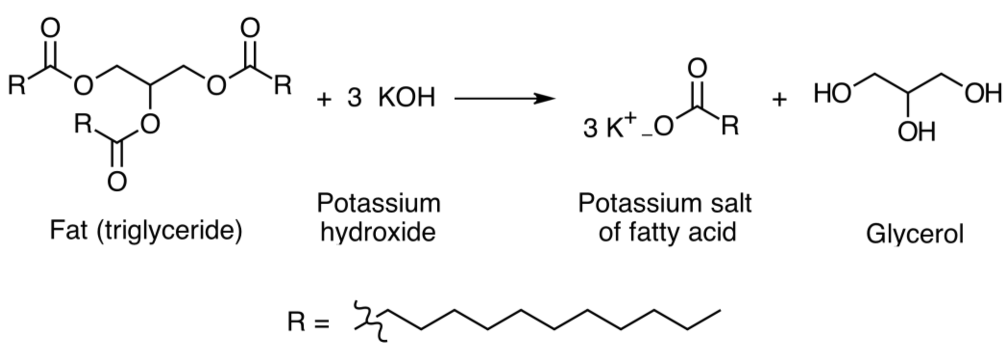
(A) Soap-based herbicides contain potassium and ammonium salts of fatty acids, which are commonly referred to as soaps.

(B) According to 40 CFR 180.910, residues of ammonium salts of fatty acids and salts of fatty acids conforming to 21 CFR 172.863, including potassium salts of fatty acids, are exempt from the requirement of a tolerance when used as inert ingredients in pesticide formulations applied to crops during or after the growing season (i.e., pre- or post-harvest).

Individual constituents of soaps (e.g., 9-octadecenoic acid (9Z)-, potassium salt) and various types of soap salts (e.g., potassium coconut oil soap, potassium salts of fatty acids (C8–C18 and C18 unsatd.) are classified as EPA List 4A and 4B inerts of minimal concern (US EPA, 2004a; US EPA, 2004b).

<u>Evaluation Question #2:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

A variety of preparatory methods are employed depending on the desired soap salt composition for a particular herbicide/algicide formulation. Potassium salts of fatty acids are produced through a process known as saponification, whereby aqueous potassium hydroxide (KOH) is added to fatty acids found in animal fats and plant oils (NPIC, 2001; Nora, 2010). Specifically, modern sources of potassium soap salts are prepared through the hydrolysis of triglycerides using water under high pressure and temperature in the range of 50 atm and 200 °C (Ball, 2011). A carbonate (CO_3^{2-}) or hydroxide (OH^-) salt of an alkali metal (potassium or sodium) is then used to trap the free fatty acids as the corresponding soap salts. Likewise, ammonium salts of fatty acids are produced through the room temperature reaction of aqueous ammonia (NH_3) or ammonium hydroxide (NH_4OH) with fatty acids (Reiling, 1962; Dunn, 2010). Commonly used fats (i.e., triglyceride substances) include coconut oil, sunflower oil, palm oil, tallow and olive oil. Equation 1 depicts the conversion of a fat containing the triglyceride glycerin trilaurate to the corresponding potassium soap salt using potassium hydroxide as the alkali species (Burns-Moguel, 2014; Kostka & McKay, 2002).



Equation 1. Potassium soaps are generally produced through the reaction of fats with potassium hydroxide in water. ***Adapted from Burns-Moguel, 2014.***

The natural fats and oils used to generate soap salts are composed of mixtures of triglycerides derived from fatty acids of varying chain lengths ranging from 12 to 24 carbons. For example, the majority of fatty acids chains in the triglycerides of olive oil contain 16 or 18 carbons in saturated or unsaturated carbon frameworks (Mailer, 2006). Therefore, the soaps used in pesticide products are mixtures of fatty acid salts having a variety of carbon chain lengths, and generally do not consist exclusively of one soap salt compound (e.g., potassium laurate).

Ammonium nonanoate is the most commonly used ammonium soap salt in commercially available herbicide, algicide and insecticide products (US EPA, 2014). Synthetic sources of nonanoic acid can be industrially prepared through the reaction with of unsaturated hydrocarbons (alkenes) with carbon monoxide (CO) and hydrogen (H_2) in the presence of a transition-metal catalyst (i.e., hydroformylation, also known as the "oxo process"), by oxidation or ozonation of oleic acid, by oxidation of methylnonyl ketone, or from heptyl iodide using the malonic ester synthesis (HSDB, 2008). A petition submitted to the

NOSB by Falcon Lab, LLC indicates that blowing air through naturally derived oleic acid (sourced from agriculturally-produced edible fats and oils) provides a 50/50 mixture of nonanoic acid and azelaic acid. These components are subsequently separated by distillation. Once purified, the isolated nonanoic acid is treated with an aqueous solution of ammonia (NH_3) and stirred at room temperature until full conversion to ammonium nonanoate is achieved (Smiley & Beste, 2009).

