Pelargonic Acid

Crops

Identification of Petitioned Substance

Chemical Names:
n-nonanoic acid (IUPAC)
pelargonic acid

Other Names:
1-nonanoic acid
1-octanecarboxylic acid
n-nonylic acid
nonanoic acid
n-nonoic acid
octane-1-carboxylic acid
pelargic acid
pelargon

Trade Names:
Cirrasol 185a
Emery 1202
Emery's L-114
Emfac 1202
Hexacid C-9
Scythe

CAS Number:
112-05-0

Other Codes:
X1007181-9 (ACX number)
217500 (US EPA PC code)
RA6650000 (RTECS code)

Characterization of Petitioned Substance

Composition of the Substance:
Pelargonic acid has the chemical formula $CH_3(CH_2)_7COOH$ and its structure is presented in Figure 1. Because it contains nine carbon atoms, it is also called nonanoic acid—including for regulatory uses (PAN 2006). Pelargonic acid is the first example of the occurrence of an odd-numbered carbon fatty acid[1] found in natural substances, and its name is derived from *Pelargonium roseum* of the geranium plant family (Cyberlipid 2006). It is found in almost all species of animals and plants, including many common foods (EPA 2006). It is chemically manufactured for use as an herbicide, fungicide, and sanitizer (PAN 2006) and is a high production volume chemical (i.e., annual production and/or importation volumes above one million pounds in the United States).

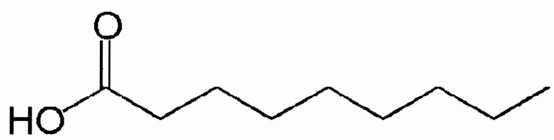

Figure 1. Chemical Structure of Pelargonic Acid

Properties of the Substance:
Pelargonic acid and related C_6-C_{12} fatty acids[2], hereafter referred to as pelargonic acid, is a colorless to slightly yellow oily liquid with a slight fatty (unpleasant) odor (Chemfinder 2006, HSDB 2003). It is stable under normal temperatures and pressures and though insoluble (but emulsifiable[3]) in water, it is soluble in ether, alcohol, and organic solvents (HSDB 2003). When heated to decomposition, pelargonic acid emits irritating and toxic fumes and carbon monoxide and dioxide gases.

Specific Usesof the Substance: Pelargonic acid is a fatty acid type herbicide (PAN 2006), and is an example of herbicides often referred to as "herbicidal soaps." (Neal 1998, Schalau 2003). The petitioner seeks the review and inclusion of pelargonic acid (and related C_6-C_{12} fatty acids) on the National List for use as an

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[1] Fatty acids are naturally occurring carboxylic acids containing the functional group COOH and are important components of lipids, especially fats and oils (Reusch 2006).
[2] Because the commercial manufacturing process for pelargonic acid uses natural sources of a parent compound, it typically contains several related C_6-C_{12} fatty acids that cannot be totally separated from the parent compound.
[3] An emulsion is a mixture of two substances that normally do not mix.

herbicide (weed management) with no restrictions in organic crop production. Although the petition primarily refers to pelargonic acid in the commercial herbicide Scythe—and which contains 57 percent pelargonic acid (and typically three percent of related C_6-C_{12} fatty acids; see Evaluation Question #1 for further information)—the petitioner is specifically requesting that pelargonic acid technical (98+percent; Analytyka 2006) be included on the National List.

Pelargonic acid has two distinct EPA-approved herbicidal uses, weed killer and blossom thinner (EPA 2006). Its use as an active ingredient in herbicides is exempt from the establishment of tolerances under 40 CFR 180.1159(b) on all plant food commodities provided that: (1) applications are not made directly to the food commodity except when used as a harvest aid or desiccant to: any root and tuber vegetable, bulb vegetable or cotton; and (2) when pelargonic acid is used as a harvest aid or desiccant, applications must be made no later than 24 hours prior to harvest. An exemption from the requirement of a tolerance has also been established for residues of pelargonic acid in or on all raw agricultural commodities and in processed commodities, when such residues result from the use of pelargonic acid as a sanitizing agent or as a blossom thinner under 21 CFR 180.1159(a) and (b), respectively. It is allowed for use in or on all foods when applied as a component of a food contact surface sanitizing solution in food handling establishments (EPA 2006). Pelargonic acid is also included on the current EPA List 3: Inerts of Unknown Toxicity (EPA 2004a).

