

Lime Sulfur

Crops

Identification of Petitioned Substance

Chemical Names:

Calcium polysulfide

CAS Numbers:

1344-81-6

Other Name:

Lime Sulfur

Other Codes:

215-709-2 (EINECS Number)

Trade Names:

Sulforix®, Rex Lime Sulfur Solution

Summary of Petitioned Use

The National Organic Program (NOP) final rule currently permits use of the synthetic substance lime sulfur in organic crop production under 7 CFR §205.601(e)(6) as an insecticide (including acaricide or mite control). In addition, use of lime sulfur is allowed for plant disease control as a fungicide (7 CFR §205.601(i)(6)). This report provides updated and targeted technical information to augment the 1995 Technical Advisory Panel Report on lime sulfur in support of the National Organic Standards Board's review of the synthetic substance under the sunset process.

Characterization of Petitioned Substance

Composition of the Substance:

Lime sulfur, also referred to by its chemical name calcium polysulfide, is a synthetic substance consisting of inorganic complexes of divalent calcium cations (Ca^{2+}) and anionic polysulfide chains ranging in length from two to seven sulfur atoms. The chemical formula may be represented as CaS_x , where $x = 2, 3, 4, 5, 6,$ and 7 . In addition, minor amounts of calcium thiosulfate (CaS_2O_3), calcium sulfite (CaSO_3), sulfur, and gypsum (CaSO_4) may be present in lime sulfur mixtures (US EPA, 2005a). Figure 1 below represents the molecular structure of the predominant pentasulfide ($x = 5$) form of the substance.

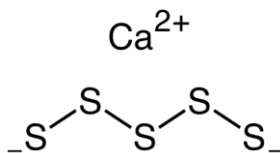


Figure 1. Molecular formula for calcium pentasulfide.

Source or Origin of the Substance:

In general, elemental sulfur (S) and a source of calcium cations are combined to produce lime sulfur. According to recent patents and information from US EPA, lime sulfur (calcium polysulfides) is produced by reacting boiling calcium hydroxide [$\text{Ca}(\text{OH})_2$] and ground sulfur (US EPA, 2005a; Hajjatie, 2006). Aqueous solutions of calcium hydroxide, known as hydrated lime or slaked lime, are generated through the exothermic (heat releasing) reaction of a weighed amount of calcium oxide, sometimes referred to as Quicklime, and a measured amount of water (Hajjatie, 2006). See Evaluation Question #2 for details regarding the production of lime sulfur and its precursor chemicals, calcium oxide, calcium hydroxide and elemental sulfur.

Properties of the Substance:

Lime sulfur may be defined as solutions of calcium polysulfides in water. These aqueous solutions are alkaline (pH = 11.5–11.8), with a deep red/orange appearance and pungent odor of rotten eggs due to the

43 release of hydrogen sulfide. Table 1 provides a summary of the chemical and physical properties of various
 44 commercial solutions of calcium polysulfides referred to as lime sulfur.

45 **Table 1. Chemical and Physical Properties for Lime Sulfur and Calcium Polysulfide**

Property	Description
Molecular formula	CaS _x (x = 2, 3, 4, 5, 6, 7)
Molecular weight	Varies 200.4 g/mole (calcium pentasulfide, x = 5)
Solubility in water (calcium polysulfide)	Soluble in water; dissolves with precipitation of elemental sulfur
pH	Alkaline (pH = 10.9–11.9) due to hydrolysis, which is accelerated by dilution
Appearance	Ruby-red/orange
Odor	Rotten eggs; unpleasant smell of hydrogen sulfide (H ₂ S)
Odor threshold	0.13 ppm faint, but easily noticeable at 0.77 ppm
Chemical stability	Stable at ambient temperatures and pressures when in solid form
Reactivity	Reacts with strong oxidizers to form explosive mixtures if heated to dryness, and releases toxic H ₂ S vapors on contact with acid.
Specific gravity	1.28 (at 15.6 °C)
Viscosity	2.95 (cP, at 20 °C)

46 Data sources: HSDB, 2003; US EPA, 2005b; NovaSource, 2013; VGS, 2006.

47 cP = centiPoise, equivalent to millipascals seconds (mPa•s).

48 **Specific Uses of the Substance:**

49 Lime sulfur is applied to crops for its fungicidal, miticidal and insecticidal activity. Specifically, the
 50 substance is used to control powdery mildews, anthracnose, scab, spider mites and other diseases on
 51 alfalfa, beans, clover and fruits (Tomlin, 1994). The available literature indicates that lime sulfur is
 52 commonly applied to growing crops for the control of mites (e.g., twospotted spider mite and broad mite)
 53 and a variety of diseases such as plum pockets, black rot, spot of rose, San Jose scale, peach leaf curl and
 54 several raspberry diseases (Janssen, 2002; Bauernfeind & Cloyd, 2012; Venzon, 2013). Scientific trials have
 55 demonstrated that curative and preventative lime sulfur treatments can significantly reduce damage on
 56 both the leaves and fruits of apple trees inoculated with the apple scab fungus *Venturia inaequalis*; however,
 57 phytotoxicity is frequently observed in treated crops (Holb, 2003). Lime sulfur treatment of harvested
 58 peaches have been shown to reduce the incidence of brown rot of peach (*Monilinia fructicola*) by up to 90%,
 59 suggesting that lime sulfur has the potential for post-infection brown rot control in organic stone fruit
 60 production (Holb & Schnabel, 2008). Because lime sulfur is one of the few organic-approved synthetic
 61 fungicides and insecticides/acaricides, the amount of lime sulfur used in agriculture has increased with the
 62 expansion of organic production in recent years (Venzon 2013).

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

64 The US Environmental Protection Agency (US EPA) regulates all agricultural uses of lime sulfur under the
 65 Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). According to the most recent Reregistration
 66 Eligibility Decision (RED) for inorganic polysulfides, there were sixteen registered products with calcium
 67 polysulfide as an active ingredient, three of which contained other active ingredients (US EPA, 2005b).
 68 However, a search of the National Pesticide Information Retrieval System shows only four actively
 69 registered products manufactured by Tessengerlo Kerley, Inc. and OR-CAL, Inc (NPIRS, 2013). Product
 70 information provided in the RED indicates that lime sulfur products were first registered in 1948. Currently
 71 registered products are formulated as soluble concentrates of 27–29% lime-sulfur as the active ingredient.
 72 Lime sulfur product labels require personal protective equipment (PPE) for all handlers and a Restricted
 73 Entry Interval (time from pesticide application to field reentry) of 48 hours (US EPA, 2005b).

74 According to the RED, lime sulfur has fungicidal and secondary acaricidal activity, and is used to control
75 powdery mildews, anthracnose, scab, and other diseases, as well as spider mites. Based on the current
76 labels, lime sulfur products are registered for feed/food and non-feed/non-food uses (US EPA, 2005b):

77 *Calcium polysulfide is registered for feed and food uses on the following sites: alfalfa, almonds, apples, beef,*
78 *blackberries, blueberries, boysenberries, caneberries, cherries (sweet), cherries (tart), citrus, clover, currants,*
79 *dairy cattle, deciduous fruit trees, gooseberries, grapes, hazelnuts (filberts), hogs, nectarines, oranges,*
80 *peaches, pears, pecans, pistachio nuts, plums, prunes, quinces, raspberries, rye, sheep, stone fruits,*
81 *tangerines, and walnuts. The non-food/non-feed use sites include the following: cherry (dormant), horses,*
82 *ornamentals, residential lawns, and sheep.*

83 US EPA determined that the aqueous solutions of calcium polysulfides found in lime sulfur products
84 rapidly degrade to calcium hydroxide and sulfur in the environment and human body. Therefore, residues
85 of lime sulfur are exempt from the requirement of a tolerance under 40 CFR 180.1232.

