Ammonium Nonanoate

Crops

Identification of Petitioned Substance

Chemical Name:
Octane-1-carboxylic acid, ammonium salt

Other Names:
Ammonium pelargonate
Pelargonic acid, ammonium salt
Nonanoic acid, ammonium salt

Trade Names:
FL-AN140F (formerly Racer® Concentrate)
FL-AN405F (formerly Racer® Ready to Use)

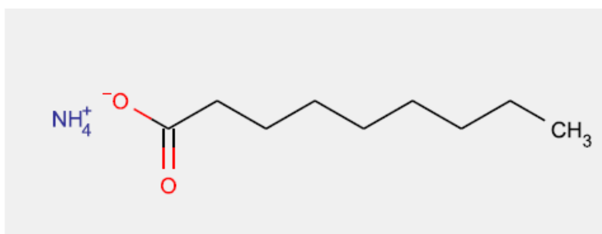
CAS Number:
63718-65-0 (ammonium nonanoate)

Other Codes:
031802 (EPA PC code for ammonium nonanoate; EPA, 2008)
031801 (EPA PC code for ammonium salts of C8-C18 and C18' fatty acids)

Characterization of Petitioned Substance

__Composition of the Substance__:
Ammonium nonanoate is a C_9 saturated-chain fatty acid soap salt with the chemical formula $NH_4(C_9H_{18}O_2)$. Ammonium salts of fatty acids, including ammonium nonanoate, are mineral salts of naturally-occurring fatty acids in the environment (75 FR 14082). Ammonium nonanoate is the ammonium salt of nonanoic acid (CAS No. 112-05-0). Nonanoic acid, also known as pelargonic acid, is found in almost all species of animals and plants and is present at low levels in many commonly eaten foods (EPA, 2000). The molecular structure of ammonium nonanoate is shown in Figure 1.

Figure 1. Molecular Structure of Ammonium Nonanoate



Source: created using MarvinSketch software available on ChemIDplus Advanced (2011)

__Properties of the Substance__:
Ammonium nonanoate is produced as a flowable concentrate for use in agriculture and as a ready-to-use solution for use in residential and landscaping settings. The product for agricultural uses that is registered by the petitioner (Falcon Labs, LLC) is named Racer® Concentrate (currently listed as "FL-AN140F" in the National Pesticide Information Retrieval System [NPIRS]). This herbicide is formulated as a solution containing 40% ammonium nonanoate and 60% other ingredients (label information for FL-AN140F in NPIRS, 2011). The "other ingredients" composition of Racer® Concentrate is specifically identified as "60% water" in the petition to the National Organic Standards Board (NOSB) made by Falcon Labs, LLC in 2009 (Smiley and Beste, 2009).

Ammonium nonanoate is a clear, colorless to pale yellow liquid with a slight fatty acid odor (EPA, 2008). It is completely miscible in water (EPA, 2008). Racer® Concentrate is reported to be stable without decomposition during storage (Smiley and Beste, 2009). There is a long history of the stability of fatty acid soaps in plastic containers without evidence of corrosiveness (EPA, 2008). Racer® Concentrate can be stored in glass, steel, plastic-lined steel, or polyethylene containers and is reported to have a pH of 7 to 8.5 (Smiley and Beste, 2009). The manufacturer states that storage at temperatures below freezing (32ºF, 0ºC) may cause crystallization of solid ammonium nonanoate from solution and bursting of the storage container (Smiley and Beste, 2009). Ammonium nonanoate is not listed in the Hazardous Substances Data Base (HSDB, 2011).

In several assessments, EPA has considered all ammonium and potassium salts of fatty acids to be similar in chemistry, toxicology, and environmental fate and effects (EPA, 1992; Sunderland, 2010).

Specific Uses of the Substance:
Many different soap salts are used in agricultural and residential settings as insecticides, herbicides, and deterrents for deer and rabbits. Ammonium nonanoate is petitioned for use as an herbicide in organic food crop production (Smiley and Beste, 2009). Specifically, the petition requests allowance for spray applications of water solutions containing ammonium nonanoate to control weeds. The requested uses are spraying prior to planting food crops, directed spraying at the base of grape vines and fruit trees, and shielded or directed spraying to the soil surface between crop rows or at the edges of plastic film mulch. Before usage, the concentrated solution of ammonium nonanoate is diluted by the user with water to the recommended dilution of 6 to 15% volume to volume of the concentrate depending on the size of the vegetation to be suppressed (Smiley and Beste, 2009). This herbicide is meant to be sprayed only on undesirable plant growth and is not recommended for use on any green parts of desirable plants.

Racer® Concentrate and four similar formulations are the only products registered with EPA that contain ammonium nonanoate as the active ingredient (NPIRS, 2011). All five products are registered with EPA by the petitioner, Falcon Lab, LLC. EPA permits the use of ammonium nonanoate as a herbicide for nonfood use in the suppression and control of weeds, vines, and underbrush by homeowners, master gardeners, farmers, landscape/turf professionals, and indoor plant experts (interiorscapers) (EPA, 2008). Racer® Concentrate is included on the Organic Materials Review Institute (OMRI) Products List for use as an algicide/demosser, herbicide (nonfood only), or insecticide. No currently marketed products containing ammonium nonanoate were found using internet searches, and Falcon Lab's website (www.falconlabllc.com) was inaccessible.

Compounds similar to ammonium nonanoate, in a group referred to as soap salts, are registered with EPA for various agricultural uses (EPA, 1992). Potassium salts of fatty acids, including potassium laureate, potassium myristate, potassium oleate, and potassium ricinoleate, are used in agricultural settings as insecticides and herbicides for food and feed crops and in residential settings for pest control (e.g., control of fleas on dogs and cats). The targeted pests include a variety of insects as well as mosses, algae, lichens, liverworts, and other weeds. Products containing potassium salts of fatty acids may be applied as a spray, in solid form (soap cake), or as an ointment. Various ammonium salts of fatty acids are used as herbicides or as deer and rabbit repellents for a variety of crops and plants. Products containing ammonium salts of fatty acids may be applied as a liquid spray. Eight products are currently registered with EPA containing the active ingredient "ammonium salts of C8-18 and C18' fatty acids" (NPIRS, 2011). These products are labeled for use as either deer and rabbit repellants or as herbicides.