Evaluation Question #3: Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).

According to USDA organic regulations, the NOP defines synthetic as "a substance that is formulated or manufactured by a chemical process or by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources" (7 CFR 205.2). Although plant oils and animal fats are naturally occurring organic materials, the fatty acid soap salts used in pesticide products are generated through chemical reactions with concentrated aqueous solutions of alkali metal hydroxide (e.g., potassium hydroxide) or ammonium hydroxide. Specifically, potassium and ammonium soap salts are formed via two sequential processes: base-mediated hydrolysis of the triglyceride molecule to release three equivalents of free fatty acids followed by formation of the corresponding potassium or ammonium soap salts (Burns-Moguel, 2014; Kostka & McKay, 2002). Commercially available ammonium nonanoate is formed through the reaction of aqueous ammonia (NH_3) with nonanoic acid (Smiley & Beste, 2009). Nonanoic acid is a naturally occurring fatty acid; however, sources of nonanoic acid used in pesticide products are most likely produced synthetically via oxidation and/or ozonation (HSDB, 2008). Based on the available manufacturing information and NOP definitions, we conclude that potassium and ammonium salts of fatty acids used as active ingredients in approved herbicide products are produced using chemical processes and are therefore synthetic substances. The NOSB previously classified these substances as synthetic; therefore, soaps are currently included in section 205.601, which only lists *synthetic* substances allowed for use in organic crop production.

Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

The environmental fate and transport of soap salt compounds is largely based on experimental information for the corresponding fatty acids. Indeed, fatty acids—such as nonanoic acid—are weak organic acids that partially or fully dissociate in water to form carboxylate anions under environmentally relevant conditions (MMWD, 2010). Because soap salts are simply the potassium and ammonium salts of the dissociated fatty acid carboxylate, we will focus on the environmental fate pathways for common fatty acids, including nonanoic acid (C9, saturated), lauric acid (C12, saturated), and oleic acid (C18, unsaturated), as well as available fate and transport summaries for ammonium and potassium soaps.

Based on their physical properties, soaps and fatty acids are expected to interact with both the organic and inorganic components of soils. Undissociated fatty acids should have low to practically no mobility in soils based on estimated soil organic carbon-water partition coefficients (K_{oc} values) of 1,700 to 340,000 mL/g. Based on the pKa values for these three representative compounds (pKa = 4.95–5.3), fatty acids will exist almost entirely as the corresponding carboxylate (anionic form) in the environment; anions generally do not absorb more strongly to soils containing organic carbon relative to their neutral (undissociated) counterparts. Volatilization from moist soil is not an important fate process based on the pKa values (HSDB, 2008a; HSDB, 2008b; HSDB, 2008c). Biodegradation is expected to be an important fate process for oleic acid in soils based on measured half-lives of 0.2 and 0.66 days in screening tests (HSDB, 2008c). Further, aerobic soil half-lives and terrestrial field test half-lives are estimated as less than one day for potassium and ammonium salts of fatty acids (Thurston County, 2009a; Thurston County, 2009b).

Soap salts and fatty acids are expected to adsorb to suspended solids and sediment when released to bodies of water based on the reported K_{oc} values for representative fatty acids. In addition, the pKa values indicate that fatty acids will exist almost entirely in carboxylate (anionic) form at environmentally relevant pH levels; therefore, volatilization from water surface is an unlikely fate process. Hydrolysis is unlikely for fatty acids due to the lack of functional groups that are readily hydrolyzed under environmental conditions. Indeed, hydrolysis of potassium salts of fatty acids did not occur over a period of 43 days in a registrant-submitted study (US EPA, 2013). The bioconcentration factors (BCFs) for nonanoic acid (BCF = 3) and oleic (BCF = 10) suggest the potential for accumulation in aquatic organisms is low. In contrast, the

BCF of 255 for lauric acid in zebrafish is indicative of bioaccumulation in aquatic organisms (Van Egmond, 1999). Fatty acids such as lauric acid are readily biotransformed to metabolites, including less polar triglyceride molecules, which are natural components of animal diets (Van Egmond, 1999; US EPA, 2013).

When released to air, fatty acids can exist in both the particulate and vapor phases and are readily degraded via photochemical processes. Shorter-chain fatty acids (nonanoic acid) are likely to exist solely as a vapor in the atmosphere based on a vapor pressure of 1.65×10^{-3} mm Hg at 25 ºC, whereas the vapor pressures for lauric acid (1.6×10^{-5} mm Hg at 25 ºC) and oleic acid (5.46×10^{-7} mm Hg at 25 ºC) suggest that longer-chain fatty acids will exist in both the vapor and particulate phases in the atmosphere. Vapor phase fatty acids are degraded in the atmosphere by reaction with photochemically produced hydroxyl radicals with half-lives ranging from several hours to 1.6 days. Particulate-phase fatty acids will be removed from the atmosphere by wet and dry deposition processes. In addition, vapor-phase unsaturated fatty acids—such as oleic acid—will be degraded in the atmosphere through reaction with ozone; half-lives of 1.4–2.1 hours have been calculated for this reaction (HSDB, 2008a; HSDB, 2008b; HSDB, 2008c).

Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

The acute and chronic toxicity of soap salts is markedly different for land- and water-dwelling organisms. Terrestrial animals—including mammals, birds, and insects—are largely unaffected by exposure to even high doses of potassium and ammonium salts of fatty acids, while aquatic animals are moderately (fish) to highly (crustaceans) sensitive to these substances (Thurston County, 2009a; Thurston County, 2009b). This section summarizes the available information regarding the toxicity of various soap salt formulations.

US EPA has waived all generic mammalian toxicity data requirements for potassium and ammonium soap salts due to the lack of effects at high doses in the available toxicity literature. Indeed, potassium salts of fatty acids are generally recognized as safe (GRAS) by the US Food and Drug Administration (FDA). Laboratory testing has demonstrated that potassium and ammonium soaps are practically non-toxic on an acute oral exposure basis with doses lethal to 50% of test rats (LD_{50} values) of greater than 5,000 mg/kg-day (Toxicity Category V). Potassium and ammonium soap salts are broken down in the environment and metabolized when ingested in small amounts. Chronic health effects are not anticipated following exposure to soap salts by any commonly anticipated exposure routes. However, potassium and ammonium soaps are severe eye irritants and mildly irritating to the skin. Further, soaps salts have caused reproductive and mutagenic effects when fed to test animals at excessively high doses (US EPA, 2012; US EPA, 1992), but are not reported to be carcinogenic by the International Agency for Research on Cancer (IARC, 2014).

Soap salts are practically non-toxic (Toxicity Category V) to birds and honey bees on an acute exposure basis. Potassium and ammonium soaps caused no mortality or sub-lethal effects at doses up to and including 2,450 mg a.i./kg body weight (oral, gavage) and 5,620 mg a.i./kg diet (oral, dietary) in upland game birds and waterfowl. Because birds act as surrogates for reptiles and terrestrial-phase amphibians, it is generally assumed that potassium and ammonium soaps are practically non-toxic to reptiles and terrestrial amphibians. The acute contact toxicity test in honey bees using potassium and ammonium soaps provided a 48-hour LD_{50} of greater than 100 μg a.i./bee (μg = microgram), suggesting that soap salts are practically non-toxic to these beneficial insects. Saturating bees with soap solution, on the other hand, would likely result in death. While the honey bee is relatively insensitive to insecticidal soaps, soft-bodied insects such as aphids, whiteflies, and mealy bugs are more susceptible to the toxic effects of soaps (US EPA, 2013). Accordingly, soaps are frequently used as contact insecticides to control many of these pests.

Studies submitted to US EPA for registration of potassium and ammonium salts of fatty acids indicate that potassium salts are generally more toxic to aquatic organisms than their ammonium counterparts. Based on data from the most sensitive species, potassium soap salts are moderately toxic to freshwater fish and marine/estuarine invertebrates on an acute exposure basis. Concentrations lethal to 50% of test organisms over four days of exposure (96-hour LC_{50} values) for freshwater rainbow trout (*Onchorhynchus mykiss*) and the marine/estuarine mysid shrip (*Americamysis bahia*) are 9.19 mg a.i./L (a.i. = active ingredient) and 1.2 mg a.i./L, respectively, placing potassium soap salts in the moderate toxicity category (US EPA, 2013). Further, potassium soaps are highly toxic to freshwater invertebrates such as the freshwater water flea

(*Daphnia spp*.), with immobility observed in 50% of experimental water fleas exposed to 0.57 mg a.i./L over a two-day period. In contrast, ammonium soaps are classified as slightly toxic to freshwater fish and both freshwater and marine/estuarine invertebrates, and practically non-toxic to marine/estuarine fish on an acute exposure basis.

As registered herbicides and algicides, soaps are toxic to aquatic plants and algae. US EPA recently reviewed nine new industry-sponsored studies on the toxicity of ammonium and potassium soap salts to aquatic plants. Nonvascular plants were typically more sensitive than vascular plants to soap salts. Cell density measurements of the most sensitive species tested—the freshwater diatom (*Navicula pelliculosa*)—were used to determine a 96-hour no observed adverse effect concentration (NOAEC) of 0.39 mg a.i./L for exposure to potassium salts of fatty acids (US EPA, 2013). The corresponding value for exposure of green algae (*Pseudokirchneriella subcapitata*) to ammonium salts of fatty acids was 2.9 mg a.i./L (US EPA, 2013). Because these soap salts rapidly degrade by metabolism, no soap salt residues were detected at the end of these studies (four to seven days in duration).

<u>Evaluation Question #6:</u> Describe any environmental contamination that could result from the petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).