In addition to its herbicidal uses, pelargonic acid is manufactured for organic synthesis of various lacquers, plastics and plasticizers, lubricants, and production of hydrotropic salts, and for use in the development and production of pharmaceuticals, synthetic flavors, and odors (HSDB 2003). The Household Products Database (HPD) (2004) lists only one household product (an herbicide) that includes pelargonic acid.

Approved Legal Uses of the Substance:

The U.S. Food and Drug Administration (FDA) has approved nonanoic (pelargonic) acid as a food additive for direct addition to food for human consumption as a synthetic flavoring substance and adjuvant provided that (1) the quantity added to food does not exceed the amount reasonably required to accomplish its intended physical, nutritive, or other technical effect in food, and (2) when intended for use in or on food it is of appropriate food grade and is prepared and handled as a food ingredient (EPA 2006, HSDB 2003). Pelargonic acid is also used as an adjuvant, production aid, and sanitizer for contact use with food. FDA allows its use as an ingredient in solutions used commercially to peel fruits and vegetables under 21 CFR 173.315. Pelargonic acid is included as one of more than 3,000 total substances that together comprise an inventory often referred to as "Everything Added to Food in the United States (EAFUS)" determined by the U.S. Food and Drug Administration (FDA) Center for Food Safety and Applied Nutrition (CFSAN). The list of substances are ingredients that may be added directly to food which FDA has either approved as food additives or listed or affirmed as "Generally Recognized As Safe" (GRAS) substances (FDA 2006).

Action of the Substance:

Pelargonic acid is a post-emergence, contact (i.e., kills only the green tissues that are contacted by the spray) herbicide that disrupts cell membranes. This disruption results in cell leakage and death of all contacted tissue, although the precise mode of action remains unclear (EPA 1997, MSUCARES 2006, Neal 1998, Ohioline 2006). However, a recent article by Lederer et al. (2004) reported that the herbicidal activity of pelargonic acid is due first to membrane leakage and second to peroxidation driven by radicals. This leads to a sudden decrease in intracellular pH, declining cellular function, desiccation, and ultimately cellular death. Because pelargonic acid only affects those plant parts that make contact with a spray solution, it provides no residual weed control and as such, repeat treatments may be necessary for ongoing vegetation control.

Status

International

Pelargonic acid is not specifically listed for the petitioned use or other uses in the following international organic standards:

- Canadian General Standards Board
- CODEX Alimentarius Commission
- European Economic Community (EEC) Council Regulation 2092/91
- International Federation of Organic Agriculture Movements
- Japan Agricultural Standard for Organic Production

A summary assessment of the use of nonanoic (pelargonic) acid as a flavoring agent by the joint FAO/WHO Expert Committee on Food Additives (JECFA 1997) found "No safety concern at current levels of intake when used as a flavouring agent." No CODEX maximum residue levels have been established for the use of pelargonic acid (EPA 2003). The British Columbia (Canadian) Environmental Protection Division's Integrated Pest Management Manual for Home and Garden Pests in BC (Adams and Gilkeson 2001) and Integrated Pest Management Manual for Landscape Pests in BC (Gilkeson and Adams 2000) both include fatty acids as a "preferred herbicide" for weed control.

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

Evaluation Question #1: Is the petitioned substance formulated or manufactured by a chemical process? (From 7 U.S.C. § 6502 (21))

Despite being a naturally occurring substance, commercial quantities of pelargonic acid are manufactured by a chemical process. In the predominant manufacturing process, it is produced by ozonolysis of oleic acid ($C_{18}H_{34}O_2$) into pelargonic acid and azelaic acid ($C_9H_{16}O_4$) (HSDB 2003). Ozone for the production process is produced by an electrical discharge in air or oxygen. The oleic acid feedstock is a monounsaturated fatty acid produced by high temperature and pressure hydrolysis of animal and vegetable fats and oils (e.g., beef tallow). Both acids produced by the process are recovered and used in a variety of applications. Azelaic acid, which is a naturally occurring bicarboxylic acid, is used commercially for its antimicrobial properties, and has several industrial applications, including use as a polymer intermediate for the production of polyarnides, polyesters, and polyurethanes (Noureddini and Rempe 1996). The pelargonic acid is removed and purified by fractional distillation; however, because the commercial manufacturing process uses natural sources of oleic acid, it typically contains several related C_6-C_{12} fatty acids (up to 7 to 8 percent of total solution) that cannot be totally separated from the parent compound (Ghorganics 2006, Mycogen Corporation 1998). Although a process diagram for the production of pelargonic acid was not located during the preparation of this review, a diagram for the production of azelaic acid (and pelargonic acid) from oleic acid is available in Appendix A of the petition (Dow, 2005).

