

Soap-Based Algicide/Demossers

Crops

Identification of Petitioned Substance

Chemical Names:	67701-09-1 (Potassium salts of fatty acids, C8-18)
Lauric acid, potassium salt	10124-65-9 (Potassium laurate)
Myristic acid, potassium salt	143-18-0 (Potassium oleate)
Oleic acid, potassium salt	63718-65-0 (Ammonium nonanoate)
Ricinoleic acid, potassium salt	
Nonanoic acid, ammonium salt	
Other Name:	Other Codes:
Potassium salts of fatty acids	Potassium salts of fatty acids, C8-18: 266-933-2 (EINECS), 079021 (EPA PC Code)
Ammonium salts of fatty acids	Ammonium salts of fatty acids, C8-C18: 031801 (EPA PC Code)
Trade Names:	
Axxe Broad Spectrum Herbicide	
BioSafe Weed Control RTU	
CAS Numbers:	

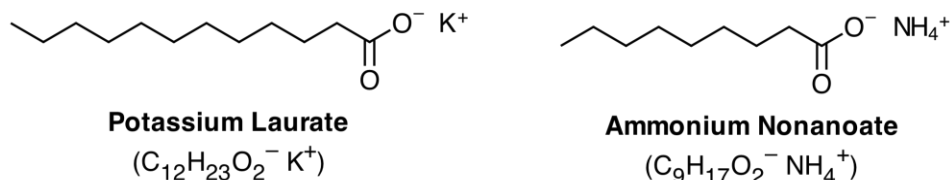
Summary of Petitioned Use

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 algicide/demossers, synthetic soaps salts are permitted for the control of algae and mosses in and around production areas, including walkways, greenhouse surfaces and irrigation systems. This technical evaluation report provides updated and targeted technical information to augment the 1996 Technical Advisory Panel Review on soap-based herbicides for the National Organic Standards Board's review of these algicidal substances under the sunset process.

Characterization of Petitioned Substance

Composition of the Substance:

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 (NH₄⁺) counterions. Potassium salts of fatty acids (C₁₂-C₁₈ saturated and C₁₈ unsaturated) include individual soap salts such as potassium laurate (C₁₂H₂₃O₂⁻ K⁺; Figure 1), potassium myristate (C₁₄H₂₇O₂⁻ K⁺), potassium oleate (C₁₈H₃₃O₂⁻ K⁺) and potassium ricinoleate (C₁₈H₃₃O₃⁻ 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 (C₉H₁₇O₂⁻ NH₄⁺), also known as the ammonium salt of pelargonic acid, is the most commonly encountered ammoniated fatty acid in commercially available soap-based herbicide products (OMRI, 2014). Commercially available soap-based algicides and demossers are typically formulated as mixtures of potassium or ammonium salts of fatty acids.



42

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

45 **Source or Origin of the Substance:**

46 A variety of preparatory methods are employed depending on the desired soap salt composition of a
47 particular algicide formulation. Potassium salts of fatty acids are produced through a process known as
48 saponification, whereby aqueous potassium hydroxide (KOH) is added to fatty acids commonly found in
49 animal fats and plant oils (NPIC, 2001; Nora, 2010). Alternatively, ammonium salts of fatty acids, such as
50 ammonium nonanoate, are produced through the room temperature reaction of aqueous ammonia (NH₃)
51 or ammonium hydroxide (NH₄OH) with fatty acids (Reiling, 1962; Dunn, 2010). See Evaluation Question
52 #2 for details regarding the synthesis of potassium and ammonium salts of fatty acids, as well as typical
53 sources of fatty acids used in these syntheses.