As stated in the response to Evaluation Question #4, potassium and ammonium salts of fatty acids decompose rapidly and do not accumulate or persist in the environment. Further, contact herbicides and algicides such as soap salts must be sprayed directly on the undesirable plant or algal growth to induce toxic effects in the target organisms (US EPA, 2013). Environmental contamination is thus unlikely for normal use of soap-based herbicide and algicide products. Misuse or improper disposal of products containing potassium and ammonium soaps may result in temporary/reversible environmental contamination. Nevertheless, the impacts of soap salt contamination are likely to be minimal due to the propensity for these compounds to rapidly degrade when released to the environment.

Chemicals used during the soap salt manufacturing process may also lead to contamination is released to the environment. Specifically, the strong bases (e.g., potassium hydroxide) used to manufacture soaps also result in the formation of alkaline (high pH) waste byproducts (Burns-Moguel, 2014). In addition, accidental spills of natural fats and oils in large quantities would be problematic for terrestrial and aquatic organisms. Aquatic organisms are particularly sensitive to oils, which cause oxygen depletion in the receiving water body through the formation of films and the metabolic activities of aquatic microorganisms (NOAA, 2010). Drums used to transport soap oils are kept tightly sealed to minimize the likelihood of large volume oil spills (Burns-Moguel, 2014). Accidental spills of chemical reagents are generally unlikely for modern soap producers employing good manufacturing practices and emergency waste interceptors.

<u>Evaluation Question #7:</u> Describe any known chemical interactions between the petitioned substance and other substances used in organic crop or livestock production or handling. Describe any environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).

Technical information was not identified regarding known chemical interactions between potassium and/or ammonium salts of fatty acids and other substances allowed for use in organic production or handling. The RED (US EPA, 1992) and recent Environmental Fate Assessment (US EPA, 2013) state that soaps of higher fatty acids are not compatible with soluble metallic salts such as zinc, manganese, and iron sulfates, but do not provide further details regarding the likelihood for these interactions. This interaction is potentially problematic in organic crop production since soluble metallic salts are permitted for use as soil amendments/micronutrients when soil deficiency is documented by testing. According to the NOP final rule, sulfate, carbonates, oxides, or silicates of zinc, copper, manganese, iron, molybdenum, selenium, and cobalt are allowed in organic crop production as micronutrients (7 CFR 205.601(j)(6)(ii)). The available data sources do not describe the potential environmental or health effects resulting from the combination of these incompatible materials.

Material Safety Data Sheet (MSDS) language for the ready-to-use Safer® Brand Insect Killing Soap with Seaweed Extract (2.0% potassium salts of fatty acids) states that the product is incompatible with concentrated mineral supplements/fertilizers, strong oxidizers and acids (Woodstream Corporation, 2014).

Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).

Specific information was not identified for soap salts regarding potential effects on biological or chemical interactions in the agro-ecosystem associated with herbicide uses. As discussed in the responses to previous evaluation questions, potassium and ammonium salts of fatty acids are expected to rapidly degrade primarily by microbial action once released to soils. Potassium and ammonium ions are incorporated into the soil in addition to organic material produced through microbial degradation of the fatty acid component of soap salts. The addition of ammonium ions associated with herbicide treatments should be minimal compared to the amount of nitrogen naturally present in soils due to the nitrogen cycle. For perspective, the highest application rate for ammonium salts of fatty acids is 205 lb a.i./acre, which corresponds to 8.3 lb nitrogen/acre for ammonium nonanoate (8% nitrogen by weight). As a point of comparison, legume cover crops—such as crimson clover, red clover and Hairy vetch—can release any where from 70 to 175 pounds of nitrogen per acre to the soil (Ketterings, 2011; Wickline & Rayburn, 2008; Duiker & Curran, 2014). Likewise, potassium is required in relatively large amounts for plant growth, and the macronutrient is commonly added as part of fertilizer regimens to deficient soils in conventional crop production (Rehm & Schmitt, 2002). Based on this analysis, it seems unlikely that use of ammonium and potassium soaps will have a significant impact on soil nitrogen and potassium levels.

Potassium and ammonium salts of fatty acids are used as fast acting herbicides, algicides and insecticides. Pesticides formulated with ammonium salts control algae, broadleaf weeds (bittercress, chickweed, and liverwort), as well as grasses and other weeds (bentgrass, fescue, and wild onion) (Emery, 2014). Further, products containing potassium soaps are effective against similar vegetative species, and help control mites, aphids, crickets, earwigs, lace bugs, leaf feeding caterpillars and beetles, leafhoppers, mealybugs, plant bugs, scale crawlers, thrips, and whiteflies (Woodstream Corporation, 2009). As insecticides and miticides, soap salts disrupt the exoskeletons of exposed insects, leading to insect death. It is therefore reasonable to assume that soft-bodied insects and other soil organisms—including earthworms, mites, and grubs—are susceptible to the toxic effects of soap-based herbicides and algicides. Indeed, Davis *et al.* (1997) demonstrated that nonanoic acid (C9 fatty acid) has considerable nematicidal activity. It is likely that large-volume releases of soap salt solutions to the soil environment would temporarily disrupt local populations of beneficial soil insects and microorganisms; however, reports of ecological impairment were not identified (US EPA, 2013).