According to 40 CFR 180.910, ammonium salts of fatty acids, including ammonium nonanoate, may be used as inert ingredients (surfactants) in pesticides applied to pre- and post-harvest crops. No further information was found on this usage.

Approved Legal Uses of the Substance:
Ammonium nonanoate is registered as a biopesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which is administered by EPA. EPA issued a Reregistration Eligibility Decision (RED) for soap salts, including ammonium salts of fatty acids, in September of 1992 (EPA, 1992). The Agency also issued a Biopesticide Registration Action Document (BRAD) for ammonium nonanoate in June 2008 (EPA, 2008). Ammonium salts of fatty acids have been registered since 2006 as a nonfood use herbicide for the suppression and control of undesirable grasses and weeds around food and ornamental

crops and in nurseries, greenhouses, landscapes, and lath or shade houses. In addition, ammonium salts of fatty acids have been registered for other nonfood uses (e.g., on crops and other plants as a deer and rabbit repellant).

According to the BRAD for ammonium nonanoate, the product Racer® Concentrate may be applied by standard spray methods, including hand-held, boom, pressure, and hose-end sprayers, at a maximum concentration of 6.0% by weight (corresponding to 2.4% ammonium nonanoate by weight) (EPA, 2008). The leaves of undesirable plants must be uniformly sprayed and thoroughly wetted in order for the product to be effective, and application can be repeated as often as necessary (EPA, 2008). In July 2008, EPA published a final rule in the Federal Register establishing a tolerance exemption for residues of ammonium salts of higher fatty acids, including ammonium nonanoate, in or on all food commodities when applied for the suppression and control of a wide variety of grasses and weeds (73 FR 39264; 40 CFR 180.1284). In March 2010, EPA published a final rule establishing a tolerance exemption for residues of ammonium salts of fatty acids, including ammonium nonanoate, when used as an inert ingredient in pesticide formulations applied to pre- and post-harvest crops (75 FR 14082; 40 CFR 180.910).

Action of the Substance:
Ammonium nonanoate is a nonselective, broad-spectrum, contact herbicide (EPA, 2008; 73 FR 39264). It has a physical, and not systemic, mode of action. According to the petitioner, it acts by penetrating the cells walls of plants and disrupting the membranes within the cells. This leads to a disturbance in the physiological functions of the cells and causes brown necrotic plant tissue (Smiley and Beste, 2009).

Combinations of the Substance:
No information could be found to suggest that ammonium nonanoate is a precursor to, component of, or commonly used in combination with any substances identified on the National List of Allowed and Prohibited Substances (hereafter referred to as the National List).

Status

Historic Use:
Pesticide products containing ammonium nonanoate as the active ingredient were first registered with EPA in 2006 and several have been registered since then (PAN, 2010). All of these products are listed as herbicides. Pesticide products containing the active ingredient ammonium salts of fatty acids were first registered with EPA in 1982 and many have been registered since that time (PAN, 2010). The use types listed for these products include herbicides, deer repellents, fungicides, and insecticides.

Ammonium nonanoate is not specifically included on the National List for use in organic agriculture. However, soap-based herbicides, algicides, or insecticides are included as a category on the National List for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops. Ammonium nonanoate would be included in this category of soap-based herbicides, algicides or insecticides. In addition, ammonium soaps are also specifically included on the National List as large animal repellents, and ammonium nonanoate can be placed in this category. The product Racer® Concentrate, containing 40% ammonium nonanoate, has been on the OMRI Products List since 2008 (Smiley and Beste, 2009). No information could be found on the current or past usage patterns of this product in organic agriculture.

The NOSB Crops Committee has twice considered the use of ammonium salts of fatty acids as herbicides in organic crop production (NOSB Committee Recommendation, 2007; NOSB Committee Recommendation, 2008). Both times, the Committee voted to reject this usage (March 2007 and November 2008). The basis for rejection each time was that there are many alternative weed management practices available and that the substance is not compatible with the provisions of the Organic Foods Production Act (OFPA) for general use on crops or cropland.

OFPA, USDA Final Rule:
The National List includes soap-based herbicides for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops (nonfood uses only) (7 CFR 205.601(b)(1)). Soap-based algicides/demossers and insecticidal soaps are permitted for use in organic crop production (7 CFR 205.601(a)(7); 7 CFR 205.601(e)(8)). Ammonium soaps are permitted for use in organic crop production as a large animal repellent and may not come in contact with soil or the edible portion of the crop (7 CFR 205.601(d)). Racer® Concentrate, containing 40% ammonium nonanoate, is included on the OMRI Products List as an algicide/demosser, herbicide (nonfood uses), or insecticide only if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011).

International:
Ammonium soaps are permitted for organic production by the Canadian General Standards Board (CGSB) as large animal repellents only. No contact with soil or edible portions of the crop is allowed (CGSB, 2009). Soaps consisting of fatty acids derived from animal or vegetable oils (including insecticidal soaps) are permitted by the CGSB for use in organic crop production and for use as cleaning agents on equipment and food contact surfaces. Ammonium nonanoate is not specifically listed in the Canadian Organic Production Systems Permitted Substances List.

Ammonium nonanoate or ammonium salts of fatty acids (ammonium soaps) are not specifically listed for use in organic crop production by the CODEX Alimentarius Commission, European Economic Community (EEC) Council Regulations (EC Nos. 834/2007 and 889/2008), International Federation of Organic Agriculture Movements (IFOAM), or the Japan Agricultural Standard (JAS) for control of weeds or any other crop uses.

