United States Department of Agriculture
Agricultural Marketing Service | National Organic Program

Document Cover Sheet

Document Type:

☒ **National List Petition or Petition Update**

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

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Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (NOSB) [7 CFR 205.607(a)].

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☐ **Technical Report**

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Read more about the technical report process in section **H. SUBSTANCE/MATERIALS REVIEW PROCESS** in the NOSB Policy & Procedures Manual posted on the AMS website.

www.ams.usda.gov/sites/default/files/media/NOSB-PolicyManual.pdf

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Petition for the Inclusion of Potassium Sorbate in § 205.601, Synthetic Substances Allowed for Use in Organic Crop Production.

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Petition for the inclusion of potassium sorbate (KS) in § 205.601, Synthetic Substances Allowed for Use in Organic Crop Production. August 2025

Item A.1 — Indicate which section or sections the petitioned substance will be included on and/or removed from the National List.

Petitioning for the inclusion of potassium sorbate (KS) in **§ 205.601**, Synthetic Substances Allowed for Use in Organic Crop Production.

Item A.2 – OFPA Category—Crop and Livestock Materials.

Potassium sorbate is petitioned for use as a "Production Aid" for providing pest control of crop pathogens through foliar applications and to give organic farmers a cost-effective alternative for reducing the use of harmful organic approved substances, namely, sulfur, copper, and petroleum oils.

Item A.3 – Inert Ingredients

NA

Item B.1—Substance Name

Potassium sorbate (CAS 24634-61-5) is the potassium salt of sorbic acid, chemical formula $CH_3CH=CH-CH=CH-CO_2K$.

Item B.2-- Petitioner and Manufacturer Information

Petitioner: Ronald Lane **[1] [Appendix A]**, Circadian Crop Sciences, LLC, PO Box 456, Weimar, CA 95736 phone 530 333-7183. California licensed Pest Control Advisor #168745.

Potassium Sorbate Manufacturer: Shandong Sparrow Chemical Co., LTD, Room 2302, 23 Floor, Cloud Access Space, Hanyu Finance Valley A8-1, Jingshi Road No. 7000, High-Tech District, Ninan City, Shandong Province. Phone: 86 531-67865410 Email: Export006@sparrowchemical.com

Item B.3 --Intended or Current Use

Potassium Sorbate (KS) is the active ingredient in the FIFRA 25(b) pesticide, All Phase, and the intended use would be similar to how All Phase is currently used as **a foliar spray with a concentration of 100 to 2,100 ppm** of potassium sorbate in the spray solution **(2) [Appendix B]**. All Phase is intended for use on agricultural crops and landscape plants for preventing bacterial and fungal diseases, such as powdery mildews, botrytis, peach leaf curl, brown rot, aspergillus, rusts, and bacterial leaf spots. All Phase solutions are intended for use as a foliar spray with sufficient volume to ensure uniform coverage to the point of saturation. All Phase may be used outdoors and within greenhouses and interiorscapes. All Phase contains 2% sodium lauryl sulfate by weight. Sodium Lauryl Sulfate is GRAS, but is not allowed for organic food production. If potassium sorbate gets approval for organic use, then a sodium lauryl sulfate free version of All Phase would be produced and growers would then be required to add in a decent wetting agent to their spray solutions for best results.

Item B.4 -- Intended Activities and Application Rates

It is intended that potassium sorbate be allowed for use as an active ingredient in foliar and seed applied fungicides and bactericides for organic production of food and ornamental crops.

All Phase (34.7% KS by weight) is labelled for use as a fungicide/bactericide on grapes, caneberries, strawberries, blueberries, hops, herbs, tobacco, row crops, fruit bearing trees, ornamental plants, nursery plants, and landscape plants for control of powdery mildews, rusts, anthracnose, bacterial leafspots, botrytis, aspergillus, peach leaf curl, brown rot blossom blight and brown rot and root diseases such as fusarium spp. pythium spp. **[Appendix B]**. Applications in the range of 100 to 2000 ppm are consistent with use in preserving foods **(3)** and good efficacy has been achieved in controlling plant pathogens in the field in this range as well, which will be elaborated upon in the research section of this document. All Phase is labeled for spray applications at 1 to 6 teaspoons per gallon (1 to 7.3 gm of potassium sorbate per gallon) in sufficient volume to provide uniform coverage (generally 50 to 150 gallons/acre) which is 100 to 1,100 grams of potassium sorbate per acre [Appendix B].