In addition to the active substances, the manufacture of potassium and ammonium soap salts could lead to adverse effects on environmental receptors. Specifically, reaction solutions containing strong bases (e.g., potassium hydroxide) could alter soil pH if released to the terrestrial environment due to improper handling and/or disposal of these materials. Drastic changes in soil pH could alter bioavailability of macro- and micronutrients for plants and beneficial soil microflora. No reports of contamination due to the manufacture of soap-based herbicides and algicides were identified, and the risk of such events is minimized when hazardous substances are treated according to state and federal law prior to disposal.

Information was not identified on the potential or actual impacts of potassium and ammonium soaps and/or manufacturing substances on endangered species, population, viability or reproduction of non-target organisms and the potential for measurable reductions in genetic, species or eco-system biodiversity.

Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

Soaps salts essentially behave as the carboxylate anions of fatty acids when released to the environment. In general, potassium and ammonium salts of fatty acids decompose rapidly and do not accumulate or persist in the environment. Biodegradation in soil and water is expected to be the primary fate process for soaps, with measured half-lives of less than one day for most fatty acid salts (Thurston County, 2009a; Thurston County, 2009b). Particulate phase fatty acid salts will be removed from the atmosphere through wet and dry deposition, and unsaturated fatty acid anions will be degraded through reaction with ozone (HSDB, 2008c). While some fatty acids (e.g., lauric acid) may bioaccumulate in aquatic animals, this process occurs naturally through the ingestion of foods containing fatty acids (Van Egmond, 1999). The addition of ammonium and potassium ions associated with herbicide and algicide treatments should be minimal compared to amounts typically observed in soils due to the nitrogen cycle and breakdown of compost materials. Soaps salts are capable of disrupting the exoskeletons of soft-bodied insects, larvae, and other soil organisms (e.g., earthworms and nematodes) directly exposed to spray solutions (Davis, 1997; US EPA, 2013).

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4)).

Potassium and ammonium soap salts are practically non-toxic through oral, dermal and inhalation exposure routes. Indeed, potassium fatty acid salts are generally recognized as safe (GRAS) by the Food and Drug Administration (FDA) due to their presence in numerous food products and additives (US EPA, 2012). Ingested fatty acids are metabolized through cellular activity, where they are oxidized to compounds that are used as an energy source and structural cell components (Thurston, 2009a; Thurston, 2009b). The 2012 qualitative human health risk assessment rationalized US EPA's decision to waive data requirements in accordance with the observed lack of effects at high doses, ubiquity of fatty acids in nature, and functionality of the substances in humans:

> *Fatty acids are normally metabolized by the cells, where they are oxidized to simple compounds for use as energy sources and as structural components utilized in all living cells. Sodium, potassium, and ammonium are normally part of the body's metabolism and electrolyte balance. Oral exposure to soaps is generally self-limiting because the taste of soap is unpleasant. Also, the ammonium soap salts have a notable ammonia odor that is self-limiting.*

Despite the lack of systemic toxicity associated with soap salts, both potassium and ammonium salts of fatty acids can lead to various forms of acute irritation. Potassium soaps are classified as corrosive to the skin based on severe erythema (skin redness) at both intact and abraded sites, as well as cracking and fissuring of epithelial layers. Based on corneal effects, potassium soaps are also considered to be severe eye irritants. Ammonium salts of fatty acids are only moderately irritating to the skin, but are corrosive to the eyes and may cause permanent eye damage in extreme exposure scenarios (US EPA, 2012). A query of the California Department of Pesticide Regulation (CDPR) Pesticide Illness Surveillance Program (PISP) data revealed no incidents of acute irritation or systemic poisoning following exposure to products containing only soap salts as the active ingredient between 1992 and 2011 (CDPR, 2014).

Reproductive and mutagenic effects were observed in laboratory animals administered soap salts at high doses. Skin reaction, irritability, weight loss and failure to maintain pregnancy were observed in mice treated with the highest doses (500 and 5,000 mg/kg-day) during gestation days two through 15. However, the incidences of fetal loss, malformations, visceral or skeletal anomalies and skeletal variants were within the historical control range (0–4.4%) for young mice in the 500 mg/kg-day dose group. Unscheduled DNA synthesis was observed in mouse cells exposed to 35 mg/kg oleic acid, a potential soap salt precursor. In addition, chromosomal abnormalities were observed in hamster fibroblasts and the bacterium *Saccharomyces cerevisiae*, treated with 2,500 μg/L and 100 mg/L oleic acid, respectively (US EPA, 2012). The international Agency for Research on Cancer (IARC) has not listed potassium or ammonium soaps as carcinogens (IARC, 2014).