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

Evaluation Question #1: What category in OFPA does this substance fall under: (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). Ammonium nonanoate is categorized as a soap.

B). Ammonium nonanoate is not listed by EPA as an inert ingredient of toxicological concern. Soap is included on the list of EPA inert ingredients of minimal concern for food and nonfood uses, but it is defined as "the water soluble sodium or potassium salts of fatty acids produced by either the saponification of fats and oils, or the neutralization of fatty acid" (EPA, 2010). Ammonium nonanoate does not meet this definition because it is an ammonium salt of a fatty acid and not a sodium or potassium salt. However, ammonium nonanoate when used as an active or inert ingredient in pesticide products is exempt from the requirement of a tolerance per 40 CFR 180.1284 and 180.910.

Evaluation Question #2: 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)).

The only information available on the processes used to manufacture ammonium nonanoate is the information provided in the petition made by Falcon Lab, LLC (Smiley and Beste, 2009). According to the petitioner, the starting materials for the manufacture of ammonium nonanoate are nonanoic acid sourced from oleic acid and ammonia dissolved in water. The oleic acid that is used to produce nonanoic acid reportedly comes from agriculturally-produced edible fats and oils. Nonanoic acid is produced by blowing air through oleic acid resulting in a 50/50 mixture of nonanoic acid and azelaic acid, which are then separated by distillation. Nonanoic acid is a fatty acid that occurs naturally in many essential oils (HSDB, 2008). Azelaic acid is a dicarboxylic acid that occurs in nature and has pharmacological uses in the treatment of skin disorders (acne and rosacea) (PubChem, 2011). In order to produce ammonium nonanoate, nonanoic acid and ammonia dissolved in water are mixed together in a vessel at room temperature. The mixture is stirred until a clear, one-phase solution with pH around 7 is evident. At that time, all of the nonanoic acid is reportedly converted to ammonium nonanoate. The petitioner states that there are no byproducts to this end process and no purification is needed (Smiley and Beste, 2009).

Evaluation Question #3: Is the substance synthetic? 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).

Ammonium nonanoate for use as an herbicide is a synthetic substance. It is produced by the mixing of two separate synthetic substances that react to form a salt as described above for Evaluation Question #2.

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)).

Once released into the soil, ammonium salts of fatty acids, such as ammonium nonanoate, are expected to rapidly degrade primarily by microbial action (EPA, 1992). This is further supported by a draft environmental risk assessment of fatty acid salts prepared by HERA, which concludes that fatty acid salts with carbon chain lengths up to C18 can be considered readily biodegradable via aerobic metabolism (HERA, 2003). According to the RED for soap salts prepared by EPA, the half-life of the fatty acid components of ammonium soaps was demonstrated to be less than one day in soil (EPA, 1992). Regarding the potential degradation products of ammonium nonanoate in the environment, the RED states that microbial metabolism of fatty acids will result in the eventual formation of carbon dioxide and an ester, or that the carbon content of fatty acids will be converted into naturally-occurring organic substances normally produced by soil microorganisms (EPA, 1992). The BRAD for ammonium nonanoate concluded that this compound will not persist in the environment when used as an herbicide as directed (EPA, 2008). Environmental fate and groundwater data were waived for ammonium nonanoate due to EPA's estimate of minimal risk (EPA, 2008). No further information could be found on the persistence or concentration of ammonium nonanoate and/or its byproducts in the environment.

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)).

No animal or laboratory toxicity studies were identified specifically for ammonium nonanoate. In several assessments, EPA has considered all compounds categorized as potassium or ammonium salts of fatty acids to be similar relative to chemistry and toxicology (EPA, 1992). Therefore, data for these compounds can be considered in assessing the toxicity of ammonium nonanoate. In experimental studies, the acid form of a chemical and the alkali salt form of the same chemical have been shown to have similar toxicological properties once available inside the body (the salt is converted to an acid form in the stomach) (HERA, 2002). Therefore, data for nonanoic acid can be considered in assessing the toxicity of ammonium nonanoate (Sunderland, 2010).

Ammonium salts of fatty acids were found to have low toxicity when administered to animals via the oral or dermal routes of exposure (75 FR 14082). Compounds in this group have the potential to be skin irritants when applied over long periods of time and are considered to be eye irritants. Permanent eye damage is possible following ocular exposure to ammonium salts of fatty acids (75 FR 14082). Soap salts are not considered to be skin sensitizers; however, ammonium salts of fatty acids may cause an allergic reaction in a small number of people (EPA, 2008). Ammonium salts of fatty acids are likely to be irritating to the respiratory tract following inhalation exposure; however, limited data are available for soap salts via this route of exposure (75 FR 14082).

One short-term dietary study in rats is available for nonanoic acid, the fatty acid component of ammonium nonanoate. No significant toxicity was observed when rats were fed nonanoic acid for 14 days at doses up to 1.8 grams per kilogram of body weight (bw)/day (73 FR 39264). No developmental or reproductive effects were observed when nonanoic acid was administered to pregnant female rats at a dose of 1.5 g/kg bw/day (73 FR 39264). Nonanoic acid exhibited negative results in genetic toxicity tests to determine its potential to cause DNA mutations (HSDB, 2008), and ammonium salts of fatty acids are not believed pose a cancer risk (75 FR 14082). No chronic exposure studies are available in animals for ammonium salts of fatty acids; however, EPA considered chronic studies unnecessary to establish a tolerance exemption for this group of compounds because of their low toxicity following short-term exposures, the nature of fatty acids and their ubiquity in nature, and the unlikelihood of prolonged human exposure due to the expected use patterns (73 FR 39264).