Item B.5—Manufacturing Potassium Sorbate: An Overview

Potassium sorbate is a widely used preservative in the food, beverage, cosmetic, and pharmaceutical industries due to its ability to inhibit the growth of mold, yeast, and some bacteria. It is derived from sorbic acid and is generally recognized as safe (GRAS) by regulatory bodies. Below is an overview of the manufacturing process, highlighting key steps and considerations **[4]**.

Raw Materials

The primary raw materials used in the production of potassium sorbate include:

1. **Sorbic Acid**: A naturally occurring compound that serves as the precursor. It is typically synthesized through the condensation of crotonaldehyde and ketene.
2. **Potassium Hydroxide (KOH)**: A strong base used to neutralize sorbic acid.
3. **Water**: Used as a medium for the neutralization reaction.

Production Process

1. Synthesis of Sorbic Acid

The first step involves the production of sorbic acid through industrial chemical processes:

- **Reactants**: Ketene and crotonaldehyde are reacted under specific conditions.
- **Catalysts**: The reaction typically requires acidic catalysts to ensure high yield.
- **Purification**: The crude sorbic acid is purified by recrystallization or distillation to remove impurities.

2. Neutralization Reaction

The neutralization of sorbic acid with potassium hydroxide forms potassium sorbate:

- **Reaction Equation**:$C_6H_8O_2$(sorbic acid)+KOH→$KC_6H_7O_2$(potassium sorbate)+H_2O
- **Procedure**:
    - Sorbic acid is dissolved in water to form an aqueous solution.
    - Potassium hydroxide is gradually added while maintaining a controlled temperature (typically between 20°C and 50°C) to prevent thermal degradation.
    - The reaction mixture is stirred until the neutralization is complete, as indicated by pH monitoring (target pH around 7).

3. Drying and Granulation

- After the neutralization step, the potassium sorbate solution is concentrated through evaporation.
- The concentrated solution is then spray-dried or crystallized to obtain solid potassium sorbate.
- The product is further processed into granules or powders, depending on its intended application.

4. Quality Control

The final product is subjected to rigorous testing to ensure compliance with industry standards, including:

- Purity levels (typically >99%).
- Absence of heavy metals and other contaminants.
- Particle size distribution.

Safety and Environmental Considerations

- **Safety**: Potassium hydroxide (also used in the manufacturing of OMRI listed soaps) is highly caustic and requires proper handling and safety protocols.
- **Waste Management**: Effluent and by-products from the synthesis and neutralization processes must be treated to prevent environmental contamination.

Item B.6 – Ancillary Substances

NA

Item B.7A – Previous Reviews

1. 2002 NOSB Executive Summary Potassium Sorbate Inclusion as Approved Synthetic Pesticide
2. 2023 PETITION TO ADD POTASSIUM SORBATE TO §205.601(e) AND §205.601(i) OF THE NATIONAL LIST
3. 2023 NOSB Recommendation on adding potassium sorbate to §205.601(e) and §205.601(i) of the National list

The 2002 NOSB Technical Advisory Panel unanimously chose to exclude potassium sorbate from inclusion in organic farming on the basis of: 1. A specific polymer was not identified. 2. Target pests and mode-of-action were not specified. 3. Justification for use in organic production was incomplete. 4. They found the substance as synthetic. 5. Considered incompatible with organic farming practices.

The 2023 NOSB panel found: 1. Many alternative products and cultural practices exist. 2. Need for more information on KS interaction with other crop inputs and how it interacts with soil microorganisms, its persistence in the environment or persistence of its biproducts. 3. Possible DNA mutagenicity. 4. Concern over KOH as a biproduct in the environment. 5. KS is not made from renewable resources. 6. KS does not complement the use of natural biological controls.

Item B.7B – Petitioner's Response to Previous Reviews

This petition builds upon previous petitions and addresses concerns from NOSB technical panels.

2002 NOSB Technical Advisory Panel-- A specific polymer was not identified

Concerns over polymers formulated with potassium sorbate are irrelevant as long as the polymers are approved as inert ingredients for organic food production. In All Phase the polymers are identified and approved as inert pesticide ingredients for organic food production.

2002 NOSB Technical Advisory Panel-- Target pests and mode-of-action were not specified

Target pests for this petition are shown in the label for All Phase **[Appendix B]**. Control of peach leaf curl, brown rot, and powdery mildews are important targets that potassium sorbate has shown good efficacy controlling in university field trials [Petition Sec. B.12].

Multiple modes of action for potassium sorbate are documented, primarily relating to shutting down cellular metabolism in various ways and compromising spore germination [Petition Sec. B.12]. On the other hand, sulfur, the most widely used agricultural pesticide, organic or otherwise, has no documented mode of action unless it changes into something else in the field [1].