<u>Evaluation Question #11:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).

A wide variety of naturally produced organic acids, botanical essential oils and other natural substances may serve as alternatives to soap-based herbicides for weed control and suppression. The efficacy of these natural herbicidal substances in combatting weeds and undesirable grasses is dependent upon the types of weeds present, the growth stages of weeds and the concentration/volume of the substance applied to weeds (Abouziena, 2009). Like soap-based herbicides, the natural alternatives are mostly non-selective substances, which provide post-emergence burn-down control and require multiple applications for prolonged efficacy (Dayan, 2011). These substances kill only the green parts of plants they contact, and do not provide long-term control of weeds with extensive root systems or underground storage structures (e.g., zhizomes, tubers, or bulbs). Therefore, plant treated with soaps, organic acids, and essential oils may recover following treatment. Products containing these substances are generally recommended for use on small, annual weeds and seedling as well as weeds in cracks and edging (Perez, 2012). Agricultural specialists suggest the following strategies for improving the efficacy of alternative herbicide products:

- Thoroughly cover all (or most) of the aboveground plant tissue with the substance, and ensure the growing points are contacted;
- Apply substances in warm weather (75–80 ºF);
- Add surfactant that improve the spread and degree of weed control of alternative herbicides, if using concentrates;
- Apply alternative herbicide substances when weeds are small; and
- Repeat applications for larger weeds, in most cases.

The following sub-sections provide additional information regarding the chemical nature, efficacy and commercial availability of naturally occurring pesticidal substances that may be used as alternatives to soap-based herbicides in organic crop production.

Organic Acids

Naturally produced organic acids—including vinegar (acetic acid active ingredient) and citric acid—may be used as pesticides in organic production if the requirements of the "crop pest, weed, and disease management practice standard (7 CFR 205.206(e)) are met (OMRI, 2014). This standard states that natural substances and synthetic substances approved for use on the National List may be used as herbicides when cultural practices (described in Evaluation Question #12) are insufficient to prevent or control weeds.

Natural vinegar is a dilute solution of acetic acid (CH_3CO_2H) in water. For example, household vinegar is typically 5% acetic acid by volume (Abouziena, 2009). As an herbicide, acetic acid provides non-selective burn-down control of aerial portions of the plant with no effect on the root systems of weeds (Dayan, 2009). It is reported that acetic acid at natural concentrations provides only variable control of small weeds (Dayan, 2009); however, Abouziena *et al.* (2009) demonstrated that 5% acetic acid solutions (household vinegar) applied two to four weeks post-emergence resulted in 93–100% control of stranglervine, black nightshade, and velvetleaf within four weeks after treatment. Solutions containing up to 25% acetic acid—commonly known as "horticultural vinegar"—provide satisfactory control of small weeds; however, these concentrated vinegar solutions are not approved for weed management in organic food production (Dayan & Duke, 2010). In general, acetic acid/vinegar is more effective in controlling broadleaf weeds than grass weeds (Dayan & Duke, 2010). No vinegar products are on the OMRI Products List specifically for crop pest, weed and disease control (OMRI, 2014). Several herbicide products formulated with acetic acid as the active ingredient are currently registered with US EPA (US EPA, 2014); for example, Grotek™ Elimaweed™ Weed and Grass Killer contains 7.15% acetic acid (Greenstar Plant Products Inc, 2010).

In addition to vinegar, natural sources of citric acid could also serve as alternative herbicides for soap salts. Abouziena *et al.* (2009) found that products containing citric acid (10%) effectively controlled many types of broadleaf weeds—including stranglervine, black nightshade, and velvetleaf—at 95% or greater within four weeks after treatment. The product showed lower activity (less than 72% of control) when applied to other broad leaf weeds, and provided no activity against narrowleaf weeds (grasses). This research group also demonstrated that the combination of citric acid (5%) and garlic (0.2%) causes 98% mortality of broadleaf weeds, and therefore has potential for use as a natural herbicide. OMRI lists several products containing citric acid as the active ingredient for crop pest, weed and disease control (OMRI, 2014). For example, the Summerset Alldown® concentrate (23% acetic acid plus 14% citric acid) and ready-to-use (8% acetic acid and 6% citric acid) products are non-selective broadleaf and grass herbicides marketed for use in organic crop production (BioLynceus Biological Solutions, 2010a and 2010b).