Soap salts of fatty acids are considered to be slightly toxic to birds on an acute basis, practically nontoxic to birds on a dietary basis, slightly toxic to warm and cold water fish, and highly toxic to aquatic invertebrates (EPA, 1992). Toxicity data for nontarget insects are not available for any soap salt (EPA, 2008). Some soap salts (e.g., potassium salts of fatty acids) are registered for use as insecticides (NPIRS, 2011).

As stated previously, the alkali salt form of a chemical will be converted to the acid form in the stomach following ingestion (HERA, 2002). Therefore, ingestion of ammonium nonanoate is expected to result in the presence of nonanoic acid in the stomach. Fatty acids, such as nonanoic acid, are common in the human diet and are metabolized by cells for use as energy sources or structural components of the cells. Ammonia and the ammonium ion are normal and essential parts of human metabolism (Sunderland, 2010).

Ammonium nonanoate suppresses the growth of weeds through a nonspecific mode of action. Therefore, it exhibits a toxic action on the green tissue of any plant when applied at sufficiently high concentrations. Upon contact with green plant tissue, it penetrates the cells walls of plants and disrupts the membranes within the cells. This leads to a disturbance in the physiological functions of the plant cells and causes brown necrotic plant tissue (Smiley and Beste, 2009).

As stated in the response to Evaluation Question #4, ammonium nonanoate is expected to rapidly degrade following contact with the soil. The breakdown products are compounds that naturally occur in the soil; therefore, no toxic effects are expected.

<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)).

Specific information regarding the potential for environmental contamination associated with the manufacture of ammonium nonanoate was not found.

As described in the response to Evaluation Question #2, the process to manufacture ammonium nonanoate is a simple process. The only byproducts identified by the petitioners are glycerin (produced during the isolation of oleic acid from fats and oils) and azelaic acid (produced during the process used to make nonanoic acid) (Smiley and Beste, 2009). Glycerin is a naturally-occurring compound with food and cosmetic uses so its production is not likely to result in environmental contamination. Azelaic acid is also a naturally-occurring compound that is present in commonly eaten foods (HSDB, 2009). It also has industrial and pharmacological uses so its production is not likely to result in direct environmental contamination. Based on its chemistry, azelaic acid is expected to readily biodegrade when released into soil or water and to chemically degrade in the atmosphere when released to the air (HSDB, 2009).

As stated in the response to Evaluation Question #4, when released into soil, ammonium nonanoate decomposes rapidly and does not accumulate or persist in the environment. Furthermore, contact herbicides, like ammonium nonanoate, must be sprayed directly on the undesirable plant growth to be effective (EPA, 2008). Therefore, environmental contamination is not likely following recommended use of pesticide products containing ammonium nonanoate. Misuse or improper disposal of products containing ammonium nonanoate may result in temporary environmental contamination. However, due to its propensity to rapidly degrade, the impacts of ammonium nonanoate contamination are likely to be minimal.

Evaluation Question #7: 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)).

No information could be found on known chemical interactions between ammonium nonanoate and other substances allowed for use in organic production or handling. The RED for soap salts states that ammonium soaps of higher fatty acids are not compatible with soluble metallic salts such as zinc, manganese, and iron sulfates (EPA, 1992), but does not provide any further details regarding the likelihood for these interactions. This is a potential issue in organic crop production because soluble metallic salts are permitted for use as soil micronutrients following documentation of a soil deficiency. Specifically, sulfates, carbonates, oxides, or silicates of zinc, copper, manganese, iron, molybdenum, selenium, and cobalt are permitted by 7 CFR 205.601(j)(6)(ii). The potential environmental or health effects resulting from the mixture of these incompatible materials in agricultural soil were not described.

The MSDS for Racer® Concentrate (40% ammonium nonanoate) states that the product is incompatible with acids, strong bases, and any material incompatible with water (Smiley and Beste, 2009).

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)).

No specific information could be found for ammonium nonanoate related to potential effects on biological or chemical interactions in the agro-ecosystem following its use as an herbicide. As stated in the response to Evaluation Question #4, ammonium salts of fatty acids, such as ammonium nonanoate, are expected to rapidly degrade primarily by microbial action once released into the soil. This action will likely release ammonium ions and degradation products of nonanoic acid into the soil. No information was found the potential effects of the breakdown products of nonanoic acid on biological or chemical interactions in the agro-ecosystem. As stated in the response to Evaluation Question #4, the breakdown products of nonanoic acid are compounds that naturally occur in the soil; therefore, no negative effects are expected. Ammonium ions are naturally present in the soil as part of the nitrogen cycle. The addition of ammonium ions as a result of ammonium nonanoate use is likely to be small compared to the amount of nitrogen that is naturally present. For perspective, consider the amount of nitrogen that would be added to the soil during the application of an ammonium nonanoate herbicide. The maximum application rate for ammonium nonanoate herbicides is a water solution containing 2.4% ammonium nonanoate by weight (EPA, 2008). The product information for Racer® Concentrate states that large weeds may need 80 to 125 gallons/acre or more for control (Smiley and Beste, 2009). Because ammonium nonanoate is about 8% nitrogen by weight, applying 125 gallons/acre of a 2.4% ammonium nonanoate solution would result in an application of about 2 pounds of nitrogen/acre (using the weight of 1 gallon of water = 8.34 pounds for the estimation of the weight of the spray solution). By comparison, using a legume as a cover crop can deliver far more nitrogen to the soil. For example, red clover interseeded with a small grain crop can provide 75 to 175 pounds of nitrogen/acre/year to the soil (Cornell University Cooperative Extension, 2011). Therefore, the amount of nitrogen added to the soil resulting from use of an herbicide containing ammonium nonanoate can be considered negligible. No information was found to indicate that the use of ammonium nonanoate as an herbicide may act as a nitrogen fertilizer for crops. Furthermore, EPA assessments of ammonium nonanoate or ammonium salts of fatty acids (EPA, 1992; EPA, 2008) do not mention the potential for increased ammonium ions or nitrogen in the soil resulting from the use of ammonium nonanoate as an herbicide.