86 **Action of the Substance:**

87 The fungicidal, insecticidal and acaricidal properties of lime sulfur are based on related modes of action
88 involving impaired electron transport and hydrogen sulfide (H₂S) formation. In general, lime sulfur
89 prevents plant disease by allowing sulfur to penetrate leaf tissues and kill germinated spores (USDA, 1995).
90 Antifungal activity is observed because the polysulfide component of lime sulfur is also capable of
91 penetrating the fungus mycelia (vegetative parts of fungus) in the water phase (Holb, 2003). Once taken up
92 by fungi, sulfur affects the mitochondrial respiratory complex by interfering with the electron flux in the
93 respiratory chain, resulting in multi-site, broad-spectrum toxicity (Holb & Schnabel, 2008; Beffa, 1993). This
94 mode of action involving the interception of electrons in the respiratory chain effectively reduces elemental
95 sulfur to hydrogen sulfide, which is also toxic to most cellular proteins (Janssen, 2002; Beffa, 1993).
96 Likewise, hydrogen sulfide formed through reaction of the polysulfide components of lime sulfur with
97 water and carbon dioxide is responsible for the observed toxicity of lime sulfur in insects and mites
98 (Venzon, 2013). At the commonly used fungicide application rate for lime sulfur (two percent solution in
99 water), the dilute lime sulfur solution has a pH of 10 and constantly releases small amounts of toxic
100 hydrogen sulfide vapors (Holb, 2003).

101 **Combinations of the Substance:**

102 Lime sulfur is produced through the reaction of lime (calcium oxide) or hydrated/slaked lime (calcium
103 hydroxide) with sulfur in water. The available procedures and patent literature do not describe the
104 addition of other natural or synthetic substances during the commercial production of lime sulfur.

105 Labels for currently registered lime sulfur products – such as the OMRI-approved Rex Lime Sulfur
106 Solution – list lime sulfur as the only active ingredient at 27–29% of the formulation, with the remaining
107 71–73% consisting of “other ingredients” (NPIRS, 2013; OMRI, 2014). Product formulations are considered
108 confidential business information, and companies may reformulate products without providing notice to
109 US EPA. As a result, it is rarely possible to know the identity of other ingredients. Pesticides marketed for
110 organic crop production must comply with section 205.601(m)(1) of the National List, which allows the use
111 of Inerts of Minimal Concern (US EPA List 4 Inerts) as other ingredients in formulated products.

112 Status

113 **Historic Use:**

115 Lime sulfur is possibly the earliest synthetic chemical used as a pesticide, with references to its production
116 and use in insect control appearing around 1800 (CUES, 2002). The first mention of lime sulfur, prepared
117 by boiling lime and sulfur together, appears to have occurred in 1833 as a means of controlling vine
118 powdery mildew (*Uncinula necator*) in wine grapes (Russell, 2005). In the early 1850s, this mixture began
119 being prepared and used in France to protect grapes from mildew (Janssen, 2002). In the United States,
120 lime sulfur use originated in California in the late 1880s for control of peach leaf curl and San Jose Scale, an
121 invasive insect pest of fruiting trees including apple, peach and pear (Janssen, 2002; CUES, 2002). Chemical
122 companies began manufacturing lime sulfur pesticide products in 1902 (Clemson, 2014). Throughout the
123 early- to mid-20th century, lime sulfur was used intensively as a winter treatment to control scales, mites

124 and some diseases, especially in fruiting trees. By the 1940s, however, lime sulfur had been largely replaced
125 by other synthetic pesticides. Lime sulfur usage has been stimulated more recently by the increase in
126 organic production and its approved status in many organic certification programs (Venzon, 2013).

127 **Organic Foods Production Act, USDA Final Rule:**

128 Section 2118(c)1(B)i of the Organic Foods Production Act of 1990 (OFPA) states that the National List may
129 provide for the use of sulfur compounds in organic farming or handling operations that are otherwise
130 prohibited only if the following conditions are satisfied:

- 131 • the substance would not be harmful to human health or the environment
- 132 • the substance is necessary to the production or handling of the agricultural product because of the
133 unavailability of wholly natural substitute products; and
- 134 • the substance is consistent with organic farming and handling.

135 In addition, the National Organic Program (NOP) final rule currently allows the use of synthetic lime
136 sulfur in organic crop production under 7 CFR 205.601(e)(6) as an insecticide (including acaricide or mite
137 control), as well as 7 CFR 205.601(i)(6) for use in plant disease control as a fungicide.

138 **International**

139 Several international organizations have provided guidance on the application of lime sulfur for plant
140 protection in organic crop production. Among these are regulatory agencies (EU, Canada, Japan) and
141 independent organic standards organizations (IFOAM, Soil Association). International organic regulations
142 and standards concerning lime sulfur are described in the following sub-sections.

143 *Canadian General Standards Board*

144 The Canadian General Standards Board permits the use of lime sulfur in organic crop production.
145 Specifically, lime sulfur (calcium polysulfide) is included in Section 4.3 (Crop Production Aids and
146 Materials) of the Canadian Production Systems Permitted Substances Lists as an allowed fungicide,
147 insecticide and acaricide/mite control on plants (CAN, 2011).

148 *Codex Alimentarius*

149 Although lime sulfur is not specifically mentioned, organic production guidelines from the Codex
150 Alimentarius Commission (CAC GL 32-1999) permit the use of sulfur for pest and disease control when the
151 certification body or authority recognizes the need for plant protection (Codex, 2013).

152 *European Union*

153 Organic production regulations in the European Union permit the use of lime sulfur (calcium polysulfide)
154 as a fungicide, insecticide and acaricide. Specifically, Annex 5 states:

155 *Where plants cannot be adequately protected from pests and diseases by measures provided for in Article 12*
156 *(1)(a), (b), (c) and (g) of Regulation (EC) No 834/2007, only products referred to in Annex II to this*
157 *Regulation may be used in organic production. Operators shall keep documentary evidence of the need to use*
158 *the product.*

159 Lime sulfur is listed under Item 6 of Annex II – Other substances from traditional use in organic farming
160 (EC, 2008).

161 *Japanese Ministry of Agriculture Forestry and Fisheries*

162 The Japanese Agricultural Standard for Organic Plants permits the use of “lime sulfur powder” under
163 Attached Table 2 – Substances for Plant Pest and Disease Control (JMAFF, 2005).

164 *International Federation of Organic Agriculture Movements*

165 The IFOAM Norms list lime sulfur (calcium polysulfide) in Section II of Appendix 3: Crop Protectants and
166 Growth Regulators (IFOAM, 2014).

167 UK Soil Association

168 In contrast to many of the international regulatory agencies, the UK Soil Association only allows the use of
169 lime sulfur for plant protection on a case-by-case basis when there is a demonstrated major threat to a
170 grower's crops (Soil Association, 2014).

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

172
173 **Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the**
174 **substance contain an active ingredient in any of the following categories: copper and sulfur**
175 **compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated**
176 **seed, vitamins and minerals; livestock parasiticides and medicines and production aids including**
177 **netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is**
178 **the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological**
179 **concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert**
180 **ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part**
181 **180?**

182 (A) Based on the chemical name and polysulfide composition, lime sulfur is considered a sulfur
183 compound or substance. The calcium and sulfur components of lime sulfur are also considered minerals.

184 (B) Lime sulfur is an active ingredient used for fungicidal, insecticidal and acaricidal applications in
185 conventional and organic crop production. Although the substance is not an inert ingredient in pesticide
186 products, residues of lime sulfur are exempt from the requirement of a tolerance (40 CFR 180.1232).