Plant Essential Oils

Essential oils extracted from natural plant material have also been investigated as alternative herbicidal agents for organic crop production. Natural clove oil, thyme oil, lemongrass oil, limonene (citrus oil) and eucalyptus oil—among many other naturally occurring essential oils—have exhibited herbicidal activity, and several of these substances are included as active ingredients in commercially available products

(Dayan, 2009; Dayan & Duke, 2010; Dayan, 2011). Products containing naturally derived essential oils may be used for weed control if the requirements of 7 CFR 205.206(e) are met (OMRI, 2014). Like organic acids, essential oils are non-selective, contact herbicides (i.e., burn-down) that can provide good but transient weed control. Only portions of vegetation directly sprayed with essential oil solution are affected since these active substances do not translocate throughout the plant (Dayan, 2009). In addition, essential oils such as clove oil are most effective against small weeds and commonly require surfactants to enhance the spread of essential oils over the surface of treated vegetation (Dayan, 2009). Examples of OMRI listed, commercially available products include St. Gabriel Organics BurnOut II Fast Acting Weed and Grass Killer (6% citric acid, 2% clove oil) and the Avenger Weed Killer [17% d-limonene (citrus oil)] manufactured by Cutting Edge Formulations, Inc.

Corn Gluten Meal

While soaps, organic acids and essential oils are post-emergence herbicides, corn gluten meal is marketed for weed prevention (Perez, 2012). The natural substance is a byproduct of the corn milling process, and is used as a fertilizer and pre-emergence herbicide in conventional and organic crop production. The herbicidal mode of action involves microbial degradation of corn gluten with concomitant release of phytotoxic oligopeptides into soils (Dayan & Duke, 2010). Although it exhibits no herbicidal activity against existing weeds, corn gluten meal affects the germination and development of emerging broadleaf weeds (Dayan, 2009). Control of grasses and other weeds requires extremely high application rates (e.g., 2 tons per acre), which may be cost prohibitive for some growers (Dayan, 2009). In greenhouse experiments, corn gluten meal at high application rates (4 tons per acre) provided 72% total weed control and 83% broadleaf weed control 46 days after planting. The results of other studies indicate that field treatment with corn gluten does not reduce the time needed to weed experimental plots; however, it is the application rate is not explicitly stated (Perez, 2012). Corn gluten meal products are not explicitly included on the OMRI Product List for crop pest, weed and disease control (OMRI, 2014). It is also highly probable that commercially available corn gluten meal is produced using excluded methods (i.e., GE corn).

Despite its utility in the production of field crops, corn gluten meal would not be an effective alternative for weed control in farmstead maintenance (roadways, ditches, rights of ways, and building perimeters) or the organic production of ornamental plants due to the manner of application.

Synthetic Substances Approved for Organic Production

According to the National List, synthetic herbicides are not permitted for use in organic food crop production. Further, soap salts are the only synthetic herbicides allowed for use on organically produced ornamental plants and for farmstead maintenance (roadways, ditches, right of ways, building perimeters) on the premises of organic farms (7 CFR 205.601(b)(1)). Newspaper or other recycled paper without glossy or colored inks, plastic mulch and covers (petroleum-based other than polyvinyl chloride), and biodegradable biobased mulch film are permitted as synthetic weed barriers on the National List for crop production (7 CFR 205.601(b)(2)).

<u>Evaluation Question #12:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

Organic farmers are generally dependent upon preventative cultural practices and physical controls for suppressing crop pests, weeds and plant diseases. In crop production, farmers commonly employ crop rotations, cover crops, intercropping and soil tillage to prevent the emergence of weeds; however, this practice will not address the emergence of weeds in ornamental production/greenhouse settings and/or along roadways, ditches, right of ways, and/or building perimeters. The NOP "crop pest, weed, and disease management practice standard" states that organic producers may control weed problems using the following activities (7 CFR 205.206(c)):

- Mulching with fully biodegradable materials;
- Mowing;
- Livestock grazing;
- Hand weeding and mechanical cultivation;
- Flame, heat or electrical means;

- Plastic or other synthetic mulches: *Provided* that, they are removed from the field at the end of the growing or harvest season.

Only a subset of the cultural practices outlined in the standard above would realistically limit and/or preclude the use of soap-based herbicides in ornamental crop production and farmstead maintenance. The most applicable methods for weed control and prevention in relevant settings include hand weeding, mowing/cutting, flaming/heat treatment, and mulching. Although these methods are labor-intensive, the land area included in the 7 CFR 205.601(b)(1) should be small compared to the acreage used to produce organic crops for most producers.

Cultivation effectively controls weeds through physical soil disturbance. Large-scale crop producers use a wide range of cultivation implements for full field, near-row and within-row cultivation (Schonbeck, 2010); however, mechanical cultivation is not a viable alternative for farmstead maintenance and organic production in greenhouses. When tending to weeds along roadways, ditches, right of ways and building perimeters, growers can choose from a wide range of hoes and other handheld weeding implements. The standards hoe—consisting of a substantial blade—is effective on small to fairly large weeds; however, this cultural practice can be tiring, labor intensive and tends to bring more weed seeds to the surface to germinate (Schonbeck, 2010). Other implements include the stirrup hoe, collinear hoe and various lightweight, ergonomic hoes designed for very shallow cultivation of small weeds. Like other handheld hoes, the short-handled Dutch hoe is labor intensive, but also provides precise cultivation similar to mechanical torsion weeders used for within-row cultivation. The wheel hoe covers large garden areas efficiently, and can be equipped with standard, stirrup or sweep blades. Lastly, the four-prong cultivator can be uproot shallow weeds as well as larger weed roots and rhizomes to the soil surface (Schonbeck, 2010). Hand weeding is the most effective non-chemical approach to controlling weeds in the organic production of ornamental plants in outdoor pots and greenhouses.