54 **Properties of the Substance:**

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

66 Nonanoic acid, a low molecular weight constituent fatty acid, is somewhat volatile (vapor pressure =
67 1.65×10⁻³ mm Hg), but is unlikely to volatilize since its dissociation constant (pK_a = 4.9) indicates the
68 substance will exist primarily in its water-soluble (ionized) form under environmental conditions (HSDB,
69 2008a; EFSA, 2013). Higher molecular weight fatty acids have larger ratios of nonpolar aliphatic regions to
70 the polar carboxylate region, thus making them less water-soluble than low molecular weight acids.
71 Although the vapor pressures of fatty acids generally decrease with increasing molecular weight, higher
72 molecular weight fatty acids have similar dissociation constants as nonanoic acid (e.g., pK_a = 5.3 for lauric
73 acid) and should thus behave similarly to nonanoic acid in the environment (HSDB, 2008b).

74 **Specific Uses of the Substance:**

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

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

95 The allowable use patterns for specific soap salt formulations are more restricted in organic agriculture.
96 According to 7 CFR 205.601(a)(7), soap salts may be used as algicides and demossers in organic crop
97 production. Unspecified soap salts are also allowed for use as insecticides, acaricides and for mite control
98 (7 CFR 205.601(e)(8)). In addition, soap salts are permitted as herbicides for farmstead maintenance around
99 roadways, ditches, right of ways and building perimeters, and for application to ornamental crops (7 CFR
100 205.601(b)(1)). Only ammonium salts of fatty acids may be used in organic crop production as large animal
101 repellents. Although not strictly stated in the final rule, it is generally assumed that soap salts used as
102 algicides, herbicides and insecticides consist of potassium or ammonium salts of fatty acids (US EPA, 2013).

103 **Approved Legal Uses of the Substance:**

104 Soap salt products are registered with US EPA as acaricides, algicides, herbicides, insecticides and animal
105 repellents. These substances are intended for residential, agricultural and commercial use. Label-mandated
106 application rates for products containing potassium and ammonium salts of fatty acids range from 205 and
107 104 lb/acre, respectively, on the high end to as low as one lb/acre or less for soap salt active ingredients
108 (US EPA, 2013). According to EPA regulations, C₁₂-C₁₈ fatty acids (saturated and unsaturated) potassium
109 salts and ammonium salts of C₈-C₁₈ saturated and C₈-C₁₂ unsaturated higher fatty acids are exempt from
110 the requirement of a tolerance for residues in or on all raw agricultural commodities (40 CFR 180.1068, 40
111 CFR 180.1284). In addition, 40 CFR 180.910 established a tolerance exemption for residues of ammonium
112 salts of fatty acids and fatty acid salts conforming to 21 CFR 172.863, including potassium salts of fatty
113 acids, when used as inert ingredients in pesticide formulations applied to crops during or after the growing
114 season (i.e., pre- or post-harvest).

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

122 **Action of the Substance:**

123 Most algicides and demossers are considered contact pesticides because they cause injury to only the cell
124 walls or filaments that are exposed to the dissolved algicidal substance with little to no intercellular
125 movement (Army Corps, 2012). Limited targeted information is available on soap-based algicides;
126 however, the herbicidal and algicidal modes of action for soap salts are presumably related. The following
127 paragraph summarizes the mode of action for soap-based herbicides against vascular plants.

128 According to US EPA, the general herbicidal mode of action for soap salts involves the disruption of
129 photosynthesis through destruction of cell membranes, thereby resulting in plant/algae death (US EPA,
130 1992; US EPA, 2013). Formation of the fatty acid salt – potassium, ammonium or sodium – provides water
131 solubility for the fatty acid(s) in the pesticide formulation (NPIC, 2001). The herbicidal mode of action for
132 soap salts is generally considered identical to that of the corresponding free fatty acids. For example,
133 nonanoic acid (C₉, saturated) applied to growing plants in sufficient quantities rapidly desiccates green
134 tissue by removing the waxy cuticle of the plant and disrupting the cell membrane, resulting in cell leakage
135 and tissue death. Fatty acids and soap salts – such as nonanoic acid and ammonium nonanoate – are not
136 translocated in treated plants and provide no residual weed control. These substances are only effective as
137 post-emergent herbicides, providing burndown of broadleaf weeds and most mosses (MMWD, 2010).