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

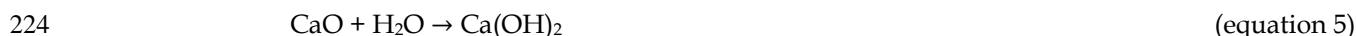
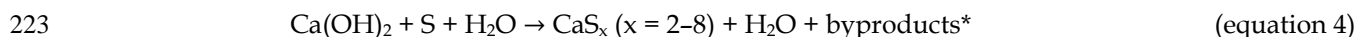
191 The basic process for lime sulfur production includes the reaction of boiling calcium hydroxide with
192 ground sulfur in water. A comprehensive evaluation of the synthetic process for lime sulfur involves
193 consideration of the methods for isolating the raw materials, sulfur and lime (calcium oxide). The following
194 paragraphs provide details on the isolation and combination of these raw materials to form lime sulfur.

195 Both of the raw materials used in lime sulfur production are obtained from natural sources. Lime is derived
196 from limestone, which contains predominantly calcium carbonate with smaller amounts of magnesium,
197 silicon, aluminum and iron. Heating raw or minimally processed limestone converts calcium carbonate to
198 calcium oxide (lime or quicklime) used in the reaction with sulfur and water to form lime sulfur (equation
199 1) (Oates, 2010). Sedimentary deposits (ores) and volcanic deposits were historically used as sources of
200 elemental sulfur for various industrial processes; however, modern sulfur production is a byproduct of
201 other industrial processes (Nehb & Vydra, 2006). Specifically, economic approaches for sulfur production
202 are based on the conversion of hydrogen sulfide (H₂S) obtained during the desulfurizing/processing of
203 petroleum, natural gas and related fossil resources to elemental sulfur. This method entails oxidation of
204 one-third of the hydrogen sulfide to sulfur dioxide (equation 2) followed by reintroduction of the reaction
205 gas to the remaining two-thirds of the hydrogen sulfide to form elemental sulfur (equation 3) (Nehb &
206 Vydra, 2006).



210 Although exact proportions may vary among recipes, the basic process for lime sulfur production
211 presented in the literature involves the addition of lime (calcium oxide), sulfur and water (equation 4). One
212 optimized recipe for generating a lime sulfur concentrate includes 80 pounds sulfur, 36 pounds of pure
213 lime (CaO), and 50 gallons of water. Practically all of the sulfur is transformed to soluble polysulfide
214 compounds when the amount of sulfur is not more than 2.25 times the amount of lime used.

215 Slaked/hydrated lime predominantly containing calcium hydroxide [Ca(OH)₂] may also be used as the
216 source of calcium in the synthetic reaction. Indeed, the calcium oxide in lime is converted into calcium
217 hydroxide (hydrated lime) (equation 5) before the chemical reaction occurs between lime and sulfur (Van
218 Slyke, 1910). An early patent describes an apparatus used to grind lump sulfur, mix the ground sulfur with
219 lime and then react the dry lime sulfur mixture with steam and hot water to form lime sulfur (Wood, 1926).
220 Recent patent methods also indicate that sulfur may be reacted with hydrated lime directly or lime may be
221 hydrated *in situ* before the reaction with sulfur. Potential byproducts generated during lime sulfur
222 production usually include calcium sulfite, calcium sulfate, and metal sulfides (Hajjatie, 2006).



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

227 According to USDA organic regulations, the NOP defines synthetic as “a substance that is formulated or
228 manufactured by a chemical process or by a process that chemically changes a substance extracted from
229 naturally occurring biological processes” (7 CFR 205.2). Lime is produced by heating/decomposing the
230 calcium carbonate content of natural limestone to form calcium oxide (lime). In addition, the vast majority
231 of commercially available sulfur is generated as a byproduct of the chemical processing of fossil fuels
232 (Nehb & Vydra, 2006). Although no longer used in the US, elemental sulfur obtained through the mining of
233 sulfur containing ores would be considered a natural substance. Both starting materials used in the
234 production of lime sulfur are therefore characterized as synthetic substances. As discussed in Evaluation
235 Question #2, lime sulfur is produced through the combination of lime and elemental sulfur in water.
236 Calcium sulfite, calcium sulfate and metal sulfides are potentially generated as byproducts depending on
237 the exact reaction conditions and purity of starting materials used in the preparatory reaction. Based on
238 NOP definitions, it is reasonable to conclude that lime sulfur used for plant pest and disease control is a
239 synthetic substance.

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

242 In evaluating the persistence and environmental fate of lime sulfur, it is generally assumed that the
243 substance is applied to growing rain-fed or irrigated crops. The calcium polysulfides comprising lime
244 sulfur are expected to rapidly dissociate in the presence of moisture to form calcium cations and elemental
245 sulfur. While most of the applied substance contacts targeted crops and soils, some may also drift to non-
246 target plants/soils. Because calcium polysulfides are assumed to dissociate quickly in the environment,
247 runoff and/or leaching into nearby water bodies is assumed to be negligible (US EPA, 2005a).

248 It is not anticipated that the amounts of calcium and sulfur resulting from lime sulfur applications will be
249 significant when compared to natural background levels of these chemical species in the environment.
250 Monitoring data does not exist for calcium polysulfides in natural waters, but background levels of the
251 dissociation products sulfur and calcium are typically observed at concentrations in the parts per million
252 range. The total sulfur content of seven different types of soils from Minnesota was reported to range from
253 560 to 1,658 pounds per acre. Assuming these sulfur concentrations are typical background levels for soils
254 throughout the U.S., the amount of sulfur contributed through lime sulfur treatments may be considered
255 insignificant compared to the total sulfur content of soils (US EPA, 2005a).

256 Owing to its limited water solubility, elemental sulfur is relatively immobile in soils and is not expected to
257 leach into lower soil horizons or groundwater. Elemental sulfur largely precipitates out of solution, but a
258 small fraction of sulfur content may remain as the thiosulfate ion (S₂O₃²⁻). Autotrophic bacteria are capable
259 of oxidizing sulfur to sulfate (SO₄²⁻) under aerobic conditions, such as those encountered in aerobic (surface
260 soils) and surface water. Under reducing conditions, such as anaerobic soils, anaerobic sediment and
261 ground water, sulfur may be converted to hydrogen sulfide (H₂S), bisulfide (HS⁻) and sulfide (S²⁻) (US
262 EPA, 2005a). The possibility of large-scale H₂S formation is low because elemental sulfur is relatively

* Note: Equation 4 is not chemically balanced because the ratio of possible products depends on reaction conditions and the ratio of lime to sulfur used in the reaction mixture.

263 immobile and will likely be subjected to oxidation before reaching reducing environments; however, small
264 amounts of H₂S may be released during normal use of the substance. Of particular relevance to lime sulfur
265 treatments, polysulfides enter the sulfur cycle immediately after application, with facile oxidation of
266 polysulfides into water-soluble sulfite (SO₃²⁻) and sulfate (SO₄²⁻) anions. The water solubility of the latter
267 species facilitates their active uptake by plants and animals as sources of essential sulfur (EFSA, 2010).

268 Calcium cations (Ca²⁺) are less mobile in the environment than would be expected based on their solubility
269 in water. In soils, calcium ions bind to cation exchange sites and therefore have limited mobility. Similarly,
270 calcium cations in natural waters form weak soluble complexes with free bicarbonate (HCO₃⁻), carbonate
271 (CO₃²⁻), and/or hydroxide (OH⁻) anions. Calcium cations are also capable of binding to surfaces of mineral
272 and colloidal fractions of suspended material in aqueous media to various degrees, depending on pH and
273 the levels of other ions present in water (US EPA, 2005a).