Other manufacturing methods include by oxidation of methylnonyl ketone, from heptyl iodide via malonic ester synthesis, or by oxidation of nonyl alcohol or nonyl aldehyde (HSDB 2003).

Evaluation Question #2: Is the petitioned substance formulated or manufactured by a process that chemically changes the substance extracted from naturally occurring plant, animal, or mineral sources? (From 7 U.S.C. § 6502 (21).)

Commercial pelargonic acid formulations are not manufactured using naturally occurring pelargonic acid. The commercial pelargonic acid is manufactured from oleic acid that is derived from naturally occurring fats or oils (see Evaluation Question #1).

Evaluation Question #3: Is the petitioned substance created by naturally occurring biological processes? (From 7 U.S.C. § 6502 (21).)

Although pelargonic acid is found naturally in almost all species of animals and plants, commercially utilizable quantities are not created by naturally occurring biological processes (see Evaluation Questions #1 and #2).

Evaluation Question #4: Is there environmental contamination during the petitioned substance's manufacture, use, misuse, or disposal? (From 7 U.S.C. § 6518 (m) (3).)

Specific information regarding pollutants emitted from pelargonic acid manufacturing was not found. In general, pelargonic acid may be released into water, soil, or air during the use of herbicidal or other products or in waste streams from its production and industrial use (see Evaluation Questions #5 and #10 below for further information).

The petitioned method of using pelargonic acid in organic crop production would involve direct spray application of a solution containing 3 to 10 percent pelargonic acid as a non-selective herbicide on perennial herbaceous plants and weed in proximity to crops. As noted previously, to be effective, contact herbicides such as pelargonic acid must come into direct contact with the plant to be eradicated. Given its rapid biodegradability, low mobility, and lack of toxicity and toxic byproducts (see Evaluation Question #5 below), pelargonic acid is not expected to contaminate the environment when applied as an herbicide if petitioned application levels are not exceeded.

Evaluation Question #5: Is the petitioned substance harmful to the environment? (From 7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i).)

As noted in Evaluation Question #4, pelargonic acid may be released into the environment (air, soil, and water) during its manufacture or industrial/commercial use, including agricultural applications as a herbicide.

If released to the atmosphere, pelargonic acid is expected to exist solely as a vapor in the ambient atmosphere and be degraded by reaction with photochemically-produced hydroxyl radicals with an estimated half-life of 1.6 days (HSDB 2003).

When released to soil, pelargonic acid decomposes rapidly and does not accumulate or persist in the environment (HSDB 2003, EPA 2006). It is expected to have low mobility and bind strongly to the upper portion of the soil (Mozel and Nijholt undated; Mozel et al. undated); volatilization from dry soil surfaces is not expected to occur based on its measured vapor pressure (HSDB 2003). However, volatilization from wet soil surfaces may be an important source of atmospheric pelargonic acid.

If released into water, pelargonic acid is expected to adsorb to suspended solids and sediment in the water column (being largely insoluble in water) with limited volatilization. The potential for its bioconcentration in aquatic organisms is high based on an estimated bioconcentration factor of 230. Limited biodegradation data, however, suggest that pelargonic acid may biodegrade rapidly in water (HSDB 2003). The EPA Fact Sheet for pelargonic acid (EPA 2006) states that "Pelargonic acid is not expected to have adverse effects on non-target organisms or the environment." However, several material safety data sheets (MSDSs) for pelargonic acid advise users to avoid runoff into storm sewers and ditches which lead to waterways and to not discharge into drains, surface waters (including wetlands), or groundwater (Analytyka 2006, Celanese 2002, Mycogen Corporation 1998). In this regard, the overall acute aquatic ecotoxicity of pelargonic acid has been characterized as not acutely toxic but some slightly toxic effects have been reported in fish, amphibians, and zooplankton (PAN 2006).