138 Combinations of the Substance:

139 Relevant pesticide formulations contain active ingredient mixtures consisting of soap salts and other
140 substances. Several soap-based herbicide products are co-formulated with the conventional herbicide,
141 glyphosate, and therefore would not be allowed for use in organic production. Other ready-to-use soap salt
142 insecticides are co-formulated with pyrethrins (0.01–0.24%), limonene (1%) and/or neem oil (0.9%). In
143 addition, some fungicidal, insecticidal and miticidal products contain a combination of fatty acid
144 potassium salts and elemental sulfur at 0.4%–6.5% in ready-to-use and concentrated formulations.
145 Naturally occurring pyrethrins, limonene and neem oil are allowed for use in organic crop production for
146 weed control. Aliphatic alcohols, including ethyl alcohol (2–18%) and methanol (1%), as well as propylene
147 glycol (37.8%) are listed as other known ingredients in a small number of soap salt products. Both ethyl
148 alcohol (CAS # 64-17-5) and propylene glycol (CAS # 57-55-6) are US EPA List 4 inert ingredients (US EPA,
149 2004), and are therefore allowed for use in organic crop production under 7 CFR 205.601(m)(1).

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

Status

158 Historic Use:

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

166 The NOSB recommended against the explicit use of ammonium salts of fatty acids as herbicides in organic
167 crop production in 2007 and 2008 (USDA, 2007; USDA, 2008). During both reviews, the NOSB voted to
168 reject the use of ammonium soap salts due to the availability of numerous alternative weed management
169 practices and incompatibility of the substance with the provisions of the Organic Foods Production Act
170 (OFPA) for general use on crops or cropland. However, these rulings are not directly relevant to the
171 current sunset review of soap salts used as algicides and demossers in operations producing organic crops.

172 Organic Foods Production Act, USDA Final Rule:

173 Synthetically produced soap-based algicides and herbicides are eligible for use in organic production due
174 to their listing in Section 2118 of the Organic Foods Production Act of 1990 (OFPA). Specifically, the OFPA
175 states that the National List may allow the use of substances that would otherwise be prohibited under
176 organic regulations (i.e., synthetics) if the substance contains an active ingredient in the following
177 categories: “copper and sulfur compounds; toxins derived from bacteria; pheromones, soaps, horticultural
178 oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and
179 production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and
180 equipment cleansers” (OFPA 2118(c)(B)(i)).

181 The National Organic Program (NOP) final rule currently permits the use of soaps for a variety of purposes
182 in organic crop production: Soap-based algicides/demossers (7 CFR §205.601(a)(7)), soap-based herbicides
183 (7 CFR §205.601(b)(a)), ammonium soaps as animal repellents (7 CFR §205.601(d)) and insecticidal soaps (7
184 CFR 205.601(e)(8)). As an approved algicide/demossers, synthetic soaps salts are permitted for the control
185 of algae and mosses in and around production areas, including walkways, greenhouse surfaces and
186 irrigation systems. The NOP final rule indicates that ammonium soaps are permitted as large animal

187 repellents but may not come into contact with soil or the edible portion of crops. Several OMRI-approved
188 herbicides/algicides are formulated with ammonium soaps, such as ammonium nonanoate (OMRI, 2014).

189 **International**

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

194 *Canadian General Standards Board*

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

204 *European Union*

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

213 *Codex Alimentarius Commission*

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

218 *Japanese Ministry of Agriculture, Forestry and Fisheries*

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

222 *International Federation of Organic Agriculture Movements*

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

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

231
232 **Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the**
233 **substance contain an active ingredient in any of the following categories: copper and sulfur**
234 **compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated**