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

277 The US EPA terrestrial effects characterization for calcium polysulfides (lime sulfur) and the breakdown
278 products calcium hydroxide and sulfur included mammals, birds and honey bees (US EPA, 2005a; US EPA,
279 2005b). An acute oral toxicity study in rats involving the one-time administration of a “calcium
280 polysulfides formulation” yielded LD₅₀ values of 712 mg/kg body weight in males and 520 mg/kg body
281 weight in females. To calculate toxicity values in terms of mg active ingredient (a.i.) per kg body weight,
282 LD₅₀ values were multiplied by the percent a.i. in the formulation tested (16.66%). The derived LD₅₀ values
283 for male and female rats are 118.62 mg a.i./kg body weight and 86.63 mg a.i./kg body weight, indicating
284 that calcium polysulfides in lime sulfur products are moderately toxic to mammals (Toxicity Category III).
285 Although lime sulfur is highly corrosive, no evidence of contact damage to the gastric mucosa was
286 reported in the mammalian studies (US EPA, 2005a). Acute oral toxicity testing of lime sulfur administered
287 to bobwhite quail via gavage provided an LD₅₀ value of 560 mg a.i./kg body weight, indicating that
288 calcium polysulfides are slightly toxic to avian species on an acute oral basis. Further, administration to
289 bobwhite quail in food yielded LC₅₀ values of greater than 5,000 mg a.i./kg diet. Calcium polysulfides are
290 therefore categorized as practically non-toxic to birds on an acute dietary basis (US EPA, 2005a). Product
291 labels carry the signal word “Danger” due to the possibility of irreversible eye damage (Tessenderlo, 2013):

292 *Fatal if swallowed. Fatal is absorbed through the skin. Fatal if inhaled. Corrosive. Causes irreversible eye*
293 *damage. Causes skin burns. Do not get in eyes, on skin, or on clothing. Do not breath vapor or spray mist.*
294 *Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using*
295 *tobacco or using the toilet. This product is corrosive to flesh because of its caustic alkaline nature.*

296 The toxicity of lime sulfur to non-target terrestrial invertebrates has been assessed in registrant-submitted
297 studies and the peer reviewed scientific literature. An acute contact toxicity study in honey bees using a
298 lime sulfur formulation afforded a 48-hour LD₅₀ value of greater than 25 µg a.i. per bee, categorizing
299 calcium polysulfides as practically non-toxic to honey bees. US EPA (2005a) reviewed several older open
300 literature studies demonstrating high levels of sensitivity to calcium polysulfides for beneficial insects and
301 mites, including Hymenoptera parasites (e.g., *Leptomastix dactylopii*, a parasitic wasp) and *Amblyseius*
302 *victoriensis* (predatory mite). In addition, Venzon *et al.* (2013) recently established the toxicity of lime sulfur
303 applications to natural enemies of *Polyphagotarsonemus latus* (broad mite), a damaging crop pest observed
304 in tropical and subtropical regions. The study found that populations of the predatory mite *Amblyseius*
305 *herbicolus* declined linearly with increasing lime sulfur concentration but were less sensitive than
306 population levels of its prey, the broad mite. Similarly, only 50% of the tested larvae of the predatory insect
307 *Chrysoperla externa* reached adulthood when exposed to 10 mL/L lime sulfur product in water (Venzon,
308 2013).

309 In addition to adverse impacts on non-target invertebrates, lime sulfur is corrosive and capable of
310 damaging plant tissues. Signs of toxicity reported in several observational studies include scorching of the
311 leaves, down-curved chlorotic brittle leaves, necrotic spotting, fruit russetting and/or fruit dropping/
312 decreased yield (US EPA, 2005a). The soluble sulfide component of lime sulfur is believed to be
313 fundamentally responsible for plant injury by reducing carbon dioxide assimilation (Holb, 2003). Because
314 lime sulfur is most effective in the water phase, heightened levels of phytotoxicity are generally observed

315 when the relative humidity and/or leaf wetness increases after spraying (Holb, 2003). The degree of
316 phytotoxicity is also dependent on plant variety; for example, Venzon *et al.* (2013) found that foliage of
317 physic nut (*Jatropha curcas*) tree exhibits severe injury when sprayed with all tested lime sulfur
318 concentrations, but no phytotoxicity was observed in chili peppers at any concentration tested. Lastly,
319 elevated temperatures may also intensify the phytotoxicity of lime sulfur in certain plants (US EPA, 2005a).
320 Organic growers must therefore find a balance between good efficacy and phytotoxic effects when using
321 applying fungicides containing lime sulfur to sensitive crops.

322 Aquatic toxicity data is available for freshwater fish and aquatic invertebrates, as well as one species of
323 green algae. The 96-hour LC₅₀ for fish exposed to lime sulfur in water range from 0.97 mg a.i./L in rainbow
324 trout to 14.1 mg a.i./L in bluegill sunfish. Based on the lowest LC₅₀ values in rainbow trout, lime sulfur is
325 categorized as highly toxic on an acute basis. The observed high level of toxicity is potentially related to the
326 alkaline nature of lime sulfur, which raises the pH of treated waters. Lime sulfur is moderately toxic to
327 freshwater invertebrates, with respective 48-hour LC₅₀ values of 2.3 and 3.2 mg a.i./L for the water fleas
328 *Daphnia pulex* and *Simocephalus serrulatus*. In addition, a related study demonstrated a dose-response
329 decrease in egg hatchability in freshwater midge *Chironomus riparius*, with a No Observed Adverse Effect
330 Concentration (NOAEC) of 3.2 mg/L. The concentration-related increase in pH and associated decrease in
331 dissolved oxygen was not controlled; thus, it is impossible to definitively conclude that lime sulfur affects
332 embryogenesis in the midge. Based on an EC₅₀ (effective concentration at which sub-lethal effects are
333 observed) of 14.1 mg a.i./L in *Selanastrum capricornutum*, lime sulfur is categorized as slightly toxic algae
334 (US EPA, 2005a). The MSDS for Lime-Sulfur Spray states that the product is not bioaccumulative
335 (NovaSource, 2013).

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

338 Environmental contamination is not anticipated from normal use of lime sulfur as an insecticide and
339 fungicide in organic crop production. Calcium polysulfides in lime sulfur products dissociate to calcium
340 and sulfur, which are naturally occurring at background levels in the environment (US EPA, 2005a).
341 However, the MSDS states that "if this product as supplied become waste, it should be checked for reactive
342 sulfides prior to disposal" (NovaSource, 2013). Lime sulfur is alkaline (high pH) and therefore highly
343 corrosive. Accidental releases of the product solutions in sufficiently large volumes could lead to
344 environmental impairment in the immediate area. Likewise, accidental spills of the chemical feedstocks,
345 calcium oxide or calcium hydroxide, to natural waters or moist soil would raise the pH of the receiving
346 medium, thus impacting supported life (i.e., aquatic species, soil organisms). Reports of environmental
347 contamination due to large volume spills of lime sulfur or the industrial discharge of quicklime (calcium
348 oxide) and hydrated lime (calcium hydroxide) were not identified.

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

352 Limited information is available regarding chemical interactions between lime sulfur and other substances
353 used in organic crop and livestock production. According to the MSDS, lime sulfur is incompatible with
354 strong oxidizers, and the combination of these substances can lead to formation of explosive mixtures if
355 heated to dryness (NovaSource, 2013). The combination of lime sulfur with acids, or other acidic materials,
356 and dilution with water will cause the release of hydrogen sulfide (H₂S) vapors, which are acutely toxic
357 and even deadly in humans at sufficiently high air concentrations (NovaSource, 2013). Therefore,
358 introducing lime sulfur to acids or acidic substances used in organic production could be problematic for
359 applicators, farmworkers, bystanders and animals, particularly in enclosed spaces.