No information could be found on the potential effects of ammonium nonanoate on soil organisms, soil temperature, water availability, pH levels, nutrient availability, salt concentration, solubility, or any other soil physicochemical and biological properties.

The BRAD for ammonium nonanoate states that "there are no concerns for non-target organisms when ammonium nonanoate is used in accordance with approved labeling" (EPA, 2008). Also, ammonium nonanoate has no systemic or residual action on plants so minor drift to nontarget plants will likely not result in harm to those plants because leaves must be thoroughly soaked for herbicidal activity to occur (EPA, 2008). In addition, EPA concluded that the use of ammonium nonanoate as an herbicide will not cause adverse effects on threatened or endangered species when used as directed (EPA, 2008).

Evaluation Question #9: Discuss and summarize findings on whether 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)).

EPA's RED for soap salts concluded that products containing ammonium salts of fatty acids are not likely to cause unreasonable adverse effects in the environment (EPA, 1992). Once applied to plants or soil, ammonium salts of fatty acids, such as ammonium nonanoate, are rapidly degraded by microbes and do not persist in the environment. They pose minimal risks to birds, fish, and other nontarget organisms in the environment except that they are highly toxic to aquatic invertebrates (see response to Evaluation Question #5). EPA's Biopesticide Registration Action Document for ammonium nonanoate concluded that herbicidal use of this compound will not result in a serious impact on aquatic invertebrates because it will not be directly applied to water under typical use patterns and it undergoes rapid biodegradation when applied to soil (EPA, 2008). Pesticidal products containing ammonium nonanoate must contain the precautionary warning: "This product may be hazardous to aquatic invertebrates. Do not apply to water bodies such as ponds or creeks, areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water by cleaning of equipment or disposal of rinse water into such water bodies" (EPA, 2008). The presence of this warning might help to mitigate the risks to aquatic invertebrates. As stated in the response to Evaluation Question #6, no specific information was found regarding the potential for environmental contamination associated with the manufacture of ammonium nonanoate.

Evaluation Question #10: 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)).

EPA's RED for soap salts concluded that products containing ammonium salts of fatty acids are not likely to cause unreasonable adverse effects on human health (EPA, 1992). The toxicity of ammonium salts of fatty acids, including ammonium nonanoate, is generally low (EPA, 1992). EPA's Biopesticide Registration Action Document for ammonium nonanoate concluded that ammonium nonanoate is practically nontoxic to mammals via the oral route of exposure (EPA, 2008). Pesticide residues of ammonium nonanoate on food are likely to be very low considering that it is not intended to be directly sprayed on food crops. Furthermore, ammonium nonanoate is a salt of a naturally occurring fatty acid and the body has the ability to metabolize it (Sunderland, 2010). Fatty acids are a significant part of the human diet and residues of fatty acids from pesticidal use of ammonium nonanoate are not likely to add significantly to the levels of fatty acids already present in foods (EPA, 2008). EPA has concluded that "there is reasonable certainty that no harm to the U.S. population, including infants and children, will result from aggregate exposure to residues of ammonium salts of fatty acids (C_8-C_{18} saturated, C_8-C_{12} unsaturated) due to their use as a pesticide" (73 FR 39264).

Prolonged dermal or inhalation exposure to ammonium nonanoate has the potential to cause skin or respiratory irritation (EPA, 2008). Also, allergic skin reactions may occur in some people although EPA has concluded this is uncommon (Sunderland, 2010). Ammonium salts of fatty acids are eye irritants, and there is a potential risk of permanent eye damage for handlers and applicators of products containing ammonium nonanoate (EPA, 1992; EPA, 2008). The risks for skin irritation and eye damage can be mitigated by wearing long-sleeved shirts, chemical-resistant gloves and boots, and protective eyewear during the handling and application of products containing ammonium nonanoate (EPA, 2008). According to EPA (2008), pesticidal products containing ammonium nonanoate must contain the precautionary warning: "Inhalation may cause nose, throat, and lung irritation on prolonged exposure to spray and should be minimized. Skin contact should be avoided by the use of long sleeved shirts and chemical resistant gloves and boots. Fatty acid salts are known eye irritants, so goggles, safety glasses with side shields or full faceshields must be used during mixing operations and application."

Evaluation Question #11: 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)).

Natural (nonsynthetic) Substances or Products:
The efficacy of natural herbicides in the control and suppression of weeds and undesirable grasses is largely dependent on the type of weeds present, the growth stage of the weeds, and the concentration of herbicide used (Abouziena et al., 2009). The petition for ammonium nonanoate provides efficacy data for several natural herbicides (Smiley and Beste, 2009). Also, Abouziena et al. (2009) provide a review of efficacy data in the literature as well as results from their own trial.

The following wholly natural herbicide ingredients were identified by the OMRI Products List (OMRI, 2011), the available literature (Abouziena et al., 2009; Dayan and Duke, 2010), and/or the NOSB Crops Committee Recommendation for ammonium salts of fatty acids (NOSB Committee Recommendation, 2008) and could be substituted for ammonium nonanoate for use as herbicides in organic crop production.

- **Vinegar**: Nonsynthetic vinegar (acetic acid in water) can be used as a pesticide if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011). Natural vinegar is a water solution that typically contains about 4 to 8% acetic acid (table vinegar is typically 5% acetic acid) (Webster's Online Dictionary, 2011). Acetic acid is a non-selective, contact herbicide that kills the aerial portions of plants but does not affect the root system (Dayan et al., 2009). Natural vinegar reportedly provides only variable control of weeds (Dayan et al., 2009). "Horticultural vinegar" (containing up to 25% acetic acid) provides satisfactory control of small weeds, but it is not approved for weed management in organic food production and the cost of using it for this purpose is high (Dayan and Duke, 2010). Acetic acid concentrations of 11% or greater can burn the skin and cause serious eye injury, including blindness (Webber and Shrefler, 2006). Occupational exposure limits for acetic acid are 10 ppm in air as reported by the Occupational and Safety Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH, 2010).