276 Ammonium nonanoate is the most commonly used ammonium soap salt in commercially available
277 herbicide, algicide and insecticide products (US EPA, 2014). Synthetic sources of nonanoic acid can be
278 industrially prepared through the reaction with of unsaturated hydrocarbons (alkenes) with carbon
279 monoxide (CO) and hydrogen (H₂) in the presence of a transition-metal catalyst (i.e., hydroformylation,
280 also known as the “oxo process”), by oxidation or ozonation of oleic acid, by oxidation of methylnonyl
281 ketone, or from heptyl iodide using the malonic ester synthesis (HSDB, 2008). A petition submitted to the
282 NOSB by Falcon Lab, LLC indicates that blowing air through naturally derived oleic acid (sourced from
283 agriculturally-produced edible fats and oils) provides a 50/50 mixture of nonanoic acid and azelaic acid.
284 These components are subsequently separated by distillation. Once purified, the isolated nonanoic acid is
285 treated with an aqueous solution of ammonia (NH₃) and stirred at room temperature until full conversion
286 to ammonium nonanoate is achieved (Smiley & Beste, 2009).

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

289 According to USDA organic regulations, the NOP defines synthetic as “a substance that is formulated or
290 manufactured by a chemical process or by a process that chemically changes a substance extracted from
291 naturally occurring plant, animal, or mineral sources” (7 CFR 205.2). Although plant oils and animal fats
292 are naturally occurring organic materials, the fatty acid soap salts used in pesticide products are generated
293 through chemical reactions with concentrated aqueous solutions of alkali metal hydroxide (e.g., potassium
294 hydroxide) or ammonium hydroxide. Specifically, potassium and ammonium soap salts are formed via
295 two sequential processes: base-mediated hydrolysis of the triglyceride molecule to release three
296 equivalents of free fatty acids followed by formation of the corresponding potassium or ammonium soap
297 salts (Burns-Moguel, 2014; Kostka & McKay, 2002). Commercially available ammonium nonanoate is
298 formed through the reaction of aqueous ammonia (NH₃) with nonanoic acid (Smiley & Beste, 2009).
299 Nonanoic acid is a naturally occurring fatty acid; however, sources of nonanoic acid used in pesticide
300 products are most likely produced synthetically via oxidation and/or ozonation (HSDB, 2008). Based on
301 the available manufacturing information and NOP definitions, we conclude that potassium and
302 ammonium salts of fatty acids used as active ingredients in approved herbicide/algicide products are
303 produced using chemical processes and are therefore synthetic substances. The NOSB previously classified
304 these substances as synthetic; therefore, soaps are currently included in section 205.601, which only lists
305 *synthetic* substances allowed for use in organic crop production.

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

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

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

326 Soap salts and fatty acids are expected to adsorb to suspended solids and sediment when released to
327 bodies of water based on the reported K_{oc} values for representative fatty acids. In addition, the pK_a values

328 indicate that fatty acids will exist almost entirely in carboxylate (anionic) form at environmentally relevant
329 pH levels; therefore, volatilization from water surface is an unlikely fate process. Hydrolysis is unlikely for
330 fatty acids due to the lack of functional groups that are readily hydrolyzed under environmental
331 conditions. Indeed, hydrolysis of potassium salts of fatty acids did not occur over a period of 43 days in a
332 registrant-submitted study (US EPA, 2013). The bioconcentration factors (BCFs) for nonanoic acid (BCF = 3)
333 and oleic (BCF = 10) suggest the potential for accumulation in aquatic organisms is low. In contrast, the
334 BCF of 255 for lauric acid in zebrafish is indicative of bioaccumulation in aquatic organisms (Van Egmond,
335 1999). Fatty acids such as lauric acid are readily biotransformed to metabolites, including less polar
336 triglyceride molecules, which are natural components of animal diets (Van Egmond, 1999; US EPA, 2013).

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

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

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

355 US EPA has waived all generic mammalian toxicity data requirements for potassium and ammonium soap
356 salts due to the lack of effects at high doses in the available toxicity literature. Indeed, potassium salts of
357 fatty acids are generally recognized as safe (GRAS) by the US Food and Drug Administration (FDA).
358 Laboratory testing has demonstrated that potassium and ammonium soaps are practically non-toxic on an
359 acute oral exposure basis with doses lethal to 50% of test rats (LD₅₀ values) of greater than 5,000 mg/kg-
360 day (Toxicity Category V). Potassium and ammonium soap salts are broken down in the environment and
361 metabolized when ingested in small amounts. Chronic health effects are not anticipated following
362 exposure to soap salts by any commonly anticipated exposure routes. However, potassium and
363 ammonium soaps are severe eye irritants and mildly irritating to the skin. Further, soaps salts have caused
364 reproductive and mutagenic effects when fed to test animals at excessively high doses (US EPA, 2012; US
365 EPA, 1992), but are not reported to be carcinogenic by the International Agency for Research on Cancer
366 (IARC, 2014).