360 Regarding plant health, it is generally understood that various mineral species interact both synergistically
361 and antagonistically in the process of absorption. Uptake of phosphate is essential for the absorption and
362 translocation of calcium within the plant; however, high concentrations of calcium in the soil may lead to
363 precipitation of less soluble calcium phosphates and associated phosphorus and calcium deficiency in
364 plants (Jakobsen, 1993). Applying excessive amounts of potash (potassium) fertilizers to agricultural soils
365 can also decrease the uptake and utilization of essential calcium in plants. As an alkaline substance,
366 aqueous solutions of lime sulfur released to soils in significant amounts will raise the soil pH, thus altering

367 the forms of calcium phosphate in the soil and potentially diminishing the uptake of calcium and
368 phosphate by plants (Jakobsen, 1993).

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

372 Lime sulfur has the potential to exert toxic effects upon beneficial soil organisms through a variety of
373 mechanisms. Technical information was not available regarding the toxicity of lime sulfur to beneficial soil
374 microorganisms such as *Rhizobia*, a class of nitrogen fixing bacteria, and *Mycorrhizae*, fungi that form
375 symbiotic associations with plant roots. Nevertheless, based on the proposed mode of action for lime sulfur
376 involving disruption of electron transport in the mitochondria of pathogenic fungi with concomitant
377 formation of toxic hydrogen sulfide (Holb & Schnabel, 2008; Janssen, 2002), it is highly probable that lime
378 sulfur released to soil would exert toxic effects on certain species of beneficial soil microflora. Indeed, foliar
379 soil drenches of non-systemic fungicides “places the greatest fungicidal load at the root zone and is
380 therefore the method most likely to cause harm to mycorrhizal fungi” (Plant Health Care, 2009). Likewise,
381 large volume spills of alkaline lime sulfur solutions would raise the pH of soils, resulting in damage to
382 sensitive populations of beneficial microorganisms, earthworms, and nematodes.

383 Plants within and outside of treatment zones are also vulnerable to the lime sulfur toxicity. In particular,
384 lime sulfur solutions are corrosive and may lead to phytotoxicity, including scorching of leaves, down-
385 curled chlorotic brittle leaves, necrotic spotting, fruit russetting and/or fruit dropping/decreased yield in
386 contacted plants (US EPA, 2005a). Holb *et al.* (2003) observed leaf necrosis, reduced leaf size and reduced
387 fruit quality in apple trees treated with lime sulfur solutions for control of *Venturia inaequalis* (apple scab).
388 Some plant varieties are most tolerant of aqueous lime sulfur; for example, Venzon *et al.* (2013) found that
389 the foliage of physic nut tree exhibits severe injury when sprayed with all tested lime sulfur concentrations,
390 but no phytotoxicity was observed in chili peppers at any concentration tested. As discussed in Evaluation
391 Question #5, the degree of phytotoxicity observed in treated plants generally increases proportionally with
392 humidity and temperature (US EPA, 2005a; Holb, 2003). In sufficient quantities, calcium released in soils
393 from lime sulfur could precipitate insoluble calcium phosphates and therefore limit the absorption of these
394 nutrients by plants (Jakobsen, 1993).

395 The available literature suggests that large volume releases of lime sulfur will adversely affect the viability
396 and reproduction of non-target microorganisms, including beneficial soil bacteria and fungi. However,
397 information was not identified on the potential or actual impacts of lime sulfur upon endangered species,
398 populations, viability or reproduction of non-target organisms and the potential for measurable reductions
399 in genetic, species or eco-system biodiversity.

400 **Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned**
401 **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)**
402 **(i)).**

403 Calcium polysulfides comprising lime sulfur are expected to rapidly dissociate in the presence of moisture
404 to form calcium cations and elemental sulfur. It is not anticipated that the amounts of calcium and sulfur
405 resulting from lime sulfur applications will be significant when compared to natural background levels of
406 these chemical species in the environment. Due to its limited water solubility, elemental sulfur is relatively
407 immobile in soils and is not expected to leach into lower soil horizons or groundwater. Sulfur is converted
408 to sulfate (SO_4^{2-}) under aerobic (oxidizing) conditions, while anaerobic (reducing) conditions result in the
409 formation of toxic hydrogen sulfide (H_2S). However, the possibility of H_2S formation is low because sulfur
410 is relatively immobile and will likely be subjected to oxidation before reaching reducing environments in
411 lower soil horizons. Binding of calcium ions to cation exchange sites in soils limits the mobility of calcium
412 in the environment (US EPA, 2005a).

413 The environmental toxicity of lime sulfur varies depending on conditions and the species under
414 consideration. Lime sulfur is moderately toxic to mammals, slightly to practically nontoxic to birds, and
415 practically nontoxic to honey bees. In contrast, several peer-reviewed studies have demonstrated
416 sensitivity of beneficial insects, such as *Leptomastix dactylopii* (a parasitic wasp) and *Amblyseius herbicolus* (a
417 predatory mite), as well as larvicidal activity against the predatory insect, *Chrysoperla externa* (US EPA,

418 2005a; Venzon, 2013). Although some plants are less sensitive, leaf damage and other signs of phytotoxicity
419 are commonly observed in treated plants as a result of fungicidal and insecticidal lime sulfur spray
420 applications. It is highly probable that both target and non-target plants, insects, mites and fungi will be
421 impacted by lime sulfur treatments to some extent due to direct application and/or spray drift to
422 neighboring areas.

423 **Evaluation Question #10: Describe and summarize any reported effects upon human health from use of**
424 **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**
425 **(m) (4)).**

426 Based on the available mammalian toxicity data, lime sulfur is considered moderately toxic via ingestion
427 and highly irritating to the eyes, skin and respiratory tract. An acute oral toxicity study in rats
428 demonstrated that lime sulfur is moderately toxic to mammals through direct ingestion of the substance
429 (US EPA, 2005a). The human health risks associated with ingestion of calcium polysulfides from lime
430 sulfur applications to foods are generally considered low due to rapid breakdown of the substance in the
431 environment (US EPA, 2005b). Labels for EPA-registered products containing lime sulfur indicate that the
432 substance is corrosive and may cause irreversible eye damage and skin burns following contact
433 (Tessenderlo, 2013). These irritating effects are largely due to the high alkalinity of lime sulfur solutions
434 and its rapid degradation to sulfur and calcium hydroxide [Ca(OH)₂], the latter of which also produces
435 high pH aqueous solutions. Indeed, US EPA classified calcium hydroxide as a highly toxic (Toxicity
436 Category I) due to primary eye irritation and potentially irreversible eye damage associated with the high
437 pH of its solutions in water (US EPA, 2005b). Applicators are therefore advised to wear personal protective
438 equipment (PPE) and exercise extreme caution during the preparation and application of lime sulfur
439 solutions in agricultural settings.