The 2002 NOSB found justification for use in organic production was incomplete.

Section B.13 of this petition provides a more comprehensive justification. Although alternatives to potassium sorbate exist, potassium sorbate offers a combination of efficacy, cost, and favorable human health and environmental characteristics that make it a practical alternative to sulfur, copper, and petroleum oils for the control of many agricultural diseases [1]. Reducing reliance on sulfur, copper, and petroleum oils should be a priority because these synthetic materials are the most widely used pesticides in organic production and are often applied at rates far exceeding crop nutritional requirements or residue levels needed for disease control, contributing to adverse environmental and human health impacts (see Petition Section B.13).

The technical panel found potassium sorbate is synthetic.

It is important to note, however, that the origin of a molecule does not change its intrinsic chemical identity. For example, carbon dioxide produced by human respiration is chemically identical to carbon dioxide produced by the combustion of gasoline, and both are naturally present in the atmosphere. Likewise, potassium sorbate occurs naturally in certain plants and is chemically identical whether it is obtained from natural sources or produced through synthesis. Although the potassium sorbate proposed in this petition is synthetically manufactured, its molecular structure and chemical properties are identical to those of the naturally occurring compound.

Accordingly, this petition seeks to add potassium sorbate to the National List of allowed synthetic substances for use in organic crop production. This request is consistent with the National List, which already includes several synthetic crop protection materials when they provide a significant benefit to organic agriculture and no suitable natural alternative exists. Notably, sulfur, copper, and petroleum oils are synthetic materials currently allowed for organic crop production. Potassium sorbate has the potential to reduce reliance on these materials while providing a favorable human health and environmental profile.

The 2002 NOSB found that many options to potassium sorbate exist.

The 2002 NOASB did not elaborate upon these options. This petitioner does not believe cost effective, reliable, and environmentally sound options exist. Sulfur, petroleum-based oils and copper are not good alternatives to potassium sorbate [Petition Sec. B.13] and they are the most commonly used pesticides used by organic farmers. Farmers using potassium sorbate for pest control are practicing farming that is better for sustainability, and the health of the environment and farming community than organic growers relying upon the organic approved options: sulfur, copper, and highly refined petroleum oils [Petition Sec. B.13]. That doesn't seem right. Shouldn't organic farming be the healthiest and most sustainable option? Isn't that what the NOSB should be working for? The OFPA has given the NOP the power to evolve practices over time, as standard practices are shown to be incompatible with the goals of the OFPA and new, better practices or chemistries, come to light.

Are there safe, reliable and cost-competitive organic approved options to sulfur and organic approved petroleum oils for controlling powdery mildews?

Soaps are ineffective unless combined with an essential oil, in which case the essential oil is doing most of the work and the material costs are too expensive for most commercial farms [1].

Mycofungicides have inconsistent or poor results in university field trials for controlling foliar diseases **[5]** and if growers were finding them cost effective alternatives to sulfur, copper, and petroleum oils they would be using these alternatives more and abandoning use of these harmful pesticides.

Neem oil has some efficacy in controlling powdery mildews, but its efficacy is not on the same level as sulfur and petroleum oils for controlling powdery mildews, plus neem oils are considerably more costly and greatly reduce photosynthesis in plants for days following an application [1].

A polyoxin D zinc salt is an active ingredient in an organic pesticide. It is reliably effective, but expensive ($40 to $80/acre/application for a vineyard) and it does introduce another heavy metal into the environment, albeit at a much more sustainable amount than copper [5] [1].

Hydrogen peroxide and derivatives of it are available but are expensive and are toxic to bees and kill indiscriminately [1]

When field tested by universities, most of these "many" organic options for controlling powdery mildews prove unreliable or are exorbitantly priced and have other problems **[5]**.

Are there cost competitive organic approved options to copper for controlling peach leaf curl and various other diseases controlled by copper? I don't think so, and we should reduce copper use in agriculture. Copper is a forever chemical. It never breaks down and far more of it is applied in organic production than is taken up by plants [Petition Sec. B.13]. Copper is well known to degrade soils when applied year after year in agricultural fields. Reliance upon copper for pest control is unsustainable. Copper also has concerning human health concerns [Petition Sec. B.13]. Potassium sorbate is a cost-effective alternative to copper with superior efficacy for controlling peach leaf curl. It breaks down rapidly in the environment, especially when foliar applied [Petition Sec. B.13].