367 Soap salts are practically non-toxic (Toxicity Category V) to birds and honey bees on an acute exposure
368 basis. Potassium and ammonium soaps caused no mortality or sub-lethal effects at doses up to and
369 including 2,450 mg a.i./kg body weight (oral, gavage) and 5,620 mg a.i./kg diet (oral, dietary) in upland
370 game birds and waterfowl. Because birds act as surrogates for reptiles and terrestrial-phase amphibians, it
371 is generally assumed that potassium and ammonium soaps are practically non-toxic to reptiles and
372 terrestrial amphibians. The acute contact toxicity test in honey bees using potassium and ammonium soaps
373 provided a 48-hour LD₅₀ of greater than 100 µg a.i./bee (µg = microgram), suggesting that soap salts are
374 practically non-toxic to these beneficial insects. Saturating bees with soap solution, on the other hand,
375 would likely result in death. While the honey bee is relatively insensitive to insecticidal soaps, soft-bodied
376 insects such as aphids, whiteflies, and mealy bugs are more susceptible to the toxic effects of soaps (US
377 EPA, 2013). Accordingly, soaps are frequently used as contact insecticides to control many of these pests.

378 Studies submitted to US EPA for registration of potassium and ammonium salts of fatty acids indicate that
379 potassium salts are generally more toxic to aquatic organisms than their ammonium counterparts. Based

380 on data from the most sensitive species, potassium soap salts are moderately toxic to freshwater fish and
381 marine/estuarine invertebrates on an acute exposure basis. Concentrations lethal to 50% of test organisms
382 over four days of exposure (96-hour LC₅₀ values) for freshwater rainbow trout (*Onchorhynchus mykiss*) and
383 the marine/estuarine mysid shrip (*Americamysis bahia*) are 9.19 mg a.i./L (a.i. = active ingredient) and
384 1.2 mg a.i./L, respectively, placing potassium soap salts in the moderate toxicity category (US EPA, 2013).
385 Further, potassium soaps are highly toxic to freshwater invertebrates such as the freshwater water flea
386 (*Daphnia spp.*), with immobility observed in 50% of experimental water fleas exposed to 0.57 mg a.i./L over
387 a two-day period. In contrast, ammonium soaps are classified as slightly toxic to freshwater fish and both
388 freshwater and marine/estuarine invertebrates, and practically non-toxic to marine/estuarine fish on an
389 acute exposure basis.

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

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

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

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

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

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

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

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

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

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

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

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

476 **Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned**
477 **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)**
478 **(i)).**

479 Soaps salts essentially behave as the carboxylate anions of fatty acids when released to the environment. In
480 general, potassium and ammonium salts of fatty acids decompose rapidly and do not accumulate or persist
481 in the environment. Biodegradation in soil and water is expected to be the primary fate process for soaps,
482 with measured half-lives of less than one day for most fatty acid salts (Thurston County, 2009a; Thurston

483 County, 2009b). Particulate phase fatty acid salts will be removed from the atmosphere through wet and
484 dry deposition, and unsaturated fatty acid anions will be degraded through reaction with ozone (HSDB,
485 2008c). While some fatty acids (e.g., lauric acid) may bioaccumulate in aquatic animals, this process occurs
486 naturally through the ingestion of foods containing fatty acids (Van Egmond, 1999). The addition of
487 ammonium and potassium ions associated with herbicide and algicide treatments should be minimal
488 compared to amounts typically observed in soils due to the nitrogen cycle and breakdown of compost
489 materials. Soaps salts are capable of disrupting the exoskeletons of soft-bodied insects, larvae, and other
490 soil organisms (e.g., earthworms and nematodes) directly exposed to spray solutions (Davis, 1997; US EPA,
491 2013).