  Field research conducted by the USDA Agricultural Research Service found that acetic acid was less effective at controlling grasses than broadleaf weeds and that 20% acetic acid was more effective than 5% acetic acid (Webber and Shrefler, 2006; Webber and Shrefler, 2007). Similar results were found in other greenhouse and field experiments (Abouziena et al., 2009; University of Delaware, 2008; The Pennsylvania State University, 2008).

  No vinegar products are on the OMRI Products List specifically for Crop Pest, Weed, and Disease Control (OMRI, 2011). Several herbicides with the active ingredient acetic acid are currently registered with EPA (NPIRS, 2011). EcoSharp Weed and Grass Killer (25% acetic acid) and EcoSharp Weed and Grass Killer Ready to Use (6.25% acetic acid) are both EPA registered, but the manufacturer's U.S. website merely states "Coming soon" (Ecoval Corp., 2011). The label information provided by EPA states that EcoSharp Weed and Grass Killer is for non-food uses only. Weed Works Weed and Grass Killer (Weed Works, Inc.) contains 20% acetic acid and is registered with EPA, however this product could not be found through an internet search. Two other acetic acid herbicidal products are registered with the EPA but have product labels that do not list food crop use. These are Fleishmann's Vinegar Weed Control (20% acetic acid) (Fleischmann's Vinegar Co., Inc.) and Grotek Elimaweed Weed and Grass Killer (7.15% acetic acid) (Greenstar Plant Products, Inc.).

- **Citric Acid and mixtures containing citric acid:** Products containing nonsynthetic citric acid can be used as pesticides if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011).

Greenhouse experiments conducted by Abouziena et al. (2009) found that, in general, products containing citric acid (10%) or citric acid (5% or 10%) plus garlic (0.2%) were effective at controlling many types of broadleaf weeds, but not effective at controlling most of the narrow-leaf weeds tested. For most of the broadleaf weeds tested, citric acid herbicides provided better control at early application (3 to 5 cm for weeds, 4 to 7 cm for grasses) as opposed to late application (6 to 10 cm for weeds, 8 to 12 cm for grasses).

Three products with citric acid as an active ingredient were found listed by OMRI for Crop Pest, Weed, and Disease Control (OMRI, 2011). These include Summerset AllDown® Concentrate Non-Selective Broadleaf and Grass Herbicide (KPT, LLC, dba Summerset Products). Summerset Alldown® Concentrate (23% acetic acid, 14% citric acid) and Summerset Alldown® RTU (8% acetic acid, 5% citric acid, 0.2% garlic) are both registered with EPA and are available to purchase through the distributor's website (BioLynceus Biological Solutions, 2011). Burnout II Concentrate (30% citric acid, 18% clove oil) and Burnout II Ready to Use (11% citric acid, 6% clove oil) are also listed by OMRI (2011) and are available to purchase through the manufacturer's website (St. Gabriel Organics, 2009). No other citric acid products were found listed by OMRI specifically for Crop Pest, Weed, and Disease Control. There may be other citric acid products available that are not included on the OMRI Products List and are exempt from EPA registration per the FIFRA 25(b) exemption (EPA, 2011).

- **Natural Clove Oil:** Products containing nonsynthetic clove oil can be used as pesticides if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011). Clove oil, like other essential oil herbicides, often requires the use of a surfactant to help spread the material (Dayan et al., 2009). Clove oil is a non-selective, contact herbicide. Products containing clove oil can control most small weeds, but the cost of using clove oil is often prohibitive (Dayan et al., 2009; Dayan and Duke, 2010).

  Greenhouse and field experiments conducted with products containing clove oil showed that it provided poor to moderate control of the majority of weeds tested (Abouziena et al., 2009; Webber and Shrefler, 2009; University of Delaware, 2008; The Pennsylvania State University, 2008; Smith, 2007). Boyd and Brennan (2006) demonstrated that high concentrations of clove oil were effective at controlling some broadleaf weeds.

  Three products with clove oil as an active ingredient were found on the OMRI Products List, classified for Crop Pest, Weed, and Disease Control (OMRI, 2011). Weed Zap® (45% clove oil, 45% cinnamon oil; JH Biotech, Inc.) is available to purchase through a variety of vendors as indicated by an internet search. Matran® EC (50% clove oil) is listed by OMRI, but the company's website no longer contains this product (EcoSMART Technologies, Inc., 2011). Matratec® (50% clove oil; Brandt Consolidated, Inc.) is listed by OMRI and is available to purchase from Arbico Organics (Arbico Organics, 2011). There may be other clove oil products available that are not included on the OMRI Products List and are exempt from EPA registration per the FIFRA 25(b) exemption (EPA, 2011).

- **Natural Thyme Oil:** This essential oil was suggested by the NOSB Crops Committee as a wholly natural substitute to ammonium nonanoate (NOSB Committee Recommendation, 2008); however, no currently marketed herbicide products containing natural thyme oil have been identified. There may be thyme oil products available that are not included on the OMRI Products List and are exempt from EPA registration per the FIFRA 25(b) exemption (EPA, 2011).

  Essential oil of red thyme was tested in a greenhouse experiment to determine its effect on three weeds: Johnsongrass, common lambsquarters, and common ragweed (Tworkoski, 2002). A 1% concentration of red thyme oil injured the weeds, and most weeds were killed 7 days after treatment with a 5 or 10% concentration (Tworkoski, 2002).

- **Natural Lemongrass Oil:** Products containing nonsynthetic lemongrass oil can be used as pesticides if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011). Lemongrass oil, like other essential oil herbicides, often requires the use of a surfactant to help spread the material (Dayan et al., 2009). Products containing 50% lemongrass oil are diluted to 7–15% before being applied to plants (Dayan et al., 2009). Lemongrass oil is a non-selective, contact herbicide that only affects the aerial portions of plants (Dayan et al., 2009).