If applied in accordance to the petitioned use in organic crop production (see Evaluation Question #4), it is unlikely that pelargonic acid will cause harmful environmental effects, either present in the applied spray or arising from its degradation.

Evaluation Question #6: Is there potential for the petitioned substance to cause detrimental chemical interaction with other substances used in organic crop or livestock production? (From 7 U.S.C. § 6518 (m) (1).)

No information was available to assess whether spray-applied pelargonic acid or its byproducts can react detrimentally with other substances used in organic crop or livestock production. In fact, pelargonic acid is often mixed with other EPA approved herbicides to improve overall weed control (Ohioline 2006). However, several MSDSs for pelargonic acid advise against mixing it with strong bases or oxidizing agents (Analytyka 2006, Celanese 2002, Mycogen Corporation 1998).

Evaluation Question #7: Are there adverse biological or chemical interactions in the agro-ecosystem by using the petitioned substance? (From 7 U.S.C. § 6518 (m) (5).)

Because pelargonic acid is an herbicide, its improper use or disposal in the agro-ecosystem could result in adverse health and/or environmental effects, especially to non-target crops (EPA 2006; see Evaluation Question #8 below). However, if pelargonic acid is properly spray-applied to only weeds during organic crop production, it is unlikely to reach the greater agro-ecosystem in significant amounts and thus is unlikely result in adverse environmental effects—including to endangered species or reductions in genetic, species, or ecosystem diversity

Evaluation Question #8: Are there detrimental physiological effects on soil organisms, crops, or livestock by using the petitioned substance? (From 7 U.S.C. § 6518 (m) (5).)

No information was available as to whether use of pelargonic acid as an herbicide in organic crop production could cause unacceptable changes in soil temperature, water availability, pH levels, nutrient availability, or salt concentration. However, improper and/or excessive use of pelargonic acid as an herbicide (or as the active ingredient in an herbicide) could adversely affect the survival and function of soil organisms, including earthworms, bacteria, algae, and protozoa. Pelargonic misuse or spills could also result in the damage and even death of nearby organic crops given its non-selective herbicidal properties (EPA 2006).

Evaluation Question #9: Is there a toxic or other adverse action of the petitioned substance or its breakdown products? (From 7 U.S.C. § 6518 (m) (2).)

Following a recent EPA (2003) review (see also CDPR 2005 and HSDB 2003) of the acute toxicology of pelargonic acid in support of an exemption for the establishment of tolerances for its use in sanitizers, EPA placed technical pelargonic acid in the following pesticide toxicity categories[4]: primary eye irritation (Toxicity Category II), acute oral toxicity (Toxicity Category IV), and acute dermal and inhalation toxicity (Toxicity Category III). Sensitization test results demonstrated that pelargonic acid cannot be considered a dermal sensitizer.

A review of subchronic and chronic toxicity of technical grade pelargonic acid was also provided by EPA (2003). In a 14-day oral toxicity study in rats, no systemic toxicity was observed in either sex even at the highest dose tested of 20,000 parts per million (ppm) (~2,000 milligrams/kilogram/day (mg/kg/day)). Furthermore, pelargonic acid showed no adverse effects on survival, clinical signs, body weight gain, food consumption, hematology, clinical chemistry, or gross pathology. EPA determined that because no toxic effects were observed at a very high dose level of approximately 2,000 mg/kg, a longer (90-day) oral study was not necessary. EPA also reviewed a 28-day dermal toxicity study conducted on male and female

[4] See http://www.epa.gov/pesticides/health/tox_categories.htm for further information on EPA pesticide toxicity categories I (highest) to IV (lowest) and related pesticide label statements.

rabbits that were dermally treated with pelargonic acid in mineral oil. In all, 10 applications were made (5 per week) at a dose level of 500 mg/kg/day and a 2-week recovery period was allowed for selected rabbits. During the first and second week of treatment, slight body weight loss and decreased food consumption were observed. All rabbits dermally treated with pelargonic acid by day 14 showed signs of severe erythema, moderate edema, and other adverse dermal reactions. However, by Day 29, all dermal reactions had reversed. Thus, at the treatment level of 500 mg/kg/day of pelargonic acid, significant dermal signs of toxicity were observed but there was no significant systemic reaction. Because of its pronounced dermal toxicity (especially to eyes), pelargonic acid is often used as a positive control in many dermal toxicity assays (Wahlberg and Lindberg 2003).