Potassium sorbate is a reliable, environmentally sound, and cost-effective alternative to the most commonly used organic pesticides: sulfur, petroleum oils, and copper.

The 2002 NOSB found that potassium sorbate is inconsistent with organic farming practices.

A purpose of organic food production, as defined in the Organic Foods Production Act (OFPA) of 1990, is to:

"respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity."
(7 U.S.C. § 6502(21)).

The most widely used organic farming practices for pest control involves spraying micronized sulfur, petroleum oils, and copper, and those materials actually are inconsistent with organic farming goals [Petition Sec. B.13]. By approving potassium sorbate for organic food production, the NOSP provides a healthier and cost-effective option to these offensive organic pesticides that organic growers rely so heavily upon [Petition Sec. B.13].

Potassium sorbate has an 80-year history of safely preserving food and being consumed at far higher rates as a food additive than would be found on crops as residues from pesticide treatments [Petition Sec. B.13].

According to a previous USDA Agricultural Marketing Service's Technical Advisory Panel's report, **"Potassium sorbate is … completely safe with regard to health and have the lowest allergenic potential of all food preservatives" (7).** The same couldn't be said for sulfur, petroleum oils or copper [1] [Petition Sec. B.13]**.**

Foliar applications of potassium sorbate **will not degrade soil biodiversity** as foliar applied rates put too little potassium sorbate onto the soil to have any effect [Petition Sec. B.13]. Foliar applied potassium sorbate at 1,100 gram per acre is the highest application rate for what Circadian Crop Sciences has had field tested and is several times higher than potassium sorbate would generally be applied in the All Phase formulation [1]. Most of the potassium sorbate from a pesticide application is going to remain on the foliage, but even if every gram of that highest application rate (1,100 gm) ended up on the soil, that equates to .025 grams of potassium sorbate per square foot of soil. If that 0.025 grams were to diffuse into a cubic foot of water it would equate to 6.6 ppm (0.00066% by wt.) of potassium sorbate. This unrealistically high deposition of potassium sorbate on the soil from a foliar application is insignificant [1]. There is absolutely no reason to believe that foliar

applied potassium sorbate will change the soil biology. Potassium sorbate will also breakdown quickly in the environment into carbon dioxide and water (8). The United States Department of Agriculture (USDA) shows half-lives for potassium sorbate of 17 days in the soil, 9 days in water, and 2.6 hours in the air **[8]**. Potassium sorbate sprays are not going to build up in the environment. Compare that with organic approved copper with a half-life of forever.

Potassium sorbate is very compatible with biological pest control. It controls plant pathogens without harming beneficial insects and mites at the dosages suggested for controlling foliar plant diseases [1].

All Phase tested as non-toxic to honeybees in standardized EPA testing **[9]**.

Potassium sorbate moves systemically from foliar applications to the roots, where it can inhibit root diseases **[10]**. Soil drenching with fungicides to control root pathogens is bound to alter soil biology. The beauty of a foliar applied fungicide to control root diseases is that you preserve soil biology while slowing the growth of root pathogens that get past the soil biology and invade the root. What other organic pesticide has the potential to work so symbiotically with soil biology in protecting roots from pathogens?

The most commonly used organic pesticides (sulfur, highly refined petroleum oils, and copper) are incompatible with the sustainable farming and to the well-being of the environment and farming communities. Potassium sorbate was invented by nature and approving it's use for organic food production can make organic farming a more responsible way of farming, the way it was meant to be.

2023 NOSB panel--Many alternative products and cultural practices exist

The 2023 NOSB panel found many alternative products and cultural practices exist, but like 2002 NOSB panel didn't elaborate. Clearly, the presence of all these alternative products and cultural practices are not cutting it with growers, as they continue to rely heavily upon sulfur, copper, and petroleum pesticides. Why? Because cultural practices generally compliment the use of fungicides and do not work alone, and the alternative pesticides out there are either much more costly than sulfur, copper, and petroleum oils, or they don't work well enough to wean organic growers from relying heavily upon these harmful pesticides [1]. See response to 2002 NOSB panel.

The 2023 NOSB panel-- Need for more information on KS interaction with other crop inputs and how it interacts with soil microorganisms, its persistence in the environment or persistence of its biproducts.

As previously discussed, the amount of potassium sorbate reaching the soil from foliar applications is at most insignificant. Even if the entire spray were to leach into the soil from rainfall following an application, the concentration is too low to have an effect on microbiology. Any potassium sorbate leaching into the soil is metabolized into carbon dioxide and water with a half-life of 17 days **[8]**.