  Field experiments with a product containing lemongrass oil (Greenmatch® EX) demonstrated that it provided poor to moderate control with the majority of weeds tested (The Pennsylvania State University, 2008).

  One product with lemongrass oil as an active ingredient was identified on the OMRI Products List, classified for Crop Pest, Weed, and Disease Control (OMRI, 2011). Greenmatch® EX (50% lemongrass oil) is available to purchase through the manufacturer's website (Marrone Bio Innovations, Inc., 2011). There may be other lemongrass oil products available that are not included on the OMRI Products List and are exempt from EPA registration per the FIFRA 25(b) exemption (EPA, 2011).

- **Limonene (citrus oil):** Products containing nonsynthetic limonene (citrus oil) can be used as pesticides if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011). Limonene, like other essential oil herbicides, often requires the use of a surfactant to help spread the material (Dayan et al., 2009). It is a non-selective, contact herbicide (Dayan et al., 2009).

  In a field experiment, a product containing d-limonene (Nature's Avenger) provided good to excellent control of some weeds when measured 4 days after treatment, but this dropped to only moderate control at 8 and 14 days after treatment (Smith, 2007).

  Five products with d-limonene as an active ingredient were identified on the OMRI Products List for Crop Pest, Weed, and Disease Control (OMRI, 2011). Greenmatch® (55% d-limonene) is available for purchase through the manufacturer's website (Marrone Bio Innovations, Inc., 2011). Avenger® Ready to Use Weed Killer (17.5% d-limonene) and Avenger® Weed Killer Concentrate (70% d-limonene) are available to purchase through the manufacturer's website (Cutting Edge Formulations, Inc., 2010). Worry Free® Weed and Grass Killer Ready to Use (17.5% d-limonene) and Worry Free® Weed and Grass Killer Concentrate (70% d-limonene) (Lilly Miller Brands) are available to purchase through a variety of vendors as indicated by an internet search.

- **Corn Gluten Meal:** Products containing nonsynthetic corn gluten can be used as pesticides if the requirements of 7 CFR 205.206(e) are met (OMRI, 2011). Corn gluten meal is obtained as a byproduct of the corn milling process and is used as a fertilizer and pre-emergence herbicide (Dayan et al., 2009). It has no effect on existing weeds, but has been shown to affect the germination and development of emerging broadleaf weeds (Dayan et al., 2009). In order to be effective, it should be applied just prior to weed seed germination (Abouziena et al., 2009). Grasses and other weeds are not as sensitive to corn gluten meal as broadleaf weeds and require large amounts for control. The cost of using such high amounts is prohibitive for many farmers (Dayan and Duke, 2010).

  In a recent greenhouse experiment, corn gluten meal provided good control of a variety of weeds when applied at a rate of 4 tons per hectare (Abouziena et al., 2009). It provided better control of broadleaf weeds than narrowleaf weeds, especially in sandy soil (Abouziena et al., 2009).

  One product with corn gluten meal as an active ingredient, Bio-Herb, is on the OMRI Products List for Crop Pest, Weed, and Disease Control (OMRI, 2011). Bio-Herb is available to purchase through the manufacturer's website (Biofix Holding, Inc., 2011). WeedBan is another product containing corn gluten meal and a dealer for purchase can be found through the manufacturer's website (Fertrell, 2011). There may be other corn gluten meal products available that are not included on the OMRI Products List and are exempt from EPA registration per the FIFRA 25(b) exemption (EPA, 2011).

Allowed Synthetic Substances:
No synthetic herbicides are included on the National List permitted for use in food crop production. The following synthetic substances are included on the National List permitted for use as weed barriers in food crop production:

- **Mulches**
    - Newspaper or other recycled paper, without glossy or colored inks
    - Plastic mulch and covers (petroleum-based other than polyvinyl chloride)

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

Most of an organic farms' weed control strategy involves preventative cultural practices and physical controls such as cultivation, mulching and flaming (Shonbeck, 2010a). Preventative cultural practices include crop rotations, cover crops, and intercropping. Sullivan (2003) and Gunderson (2010) provide reviews of cultural weed management practices, many of which can be used in the absence of herbicides. Crop rotations act to limit the buildup of weed populations because weeds tend to prosper in crops that have similar growth requirements as the weeds (Sullivan, 2003). Effective rotations alternate between cool and warm season crops to prevent the weeds associated with each type of crops to become well established (Gunderson, 2010). Certain cover crops can be used to suppress weed growth. This is especially true when the cover crop has allelopathic properties. Allelopathy refers to a plant's ability to chemically inhibit the growth of other plants (Sullivan, 2003). Using cover crops to suppress weed growth works best when the allelopathic residues are allowed to remain on the soil surface rather than be incorporated into the soil through tillage (Gunderson, 2010). Typical cover crops may be rye, wheat, sorghum, sunflowers, field peas, and hairy vetch (Gunderson, 2010). Intercropping, or the growing of two or more crops together, is another effective weed management tool. Other crops can be used to smother weeds by growing faster and out-competing them (Sullivan, 2003).