492 **Evaluation Question #10: Describe and summarize any reported effects upon human health from use of**
493 **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**
494 **(m) (4)).**

495 Potassium and ammonium soap salts are practically non-toxic through oral, dermal and inhalation
496 exposure routes. Indeed, potassium fatty acid salts are generally recognized as safe (GRAS) by the Food
497 and Drug Administration (FDA) due to their presence in numerous food products and additives (US EPA,
498 2012). Ingested fatty acids are metabolized through cellular activity, where they are oxidized to compounds
499 that are used as an energy source and structural cell components (Thurston, 2009a; Thurston, 2009b). The
500 2012 qualitative human health risk assessment rationalized US EPA's decision to waive data requirements
501 in accordance with the observed lack of effects at high doses, ubiquity of fatty acids in nature, and
502 functionality of the substances in humans:

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

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

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

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

530 A variety of alternative substances and practices are available for the prevention and control of algae in
531 agricultural production areas. Frequent and thorough disinfection is required to prevent algae from
532 developing in warm, damp, nutrient rich areas such as greenhouses and walkways. While mosses prefer
533 cooler conditions, it grows vigorously in the moist, shady areas with restricted air movement and poor

534 drainage that also favor the development of algae (Le Strange, 2011). Evaluation Question #12 provides
 535 details on the manual cleaning and disinfection practices that minimize the occurrence of algae and mosses
 536 in production areas. According to greenhouse specialists, natural or synthetic disinfectants should be used
 537 on a routine basis as part of a pre-planting program and throughout the growing season to prevent
 538 problems with algae and mosses (Pundt, 2013).

539 Disinfectant substances are available for the control of existing algae and mosses or when preventative
 540 measures provide insufficient control. Naturally produced organic acids – including vinegar (acetic acid
 541 active ingredient) and citric acid – may be used as pesticides in organic production if the requirements of
 542 the “crop pest, weed, and disease management practice standard (7 CFR 205.206(e)) are met (OMRI, 2014).
 543 This standard states that natural substances and synthetic substances approved for use on the National List
 544 may be used as pesticides when cultural practices (described in Evaluation Question #12) are insufficient to
 545 prevent or control weeds. The available information indicates that white vinegar (5% acetic acid) or
 546 commercial patio and path cleaners containing acetic acid may provide satisfactory control of algae and
 547 mosses (RHS, 2014). Limonene – the major component of citrus oil – effectively controls several species of
 548 moss on lawns, roofs, decks, driveways, walkways and fences (Golembiewski, 2008; Cutting Edge
 549 Formulations Inc, 2014). Highway salt (calcium or sodium chloride) is extremely toxic to algae, mosses and
 550 weeds when scattered under benches and on walkways (Laemmlen, 1979). All of the substances described
 551 in this section are non-persistent; therefore, occasional retreatment is necessary for continuous control of
 552 mosses and algae.

553 Disinfectants such as chlorine dioxide, hydrogen peroxide and sodium carbonate peroxyhydrate are
 554 commonly used to control existing algae in greenhouse settings and allowed for use in organic crop
 555 production (Pundt, 2013). According to the most recent OMRI product list, commercially available
 556 products containing soaps, hydrogen peroxide, limonene and sodium carbonate peroxyhydrate are
 557 allowed for use as demossers and algicides in organic production (OMRI, 2014). For example, the
 558 OxiDate® product containing hydrogen peroxide (BioSafe Systems LLC, 2010), Moss Avenger – Moss &
 559 Algae Control product containing limonene (Cutting Edge Formulations Inc, 2014) and PAK® 27 Algicide
 560 containing sodium carbonate peroxyhydrate (Solvay Chemicals Inc, 2012) are OMRI-approved alternatives
 561 to soap-based demossers/algicides. Further, numerous other commercially available algicides and
 562 demossers based on these alternative active ingredients are included in the updated OMRI product list
 563 (OMRI, 2014).