440 Poisoning incidents associated with lime sulfur exposure have been reported to multiple state agencies.
441 The California Department of Pesticide Regulations received 10 reports of acute symptoms in humans –
442 ranging from headache, dizziness and eye irritation to nausea, vomiting and diarrhea – following exposure
443 to lime sulfur through the Pesticide Illness Surveillance Program between 1992 and 2011. Over the same
444 time period, another 16 poisoning cases were reported involving exposure to mixtures of lime sulfur and
445 other substances, such as the organophosphate insecticide chlorpyrifos (CDPR, 2011). Combinations of lime
446 sulfur with acids, acid species and certain fertilizers may result in the release of deadly hydrogen sulfide
447 gas. The Occupational Safety and Health Administration (OSHA) for the state of Oregon provided the
448 following details for a poisoning incident with hydrogen sulfide formed via the reaction of lime sulfur and
449 fertilizer (OR-OSHA, 2014):

450 *An orchard worker was admitted to the hospital after attempting to fill a 325-gallon poly tank, which had*
451 *approximately 30 gallons of lime sulfur in the bottom, with NPK 5-10-10 fertilizer. The worker noticed an*
452 *odor and had difficulty breathing as he filled the tank. Before the tank was half full, the worker had passed*
453 *out, and when emergency medical services arrived, he was in convulsions. He was admitted to the intensive*
454 *care unit with respiratory failure, life-threatening metabolic acidosis, coma, and hematuria.*

455 At sufficiently high concentrations, gaseous hydrogen sulfide can be deadly via inhalation exposure. The
456 effects of brief exposure to hydrogen sulfide can range from inflammation and irritation of the eyes to
457 unconsciousness, respiratory paralysis and death. The immediately dangerous to life or health (IDLH) level
458 for hydrogen sulfide is 100 parts per million (OR-OSHA, 2014). Use of insecticidal and fungicidal lime
459 sulfur treatments is unlikely to result in the exposure of organic agricultural workers to hazardous levels of
460 hydrogen sulfide, as these solutions are prepared in the absence of acids and synthetic phosphate fertilizers
461 in accordance with organic practices.

462 Humans should not be chronically exposed to lime sulfur based on the current use pattern of the substance
463 and rapid breakdown in the environment. US EPA therefore waived the requirements for chronic toxicity
464 studies in terrestrial animals used to extrapolate to human health impacts (US EPA, 2005a).

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

468 A number of naturally occurring, non-synthetic substances exist for the management of insect pests and
469 plant diseases. Natural sources of elemental sulfur have been used to manage grapevine powdery mildew
470 for almost 200 years (Vasquez, 2009); however, the sulfur used in modern formulated products is likely
471 produced synthetically from fossil fuels (Nehb & Vydra, 2006). Sulfur operates through a multi-site mode
472 of action involving inhibition of fungal spore germination and production of toxic vapors that impair
473 cellular respiration in target organisms (Vasquez, 2009).

474 Biofungicides containing microorganisms as the active ingredient are also commercially available.
475 Beneficial microorganisms provide control of plant diseases through various modes of action: (1)
476 outcompeting the pathogen for nutrients or space, (2) producing a chemical compound that acts against the
477 pathogen, (3) directly attacking the pathogen, and/or (4) triggering a defensive response in the host plant
478 that limits the invading ability of the pathogen (Swain, 2014). For example, the gram-positive bacterium
479 *Bacillus subtilis* is used as the active ingredient in several biological fungicides, including the Serenade
480 products manufactured by Bayer CropScience, by producing proteins that inhibit spore germination in
481 fungi that cause powdery mildew and other plant diseases (Vasquez, 2009). Likewise, the gram-negative
482 bacterium *Pseudomonas fluorescens* (Frostban™ by Nufarm Americas, Inc) is used as a foliar spray to
483 compete with fire blight bacterium for nutrients in apple and pear tree blossoms. Biofungicides work best
484 when applied preventatively (Swain, 2014).

485 Natural products and horticultural oils derived from plant sources are commonly used to combat insects,
486 mites and plant diseases. Sabadilla alkaloids derived from the seeds of the sabadilla lily are botanical
487 insecticides with activity against caterpillars, leaf hoppers, thrips, stink bugs and squash bugs (Pottorff,
488 2010). For example, Veratran D® is an OMRI-listed botanical insecticide used to control thrips on citrus,
489 avocados and mangos (MGK, 2014). Likewise, pyrethrum extracted from the chrysanthemum plant
490 contains the active ingredient, pyrethrin, which is widely used as a fast-acting insecticide. Neem oil
491 containing the active ingredients azadirachtin and salannin is a botanical fungicide, insecticide and
492 miticide derived from the neem tree (Pottorff, 2010). Commercially available neem oil products, such as the
493 OMRI-listed product Neem Oil 70% manufactured by Certis USA, are used to control aphids, psyllids,
494 mealybugs, leafhoppers and scale insects, as well as anthracnose, scab, and leaf blight on a variety of crops
495 and ornamentals (Certis USA, 2014). Horticultural oils produced synthetically are included on the National
496 List for organic crop production (see below).

497 In addition to naturally occurring materials, several synthetic substances are also permitted for use as
498 insecticides (including acaricides for mite control) and plant disease control agents in organic crop
499 production:

- 500 • **Elemental sulfur.** Synthetic elemental sulfur is approved for use in organic crop production as an
501 insecticide (7 CFR 205.601(e)(5)) and for plant disease control (7 CFR 205.601(i)(10)) without
502 restrictions.
- 503 • **Horticultural oils.** These substances are allowed for use as insecticides in organic crop production
504 (7 CFR 205.601(e)(8)). In addition, narrow range oils, such as dormant, suffocating and summer oils
505 may be used for plant disease control (7 CFR 205.601(i)(7)).
- 506 • **Aqueous potassium silicate (CAS # 1312-76-1).** According to the final rule, the silica used in the
507 manufacture of potassium silicate must be sourced from naturally occurring sand when used in
508 organic crop production as an insecticide/miticide (7 CFR 205.601(e)(2)) and for plant disease
509 control (7 CFR 205.601(i)(1)).
- 510 • **Ammonium carbonate.** The substance is allowed for use in organic crop production as bait in
511 insect traps only; it may not come into contact with crops or soils (7 CFR 205.601(e)(1)).
- 512 • **Boric acid.** The substance may be used in organic crop production for structural pest control only;
513 it may not come into contact with organic foods or crops (7 CFR 205.601(e)(3)).
- 514 • **Copper sulfate.** As an insecticide, only allowed for use as tadpole shrimp control in aquatic rice
515 production. Treatments are limited to one application per field during any 24-month period.
516 Application rates are limited to levels which do not increase baseline soil test values for copper
517 over a timeframe agreed upon by the producer and accredited certifying agent (7 CFR
518 205.601(e)(4)). The substance may also be used for plant disease control in a manner that minimizes
519 accumulation of copper in soil (7 CFR 205.601(i)(3)).

- 520 • **Coppers, fixed.** Copper hydroxide, copper oxide, copper oxychloride (includes products exempted
521 from EPA tolerance) may be used for plant disease control provided that copper-based materials
522 are used in a manner that minimizes accumulation in the soil and shall not be used as herbicides (7
523 CFR 205.601(i)(2)).
- 524 • **Sticky traps/barriers.** These materials are allowed for use as insect control agents in organic crop
525 production (7 CFR 205.601(e)(9)).
- 526 • **Sucrose octanoate esters (CAS #s 42922-74-7; 58064-47-4).** A biochemical insecticide/miticide
527 manufactured from sugar and vegetable oil-derived fatty acids. The substance kills either by rapid
528 suffocation or by removing the insects' protective coating, causing them to desiccate (US EPA,
529 2006). The insecticide/miticide may be used in organic crop production in accordance with
530 approved labeling (7 CFR 205.601(e)(10)).
- 531 • **Hydrated Lime.** Allowed for use as a plant disease control agent in organic crop production (7 CFR
532 205.601(i)(5)).
- 533 • **Hydrogen peroxide.** Allowed for use as a plant disease control agent in organic crop production (7
534 CFR 205.601(i)(6)).
- 535 • **Peracetic acid.** Used to control fire blight bacteria. Also permitted in hydrogen peroxide
536 formulations as allowed in §205.601(i) at a concentration of no more than 6% as indicated on the
537 pesticide product label (7 CFR 205.601(i)(8)).
- 538 • **Potassium bicarbonate.** Allowed for use as a plant disease control agent in organic crop
539 production (7 CFR 205.601(i)(9)).
540

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

543 Crop rotation and the incorporation of cover crops are commonly employed methods of controlling soil-
544 borne pests and pathogens in annual cropping systems. However, these methods do not address the foliar
545 pests of perennial fruit trees, grape vines and bushes (e.g., raspberries and blackberries) typically treated
546 with lime sulfur to control insects, mites and diseases caused by various plant pathogens. Despite these
547 limitations, several alternative strategies have been developed to minimize the use of chemical fungicides
548 on perennial crops.