Mowers and cutting tools—such as the rotary, sicklebar, or flail mowers—can be used to control or suppress the growth or erect weedy grasses and many broadleaf weeds in pastures, field margins, and even certain crop fields (Green, 2006; Schonbeck, 2010). Mowing or spot clipping simply removes the top growth, leaving approximately an inch of aboveground plant materials and roots intact. Although the entire plant is not removed using this method, mowing can have a significant impact on certain weeds. Some annual weeds are particularly susceptible to mowing and can be prevented from setting seed by one or two mowing events. In addition, the growth and vegetative production of perennial weeds can be restricted with timely and/or repeated mowing (Schonbeck, 2010). Frequent mowing—repeated over a three- to five-year period—can deplete root reserves of some perennial weeds such as horsenettle or johnsongrass. However, low-growing plants (dandelions, crabgrass, and nimblewill) tend to be more prevalent in pastures that are regularly mowed (Green, 2006). Mowing should begin when weeds are in the stem elongation stage but before flowers or grass seed heads are produced to minimize future weed problems. Best results are obtained when the vegetation is clipped as close to the soil as possible (Green, 2006). Organic growers employing this control method for farmstead maintenance may use a lawn mower, weed whacker, sickle, scythe, or garden shears to cut weeds along roadways, ditches, right of ways and building perimeters.

Flame and other heat-kill tools may be used to kill small weeds just prior to crop emergence in vegetable production and along roadways for farmstead maintenance (Schonbeck, 2010; Barker & Prostak, 2014). Flame weeders equipped with flame hoods or shields focus the heat on target weed, thus enhancing the energy efficiency of flame weeding (Schonbeck, 2010). Although burning fields to reduce weed populations is an historic practice, this practice has many disadvantages including air pollution, reduced visibility from smoke production, and the potential for uncontrolled fire development (Barker & Prostak, 2014). The primary objective of flaming is not to burn the weeds, but rather to briefly subject weeds to intense heat that disrupts cell membranes and causes to weed to dehydrate and die within days. Flaming is most effective and energy-efficient on small weeds up to two inches tall (Schonbeck, 2010). In a recently published study, it was found that field plots of perennial weeds (almost entirely quackgrass) flamed with a weed torch had weed masses that were about 20% of the end-of-season growth of the untreated perennial weed plots (Barker & Prostak, 2014). In addition to propane-fueled weeders, other modes of thermal weed control include infrared heaters, as well as hot water and steam weeders. These thermal alternatives to flame weeding eliminate the potential fire hazards associated with flame weeders in dry conditions (Schonbeck, 2010).

In combination with other cultural practices, mulching is a highly effective method for preventing the emergence of annual and perennial weeds. Organic mulches such as hay, straw, tree leaves, and wood shavings/bark keep light responsive weeds seed in dark conditions, physically hinder emergence of weed seedlings and can provide shelter for ground beetles and other consumers of weed seeds (Schonbeck, 2010). In addition, organic mulches conserve soil moisture, prevent surface crusting, feed soil microorganisms, and may continually release nutrients to soils. Three to four inches of hay or straw mulch can significantly reduce the emergence of broadleaf weeds; however, these organic mulches are less effective against grassy weeds and perennial weeds grown from rootstocks, tubers, rhizomes, or bulbs (Schonbeck, 2010). Despite this generalization, Barker and Prostak (2014) determined that mulching with wood chips or bark chips had strong suppressive effects on perennial vegetation through the entire season. The authors also noted that mulching provided greater suppression of weed mass than alternative herbicides (citric-acetic acids, clove oil, corn gluten meal, limonene, and pelargonic acid) or flame treatments (Barker & Prostak, 2014).

Black and clear plastic film mulches and paper mulches are also permitted as organic weed control measures. Black films eliminate the light stimulus for weed seed germination, thereby blocking the emergence of most weeds. Unlike organic mulches, black plastic films do not enhance soil quality and can interfere with penetration of rainfall in the covered area (Schonbeck, 2010). When used alone, paper mulches are less effective than plastic covers, but application of paper mulch beneath an organic mulch may enhance weed control over organic mulch alone (Schonbeck, 2010). Clear plastic film mulch raises soil temperatures, and can lead to soil solarization (a form of thermal weed control) under warm and sunny conditions. However, cooler weather can effectively provide greenhouse conditions that accelerate weed growth under the plastic layer (Schonbeck, 2010). Mulching with natural or synthetic materials is particularly compatible for weed control along roadsides and around building perimeters.

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