564 The following is a comprehensive list of synthetic algicides, disinfectants and sanitizers (including
 565 irrigation system cleaners) permitted for use in organic crop production that may aid in the prevention or
 566 control of algae and mosses:

- 567 • Ethanol (CH₃CH₂OH) 7 CFR 205.601(a)(1)(i)
- 568 • Isopropanol ((CH₃)₂CHOH) 7 CFR 205.601(a)(1)(ii)
- 569 • Calcium hypochlorite [Ca(ClO)₂] 7 CFR 205.601(a)(2)(i)
- 570 • Chlorine dioxide (ClO₂) 7 CFR 205.601(a)(2)(ii)
- 571 • Sodium hypochlorite (NaClO) 7 CFR 205.601(a)(2)(iii)
- 572 • Copper sulfate (CuSO₄) 7 CFR 205.601(a)(3)
 - 573 ○ For use as an algicide in aquatic rice systems; limited to one application per field during
 - 574 any 24-month period
- 575 • Hydrogen peroxide (H₂O₂) 7 CFR 205.601(a)(4)
- 576 • Ozone gas (O₃) 7 CFR 205.601(a)(5)
 - 577 ○ For use as an irrigation system cleaner only
- 578 • Peracetic acid (CH₃CO₃H) 7 CFR 205.601(a)(6)
 - 579 ○ For use in disinfecting equipment, seed, and asexually propagated planting material. Also
 - 580 permitted in hydrogen peroxide formulations as allowed in §205.601(a) at concentration of
 - 581 no more than 6% as indicated on the pesticide product label
- 582 • Soap-based algicide/demossers 7 CFR 205.601(a)(7)
- 583 • Sodium carbonate peroxyhydrate 7 CFR 205.601(a)(8)
 - 584 ○ Federal law restricts the use of this substance in food crop production to approved food
 - 585 uses identified on the product label

586 In addition to the substances listed above, the available literature indicates that barley straw has been used
587 to control algal populations in irrigation ponds and reservoirs. Compounds released from the breakdown
588 of barley in water are algistatic, and thus only prevent the growth of algae. When used in ponds, barley
589 straw must be added to the pond in later winter such that the material will break down and release
590 algistatic compounds before algae populations increase during warmer weather. One application of barley
591 straw can provide up to six months of algae control (Camberato & Lopez, 2010).

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

594 Both mosses and algae are high moisture requiring plants, which thrive in intermediate light and shade.
595 Not surprisingly, high humidity and standing water are common in greenhouses and other areas where
596 mosses and algae are found. Improving drainage, reducing the amount or frequency of watering and
597 increasing ventilation or air movement can greatly reduce the development of mosses and algae
598 (Laemmlen, 1979). Proper ventilation reduces the moisture level in greenhouses, and can be accomplished
599 using horizontal airflow fans and retractable roof or open roof greenhouse structures (Pundt, 2013).
600 Installing surfaces that dry rapidly and remain dry for several hours between watering events do not favor
601 the development of these species. When constructing walkways and greenhouses, it is helpful to
602 incorporate a slight slope to cement walks or install drainage systems to minimize water accumulation on
603 the surface. The use of porous materials such as gravel and cinders can also be helpful in minimizing the
604 likelihood of algae problems by allowing the top of the walkway to drain and quickly dry after watering.
605 The occurrence of mosses and algae in plant containers is indicative of overwatering, high humidity
606 and/or ceiling droplets due to condensation within the greenhouse structure. Changing the watering
607 protocol (schedule or volume) and ventilation patterns described above can help mitigate conditions
608 leading to algae and moss growth in plant containers (Laemmlen, 1979). Operators should avoid
609 overwatering plants, choose a growing media with appropriate drainage, and water containers only as
610 needed to prevent the growth of moss and algae in greenhouse and nursery settings (Pundt, 2013).