A supplemental study on chronic (80-week) toxicity/carcinogenicity in mice was also reviewed by EPA (2003). A dose of 50 mg/kg/day of pelargonic acid was dermally applied to each mouse twice/day throughout the study duration. Histopathology showed no non-neoplastic or neoplastic lesions on skin and internal organs of mice. EPA concluded that this study, although not conducted entirely according to established guidelines, adequately assesses the chronic toxicity and the carcinogenic potential of pelargonic acid via the dermal route.

EPA (2003) reviewed a developmental toxicity study on pregnant rats that were treated with pelargonic acid in corn oil at a dose of 1,500 mg/kg on gestation days 6 through 15. Maternal body weight was not significantly affected during the treatment and only 1 out of 22 animals showed signs of clinical toxicity. No significant histopathology effects were observed in the maternal rats and there was no significant effect on cesarean section observations. However, four fetuses in one litter showed a higher incidence of cleft palate compared to the control mean. For maternal toxicity, EPA determined the no observed adverse effect level (NOAEL) to be greater than 1,500 mg/kg/day. Because fetal effects were observed at the only dose tested (1,500 mg/kg/day), the NOAEL for developmental toxicity was not determined (EPA 2003).

Regarding the potential genetic toxicology of pelargonic acid, Ames Test results (Salmonella/reverse mutation assay) have demonstrated it to be non-mutgenic. An in vivo cytogenetics study using micronucleus assay also yielded negative results. In a mouse lymphoma forward mutation study, pelargonic acid appears to induce a weak mutagenic response at or higher than 50 milligrams/milliliter (mg/mL) level. Because this was observed in the presence of increasing toxicity, it may be an indication of gross chromosomal changes or damage and not actual mutational changes (EPA 2003).

As described in Evaluation Question #5, the overall acute aquatic ecotoxicity of pelargonic acid has been characterized as not acutely toxic (PAN 2006). There are no completed or planned toxicology, carcinogenesis, reproductive, developmental, immunology, or genetic toxicology studies by the National Toxicology Program (NTP) of the National Institute of Environmental Health Sciences summary for pelargonic acid. There is also no data on whether pelargonic acid can act as an endocrine disruptor (PAN 2006). EPA (2006) has concluded that "No risks to humans or the environment are expected when pesticide products containing pelargonic acid are used according to the label directions."

<u>Evaluation Question #10:</u> Is there undesirable persistence or concentration of the petitioned substance or its breakdown products in the environment? (From 7 U.S.C. § 6518 (m) (2).)

As noted previously (see Evaluation Question #5), pelargonic acid decomposes rapidly in land and water so it does not accumulate or persist in the environment (HSDB 2003). When applied to soil—and where it naturally occurs—pelargonic acid degrades quickly (within two days), primarily through microbial degradation (Mozel and Nijholt undated; Mozel et al. undated).

<u>Evaluation Question #11:</u> Is there any harmful effect on human health by using the petitioned substance? (From 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).)

Occupational exposure to pelargonic acid may occur through dermal or inhalation contact at workplaces where nonanoic acid is produced or used. The general population may be exposed to pelargonic acid via inhalation of ambient air, ingestion of food and drinking water, and dermal contact with food and other products containing it. Because pelargonic acid occurs naturally in many plants, including food crops and other processed foods (e.g., hamburger beef, grapes, milk, cheese), most people are regularly exposed to small amounts of this fatty acid (EPA 2003, 2006, HSDB 2003). Furthermore, the EPA Fact Sheet (EPA 2003) for pelargonic acid states the following:

> The use of pelargonic acid as an herbicide...on food crops is not expected to increase human exposure or risk. Furthermore, tests indicate that ingesting or inhaling pelargonic acid in small amounts has no known toxic effects. Pelargonic acid is a skin and eye irritant, and product labels describe precautions that users should follow to prevent the products from getting in their eyes or on their skin.

Based on the preceding review of the toxicology of pelargonic acid (see Evaluation Question #9 above) and an assessment of potential occupational and non-occupational exposure of humans to this fatty acid, EPA (2003) concluded that "...pelargonic acid is unlikely to pose a risk under all reasonable exposure scenarios." Furthermore, fatty acids such as pelargonic acid are processed by known metabolic pathways within the human body and contribute to normal physiological function.