549 Providing effective control of plant diseases on tree crops and ornamentals requires an integrated
550 approach. Starting with certified and disease-free plant material will allow for faster growth and
551 heightened resistance to environmental stressors and less susceptibility to fungal pathogens (Holb, 2009).
552 Using apple scab control as an example, sanitation practices such as picking up and disposing of fallen
553 leaves in the fall can be effective for smaller operations but is not always practical for large orchards. In
554 conventional production, urea can be applied to apple trees just before leaves drop or directly to leaves on
555 the ground followed by tilling the fallen leaves into the soil or chopping them into small pieces to
556 accelerate leaf decomposition. This practice significantly decreases the amount of apple scab pathogen
557 available the next growing season (Vaillancourt, 2005). Although similar mechanical strategies can be
558 employed in organic orchards, urea—a synthetic nitrogen fertilizer—is not approved for use in organic
559 crop production. Flaming using a torch-directed flame sears the leaf litter on the orchard floor and ruptures
560 fungal cells on the affected leaves (Holb, 2009). Regular pruning of apple trees enables direct management
561 of several fungal diseases through removal of diseased shoots, fruit, stems or dead wood that can harbor
562 pathogens (Holb, 2009). Pruning also enhances air movement and the penetration of sunlight within the
563 canopy, thus hastening the drying process for leaves and fruit. Likewise, it is generally recommended that
564 growers avoid overhead irrigation, especially when weather conditions are favorable for apple scab
565 development. Both of the latter two strategies minimize the occurrence of moist conditions that support
566 fungal infections (Vaillancourt, 2005; Holb, 2009).

567 Several related cultural practices are frequently used for insect and mite control. In addition to minimizing
568 pathogen levels, prudent sanitation practices can also minimize the occurrence of pest insects. Examples of
569 sanitation include the “removal of weeds in greenhouses that may harbor mites, aphids or whiteflies;
570 destruction of crop residues such as corn stubble, squash vines or fall apples that may be overwintering
571 sites for pests; and removal of manure that provides breeding sites for flies” (Mahr, 1993). Intercropping or
572 companion cropping can be used to repel pest insects or attract beneficial insects that attack the insects. For

573 example, trap cropping can be used to lure pest insects away from vulnerable crops (Hillock, undated).
574 This process involves the planting of a preferred food source for a specific pest insect in close proximity to
575 the protected crop followed by destruction of the trapping crop once infested with insects. Planting buffer
576 strips to create environments for insects like ladybugs, lacewings and other beneficial insect predators is
577 another natural way of controlling pest insects (Xerces Society, 2014).

578 The cultural practices summarized above may minimize but are unlikely to eliminate the need for natural
579 or synthetic pesticides during periods of intense insect and disease pressure. Alternative substances to lime
580 sulfur for insect, mite and plant disease control are summarized in Evaluation Question #11.

581 **References**

- 582 Bauernfeind RJ, Cloyd RA. 2012. Lime-Sulfur: A Multi-Use Pesticide. Kansas Insect Newsletter. Kansas
583 State Research and Extension. Retrieved October 16, 2014 from [http://entomology.k-](http://entomology.k-state.edu/doc/extension-newsletters/ks-insect-newsletter-14-1.pdf)
584 [state.edu/doc/extension-newsletters/ks-insect-newsletter-14-1.pdf](http://entomology.k-state.edu/doc/extension-newsletters/ks-insect-newsletter-14-1.pdf).
- 585 Beffa T. 1993. Inhibitory action of elemental sulphur (S⁰) on fungal spores. Canadian journal of
586 microbiology 39: 731–735.
- 587 CAN. 2011. Organic Production Systems Permitted Substances Lists: CAN/CGSB-32.311-2006. Canadian
588 General Standards Board. Retrieved October 20, 2014 from [http://www.tpsgc-pwgsc.gc.ca/ongc-](http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/programme-program/normes-standards/internet/bio-org/documents/032-0311-2008-eng.pdf)
589 [cgsb/programme-program/normes-standards/internet/bio-org/documents/032-0311-2008-eng.pdf](http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/programme-program/normes-standards/internet/bio-org/documents/032-0311-2008-eng.pdf).
- 590 C DPR. 2011. Pesticide Illness Surveillance Program. California Department of Pesticide Regulation.
591 Retrieved November 18, 2014 from <http://www.cdpr.ca.gov/docs/whs/pisp.htm>.
- 592 CUES. 2002. A History of Crop Protection and Pest Control in our Society. Center for Urban Ecology and
593 Sustainability. University of Minnesota. Retrieved October 20, 2014 from
594 <http://www.entomology.umn.edu/cues/ENT50092011/insecticides/PesticideUSHistory.pdf>.
- 595 Certis USA. 2014. Master Label/Sublabel A – Neem Oil 70%. Retrieved October 27, 2014 from
596 http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:102:::NO::P102_REG_NUM:70051-2.
- 597 Clemson. 2014. Chronological History of the Development of Insecticides and Control Equipment from
598 1854 through 1954. Clemson University. Retrieved October 20, 2014 from
599 http://www.clemson.edu/extension/pest_ed/histor.html.
- 600 Codex. 2013. Guidelines for the Production, Processing, Labeling, and Marketing of Organically Produced
601 Foods. Codex Alimentarius Commission. Retrieved October 20, 2014 from
602 http://www.codexalimentarius.org/standards/list-of-standards/en/?no_cache=1.
- 603 EC. 2008. Commission Regulation (EC) No. 889/2008. European Commission. Retrieved October 20, 2014
604 from <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:250:0001:0084:EN:PDF>.
- 605 HSDB. 2003. National Library of Medicine, TOXNET. *Lime Sulfur*. Hazardous Substances Data Bank.
606 Retrieved October 16, 2014 from <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>.
- 607 Hajjatie MM, III HCK, Aspengren MD, Clarkson MP, Lockhart CLF. 2006. Sulfiding calcium hydroxide
608 with sulfur to form calcium polysulfide, cooling to oxidation, filtering to get a pure concentrate clarity
609 product; by-product inhibition, efficiency; optional starting material calcium oxide. Patent # US6984368 B2.
610 Retrieved October 16, 2014 from <http://www.google.com/patents/US6984368>.
- 611 Hillock D, Borthick C. Undated. Earth-Kind Gardening Series: Cultural Control Practices. Oklahoma
612 Cooperative Extension Service. Retrieved October 27, 2014 from
613 <http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2297/HLA-6431web.pdf>.
- 614 Holb IJ. 2009. Fungal Disease Management in Environmentally Friendly Apple Production – A Review. In
615 *Climate Change, Intercropping, Pest Control and Beneficial Microorganisms* (E. Lichtfouseed.), pp. 219–292,
616 Springer Netherlands, Dordrecht.