The "Crop pest, weed, and disease management practice standard" in the NOP rule states that weed problems may be controlled through:

1. Mulching with fully biodegradable materials;
2. Mowing;
3. Livestock grazing;
4. Hand weeding and mechanical cultivation;
5. Flame, heat, or electrical means; or
6. Plastic or other synthetic mulches: *Provided* that, they are removed from the field at the end of the growing or harvest season. (7 CFR 205.206(c)(1–6)

Organic and biodegradeable mulches that can be used to control weeds include hay, straw, tree leaves, and wood shavings (Shonbeck, 2010b). These mulches can prevent light-responsive weed seeds from sprouting, hinder the growth of weed seedlings, and provide shelter for weed seed consumers (Shonbeck, 2010b). Organic mulches also provide many other benefits to crops such as conserving soil moisture and releasing nutrients. Organic mulches are less effective at controlling grass weeds than broadleaf weeds and do not prevent the emergence of perennial weeds (Shonbeck, 2010b). The use of a paper mulch (such as newspaper or recycled paper) under an organic mulch can enhance weed control compared to the use of organic mulch alone (Shonbeck, 2010b). The application of organic mulches may be too labor-intensive for large crops, however several alternative methods of using mulch to control weeds with these crops have been developed. These include the use of bale choppers to mechanically apply hay or straw between crop rows, the use of high biomass cover crops to produce *in situ* mulch, and the use of living mulches or low growing cover corps for crops such as tree fruits and grapes (Shonbeck, 2010b). In the production of *in situ* mulch, farmers may use rollers, roll-crimpers, flail mowers, and/or undercutters to convert mature cover crops to finely chopped mulch or coarsely chopped mulch placed parallel to future crop rows (Shonbeck, 2010b).

Mowing to remove weeds in pastures, field margins, and even in crop fields can be accomplished using rotary (bush-hog), sicklebar, or flail mowers (Schonbeck, 2010b). Even though mowing only removes the top growth of weeds, it can still significantly impact the growth and reproduction of annual and perennial weeds if done at the rights times (Schonbeck, 2010b). Weed management of vegetable crops may include mowing between the rows, over the top of crops, and post-harvest mowing (Schobeck, 2010b). When weed removal through cultivation is not desirable due to the developmental stage of a crop, mowing between vegetable rows may be sufficient to prevent crop yield reductions caused by weeds as well as to reduce weed seed production (Schonbeck, 2010b). Mowing above a crop canopy can help eliminate shading and seed set of taller weeds, and mowing after crop harvest can interrupt weed seed production without disrupting the soil habitat of helpful insects such as ground beetles (Shonbeck, 2010b).

Livestock grazing may be another part of an effective weed management strategy. Rotational grazing practices may be used when a crop production field becomes too weedy. Rotating a field to livestock pasture for a few years may help to reduce the perennial weed pressure when the field is later returned to crop production (Shonbeck, 2010a). Grazing livestock may be also used to reduce weed growth and seed production immediately after a harvest or to clean up a weed-infested field for future crop use (Shonbeck, 2010a). Multispecies grazing helps to reduce the number of weed species because different grazing species (e.g. goats, sheep, and cattle) prefer different plants (Shonbeck, 2010a). Running hogs along with grazing livestock will help control perennial weeds because they root out vegetation below the surface such as roots, rhizomes, and tubers (Shonbeck, 2010a). Running poultry can be used to help reduce weeds and surface weed seeds either before or after a crop (Shonbeck, 2010a). Weeder geese are sometimes used to control small grassy weeds in established vegetable or row crops, orchards, and vineyards (Shonbeck, 2010a). A few limitations of livestock grazing for weed control are that it doesn't work well for unpalatable species and the presence of large amounts of toxic weeds can harm the livestock (Shonbeck, 2010a). Furthermore, the manure of grazing livestock can spread the undigestable weed seeds from field to field so it is best to graze the livestock before the weeds set seed (Shonbeck, 2010a). Finally, food safety must be kept in mind in regards to animal droppings and manure being present in fields with food crops.

Cultivation refers to physical soil disturbance done mainly for the control of weeds (Shonbeck, 2010b). A wide range of tools are available for large scale cultivation in field crops. Different implements are used depending on the specific crop, planting pattern, stage of crop and weed development, soil conditions, and surface residue (Shonbeck, 2010b). The implements are mounted on tool bars are pulled through the fields. Full-field cultivation can be accomplished with the rotary hoe or a number of weeding harrows. Shovels, sweeps, rolling cultivators, rotary tilling cultivarors/multivators, and horizontal disk cultivators are used for interrow cultivation. Near-row cultivation can be accomplished with disk hillers, spyders, brush weeders, basket weeders, tosion weeders, spring hoes and ground-driven spinners, and finger weeders. High precision is needed during within-row and near-row cultivation to protect crops from damage. Electronic guidance systems have been developed to help prevent damage to crops during cultivation (Shonbeck, 2010b). One limitation of cultivation is that is becomes less effective as weed density increases (Shonbeck, 2010b).

Pre-plant, pre-emergent, and post-emergent flame weeding are practices commonly used to control weeds (Gunderson, 2010; Sullivan, 2003). Backpack or tractor-mounted propane-fueled flame weeders can be used just before or after planting a crop, prior to crop emergence to control small weeds, or between crop rows with the use of protective shields to prevent heat damage to the crop (Shonbeck, 2010b). Flame weeding works best on small weeds (up to two inches tall) (Shonbeck, 2010b). When weeds are briefly exposed to intense heat, it functions to disrupt the cell membranes and dehydrate the plant causing death in a few days (Shonbeck, 2010b). Safer forms of controlling weeds with heat included the infrared heater and hot water and steam weeders, which require large amounts of water to be hauled into the field (Shonbeck, 2010b).

The use of plastic mulches, such as black plastic film may effectively block the emergence of most weeds, however these can interfere with water absorption into the soil and weeds may still emerge through the holes used for planting (Shonbeck, 2010b). Furthermore, non-biodegradeable mulches must be removed and disposed of at the end of the season which is a labor-intensive process (Shonbeck, 2010b). Clear plastic film is effective at killing emerging weeds, and even provides other benefits such as killing crop pathogens in the soil and insect pests if enough sunlight is present to sufficiently elevate the soil temperature. However, without sufficient sunlight the soil temperature beneath clear plastic films may actually cause increased weed growth (Shonbeck, 2010b).

Biological control agents not already mentioned, such as weed seed consumers, soil microorganisms, and insects, can also be utilized in the control of weeds.

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