As noted previously, FDA has approved pelargonic (nonanoic) acid as a food additive (synthetic flavoring substance and adjuvant) and in solutions used commercially to peel fruits and vegetables (HSDB 2003). "These approvals indicate that FDA considers it safe for humans to eat food containing small amounts of pelargonic acid" (EPA 2006).

Evaluation Question #12: Is there a wholly natural product which could be substituted for the petitioned substance? (From 7 U.S.C. § 6517 (c) (1) (A) (ii).)

Vinegar (acetic acid) is considered to be a natural herbicide if applied in sufficient concentrations (5 to 20 percent) to weeds and is included on the EPA List 4A Minimal Risk Inerts (Sullivan 2003). Several other substances included on the List 4A Minimal Risk Inerts (e.g., citric acid, sodium chloride) and on the most recent list of "Active Ingredients Which May Be in Minimum Risk Pesticide Products" that are exempt to Section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (i.e., the 25(b) list; EPA 2004b), such as clove and thyme oil can also be considered wholly natural products with herbicidal properties.

Corn gluten meal is a natural byproduct of processing corn to make corn starch and corn syrup and has been shown to prevent sprouting seeds of weeds from developing normal roots; that is, acts a pre-emergent herbicide (Christians 2006, Cox 2005, Sullivan 2003). Although it does not directly kill the seedlings, it makes them susceptible to dehydration if the soil gets, or is allowed to dry.

Notably, the Pennsylvania Integrated Pest Management Program (PA IPM 2006) lists pelargonic acid along with corn gluten meal and vinegar (and herbicidal soaps) as a "less toxic product" for the control of weeds.

Evaluation Question #13: Are there other already allowed substances that could be substituted for the petitioned substance? (From 7 U.S.C. § 6518 (m) (6).)

NOP §205.601(b)(1) allows for use of soap-based herbicides "...for use in farmstead maintenance (roadways, ditches, right of ways, building perimeters) and ornamental crops" in organic crop production. Many commercially available soap-based herbicides are manufactured from fatty acids, but "While herbicidal soaps do not really fall into the category of 'natural,' they are acceptable to many people as a substitute for synthetic herbicides" (Christians 1999). NOP §205.601(b)(2) allows for use of two types of mulches as weed barriers (1) newspaper or other recycled paper, without glossy or colored inks; and (2) plastic mulch and covers (petroleum-based other than polyvinyl chloride).

Evaluation Question #14: Are there alternative practices that would make the use of the petitioned substance unnecessary? (From 7 U.S.C. § 6518 (m) (6).)

Sullivan (2003) provides a review of weed management practices, many of which can be used in the absence of herbicides—including pelargonic acid and herbicides containing it as an active ingredient for use in organic crop production. Crop rotations act to limit the buildup of weed populations as weeds tend to prosper in crops that have similar growth requirements as the weeds. Certain cereal "cover" crops (e.g., rye, wheat) can be used to suppress other plants that attempt to grow around them through a natural mechanism called allelopathy. This refers to the natural ability of a plant to chemically inhibit the growth of other surrounding plants; however, this effect can be significantly diminished or lost when the soil is disturbed (tilled). Other crops can be used to smother weeds by growing faster and out-competing them. All of these practices are allowed under NOP §205.203(b), which states that "The producer must manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials." Intercropping (i.e., growing two or more crops together, such as soybeans and green wheat) can also be used as an effective weed control strategy as growing different plant types together enhances weed control by increasing shade and increasing crop competition with weeds because of tighter crop spacing (Sullivan 2003). Appropriate soil- and crop-specific tillage and cultivation practices are the most traditional means of weed management in agriculture and NOP §205.203(a) requires that "The producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion."

Careful application of animal manure as a fertilizer, as currently allowed under NOP §205.203, to crop rows helps to ensure that crops, not weeds, get fertilized. Although use of manure from hoofed livestock (e.g., sheep, cattle) may contain weed seed that has passed intact through their digestive systems, use of composted manure (NOP §205.203(c)(1)) contains far fewer weed seeds than does raw manure because the heat generated during the composting process kills them (Sullivan 2003).

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