611 As discussed in the response to Evaluation Question #11, regular cleaning – involving physical weed,
612 debris and soil removal – is essential to avoiding the development of algae and moss. When possible, use
613 wire benches that can be easily disinfected in greenhouses. Bench tops and worktables should be
614 constructed from non-porous surfaces such as laminate that can be easily disinfected (Smith, 2014). Algae
615 tend to grow on the surface of wooden benches creating an ideal environment for other pests, including
616 fungus gnats, shore flies and various plant pathogens. High-pressure power washing can effectively
617 remove dirt and other organic material from the walls and lower surfaces of greenhouses. Surfaces must be
618 kept free of debris and weeds that may serve as nutrient sources for the growth of algae. Like these organic
619 materials, organic fertilizer is used as a food source for developing algae. It is therefore important to avoid
620 excessive fertilizer runoff and water puddles on floors, benches, and greenhouse surfaces (Smith, 2014).

621 In lieu of chemical controls, it may be necessary to physically remove algae and moss from affected areas.
622 Carefully running a sharp knife and/or a block paving brush along the cracks, or using a pressure washer
623 can effectively dislodge moss from between paving. Proper drainage in the affected area should be
624 established prior to pressure washing to remove algae and moss. Regularly brushing hard surfaces with a
625 stiff broom can help prevent small algae and moss growths from taking hold on hard surfaces. Likewise,
626 raking loose surfaces such as gravel can help remove small deposits and keep these areas free of algae,
627 moss and weeds (RHS, 2014).

628 Algae buildup can become a significant problem in irrigation systems. Whole algae cells and organic
629 residues of algae are generally small enough to pass through the filters of irrigation systems. In some cases,
630 algae transported from the water sources into the irrigation system may promote the formation of
631 aggregates that plug emitters (spouts in drip irrigation systems). In addition, residues of decomposing
632 algae can accumulate in pipes and emitters and support the growth of slime-forming bacteria (Haman,
633 2014). Reducing the amount of algae in the source water pond is essential to minimizing problems with
634 algae in the lines and components of irrigation systems (Camberato & Lopez, 2010). The following factors
635 influence algae growth in irrigation ponds:

- 636 • Pond size and depth. Small, shallow ponds (high light and water temperature) facilitate algae
637 growth.

- 638 • Stagnant water, shallow depth. Limited wave action and movement favors algae.
639 • High levels of nutrients, especially phosphorus and nitrogen. These nutrients are food sources for
640 algae.

641 Making physical alterations to the pond can help reduce algae problems. Since nutrients facilitate the
642 development of large algae populations, reducing the amount of nitrogen and phosphorus nutrients that
643 enter the bond should significantly reduce algae growth. In addition, installing a vegetation filter strip
644 around the pond can reduce nutrient runoff into the water source. It may also be helpful to dredge and
645 deepen existing ponds or reservoirs that have considerable areas of shallow water. In combination with the
646 other control methods, installing an aerator may help reduce algae populations by dispersing and
647 fragmenting algae colonies in the pond (Camberato & Lopez, 2010).

648 If prevention practices prove insufficient, physically removing filamentous algae growth provides
649 immediate control without the introduction of chemical residues to the system. This practice can be
650 effective for small-scale nurseries, but larger nurseries may require expensive harvesting equipment to
651 remove algae from ponds and reservoirs. It is important to note that all removed material should be
652 deposited where the nutrients and algal fragments cannot re-enter the water source. Physical removal is
653 not permanent, and therefore repeated removal events may be necessary throughout the growing season
654 (Camberato & Lopez, 2010).

655 Lastly, biological control measures have also been used for algae control in irrigation ponds and reservoirs.
656 Triploid grass carp introduced into ponds will feed on mat forming algae when their preferred food source
657 is depleted. However, variable levels of control have been observed using carp (Camberato & Lopez, 2010).
658 Biological control is not generally employed in conventional production since chemical controls (e.g.,
659 copper compounds) are more effective, but may provide sufficient control of algae populations when used
660 in combination with other practices.

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