- 617 Holb IJ, Schnabel G. 2008. A detached fruit study on the post-inoculation activity of lime sulfur against
618 brown rot of peach (*Monilinia fructicola*). *Australasian Plant Pathology* 37: 454; doi:10.1071/AP08041.
- 619 Holb IJ, Jong P de, Heijne B. 2003. Efficacy and phytotoxicity of lime sulphur in organic apple production.
620 *Annals of Applied Biology* 142: 225–233.
- 621 IFOAM. 2014. The IFOAM Norms for Organic Production and Processing. International Federation of
622 Organic Agriculture Movements, August 2014. Retrieved October 20, 2014 from
623 <http://www.ifoam.org/en/ifoam-norms>.
- 624 JMAFF. 2005. Japanese Agricultural Standard for Organic Plants (Notification No. 1605). Japanese Ministry
625 of Agriculture, Forestry and Fisheries. Retrieved October 20, 2014 from
626 http://www.maff.go.jp/e/jas/specific/pdf/833_2012-3.pdf.
- 627 Jakobsen ST. 1993. Interaction between Plant Nutrients: IV. Interaction between Calcium and Phosphate.
628 *Acta Agriculturae Scandinavica, Section B – Soil & Plant Science* 43(1): 6–10;
629 doi:10.1080/09064719309410224.
- 630 Janssen D. 2002. Lime-Sulfur: A fungicide used to control a variety of diseases. University of Nebraska-
631 Lincoln Extension in Lancaster County. Retrieved October 16, 2014 from
632 <http://lancaster.unl.edu/hort/articles/2002/lime-sulfur.shtml>.
- 633 MGK. 2014. Veratran D®. MGK Insect Control Solutions. Retrieved October 27, 2014 from
634 <http://www.mgk.com/crop-protection/veratran-d/>.
- 635 Mahr DL, Ridgway NM. 1993. Biological control of insects and mites: An introduction to beneficial natural
636 enemies and their use in pest management. University of Wisconsin. Retrieved October 27, 2014 from
637 <http://www.entomology.wisc.edu/mbcn/fea102.html>.
- 638 NPIRS. 2013. Search Federal Pesticide Products. National Pesticide Information Retrieval System. Retrieved
639 October 16, 2014 from <http://ppis.ceris.purdue.edu/>.
- 640 Nehb W, Vydra K. 2006. Sulfur. In *Ullmann's Encyclopedia of Industrial Chemistry* (Wiley-VCH Verlag GmbH
641 & Co. KGaA, Weinheim, Germany).
- 642 NovaSource. 2013. Safety Data Sheet: Lime Sulfur Solution. EPA Reg No 61842-30. Retrieved October 16,
643 2014 from www.cdms.net/ldat/mpBA1001.pdf.
- 644 OMRI. 2014. Product List Search: Lime, Sulfur. Organic Materials Review Institute. Retrieved November
645 18, 2014 from <http://www.omri.org/simple-opl-search/results/Lime%20sulfur>.
- 646 OR-OSHA. 2014. Hazard Alert: Lime Sulfur reacts to form deadly Hydrogen Sulfide Gas. Oregon
647 Occupational Safety and Health Administration. Retrieved October 27, 2014 from
648 <http://www.orosha.org/pdf/hazards/2993-19.pdf>.
- 649 Oates T. 2010. Lime and Limestone. In *Kirk-Othmer Encyclopedia of Chemical Technology*, pp. 1–53, John Wiley
650 & Sons, Inc.
- 651 Plant Health Care. 2009. Effects of Fungicides on Mycorrhizal Fungi and Root Colonization. Plant Health
652 Care, Inc. Retrieved October 24, 2014 from
653 <http://www.planthealthcare.com/pdf/Myconate/Fungicide%20effects%20on%20Mycorrhizal%20Fungi%20and%20Root%20Colonization%208-2009.pdf>.
- 654
- 655 Pottorff LP. 2010. Some Pesticides Permitted in Organic Gardening. Colorado State University Cooperative
656 Extension. Retrieved October 27, 2014 from
657 <http://www.colostate.edu/Depts/CoopExt/4DMG/VegFruit/organic.htm>.
- 658 Russell PE. 2005. A century of fungicide evolution. *The Journal of Agricultural Science* 143: 11–25;
659 doi:10.1017/S0021859605004971.

- 660 Van Slyke LL, Bosworth AW, Hedges CC. 1910. Bulletin No. 329. Chemical Investigation of Best Conditions
661 for Making the Lime-Sulfur Wash. Retrieved October 16, 2014 from
662 <http://ecommons.library.cornell.edu/handle/1813/4230>.
- 663 Soil Association. 2014. Soil Association organic standards, farming and growing. Revision 17.2. United
664 Kingdom Soil Association. Retrieved October 20, 2014 from
665 <http://www.soilassociation.org/organicstandards>.
- 666 Swain S. 2014. Biological Fungicides: Do They Work and Are They Safe? University of California
667 Cooperative Extension | Agricultural Experiment Station. Retrieved October 27, 2014 from
668 <http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=13543>.
- 669 Tessenderlo. 2013. Label: Lime-Sulfur Solution. Tessenderlo Kerley, Inc. Retrieved October 16, 2014 from
670 http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:102::NO::P102_REG_NUM:61842-30.
- 671 Tomlin C. 1994. Pesticide Manual 10th edition. British Crop Protection Council. Cambridge, U.K.: The Royal
672 Society of Chemistry.
- 673 US EPA. 2006. Sucrose Octanoate Esters (035300) Fact Sheet & Sorbitol Octanoate (035400). US
674 Environmental Protection Agency. Retrieved October 27, 2014 from
675 http://www.epa.gov/opp00001/chem_search/reg_actions/registration/fs_G-108_10-Jan-06.pdf.
- 676 US EPA. 2005a. Environmental Fate and Ecological Risk Assessment for the Reregistration Eligibility
677 Decision Document (RED) of Calcium Polysulfides, a Fungicide/Acaricide. US Environmental Protection
678 Agency, October 2005. Retrieved October 16, 2014 from
679 <http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2007-0008-0004>.
- 680 US EPA. 2005b. Reregistration Eligibility Decision for Inorganic Polysulfides. US Environmental Protection
681 Agency, September 2005. Retrieved October 16, 2014 from
682 <http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2007-0008-0002>.
- 683 VGS. 2006. Material Safety Data Sheet: Aqua Clear product containing Calcium Polysulfide. Value Garden
684 Supply. Retrieved October 17, 2014 from www.calciumpolysulfide.com/msds.pdf.
- 685 Vaillancourt LJ, Hartman JR. 2005. Apple scab. American Phytopathological Society; doi: 10.1094/PHI-I-
686 2000-1005-01. Retrieved October 27, 2014 from
687 <http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/AppleScab.aspx>.
- 688 Vasquez SJ. 2009. Minimizing fungicide resistance. University of California Cooperative Extension |
689 Agricultural Experiment Station. Retrieved October 27, 2014 from
690 <http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=1185>.
- 691 Venzon M, Oliveira RM, Perez AL, Rodríguez-Cruz FA, Martins Filho S. 2013. Lime sulfur toxicity to broad
692 mite, to its host plants and to natural enemies: Toxicity of lime sulfur. *Pest Management Science* 69: 738-
693 743; doi:10.1002/ps.3431.
- 694 Wood CD. 1928. Method of making calcium polysulphide. Patent # US1685895 A. Retrieved October 15,
695 2014 from <http://www.google.com/patents/US1685895>.
- 696 Xerces Society. 2014. *Farming with Native Beneficial Insects: Ecological Pest Control Solutions*. Storey
697 Publishing, North Adams, MA.