Potassium sorbate is the potassium salt of sorbic acid. Potassium is an essential plant macronutrient. Foliar applications of potassium sorbate will provide a small amount of potassium. In the case of All Phase, lab analysis shows it contains 9.5% potassium by weight **[11]**. At a rate of 2 lbs/acre, All Phase would provide 3 ounces of potassium per acre. If applied multiple times throughout a growing season you might end up contributing a little over a pound of potassium per acre, which is well below the needs of any commercial crop, so it will not build up in the environment.

2023 NOSB panel— Concern over KOH as a biproduct in the environment

KOH is a natural substance. Potassium sorbate is not KOH and KOH is also not a biproduct in the decomposition of potassium sorbate. We are talking about adding .025 grams of potassium sorbate per square foot (2.4 lb/acre) of land as a maximum, and that would only occur if it potassium sorbate is sprayed at the highest rate and there is no deposition on foliage. Even if that potassium sorbate actually was potassium hydroxide it would have no effect on soil pH. To put this into perspective let's look at a typical loam soil. They often require 2 to 4 tons of CaCO3 per acre to raise soil pH by 1.0 units in the top 6 inches. That is the equivalent of 200 to 400 lbs per acre of CaCO3 to change the pH by 0.1 units. 1 lb KOH neutralizes slightly fewer H^+ equivalents per unit mass than $CaCO_3$ (1 lb KOH ~0.892 lb CaCO3). So, it would take 225 to 450 lbs KOH/acre to raise the pH of a typical loam by 0.1 to a depth of 6 inches [1].

2023 NOSB-- Possible DNA mutagenicity.

According to 21 CFR § 582.3640, potassium sorbate is GRAS when used in accordance with good manufacturing practice (i.e. as low as needed to achieve preservation effect)**.**

Potassium sorbate has been safely used as a food preservative for some 80 years, and at concentrations far higher than would be consumed from residues that might remain on foods from pesticide sprays [1]. The EU provides for adding potassium sorbate directly to food and drink in the range of 300 to 2,000 ppm **[3]**. Humans consume these potassium sorbate treated foods and drink with regularity and without incidence. As previously discussed, a high-end foliar application rate for potassium sorbate would at most deposit around .025 grams of potassium sorbate per square foot in a flat vacant field. When you add the verticality of a plant canopy the deposition per unit area is even less. The amount of potassium sorbate that could possibly remain on treated fruits and vegetables from field applications is far below amounts allowed for in using potassium sorbate as a food preservative, and no study has documented or even implicated any genotoxic effects from potassium sorbate's use as a food preservative.

No study involving living animals has shown genotoxicity from eating a diet high in potassium sorbate. There are only studies where cell cultures are exposed to various concentrations of potassium sorbate or sorbic acid in a laboratory where any genotoxicity has been observed. Results from in vitro assays are often highly dependent on the cell line, culture conditions, and concentration tested. Consequently, a compound may appear to produce DNA damage or other adverse cellular responses in one experimental system while showing no such effects in another.**[12][13]** This dose- and model-dependent behavior has also been reported for antioxidants such as Vitamin C, retinol (Vitamin A), and Vitamin E, which are generally protective at normal dietary exposure but may exhibit pro-oxidant or other adverse effects under certain experimental conditions.**[14][15][16].**

Pongsavee & Mishra found that cultures of human lymphocyte tissues exposed to potassium sorbate concentrations as low as 0.5 mg/ml showed signs of genotoxicity **[13]**. To achieve such an exposure in the real world, one would have to consume around 25 grams of potassium sorbate in a brief period **[17].** Now remember, we have a maximum deposition of around .025 grams of potassium sorbate per square foot of surface area in treated fields and that potassium sorbate has a half-life in the air of 2.6 hours. We are talking about very low levels of human cell exposure to potassium sorbate from field applications, far below what can induce genotoxicity in certain cell lines in within a lab.

Low levels of potassium sorbate consumption might actually be good for people. Such low levels of exposure may stimulate upregulation of endogenous antioxidant enzymes and reduce bacterial endotoxins, which would tend to protect DNA. At least one study provides strong evidence that low-dose potassium sorbate exerts anti-inflammatory effects in vivo and in vitro, particularly via epigenetic regulation of inflammation genes and suppression of macrophage responses **[18].**

Rowan berries from the Rowan Tree contain 0.75% sorbic acid by dry weight, which equates to 7,500 ppm of sorbic acid **[19]**. As discussed earlier, spray solutions of All Phase will contain 100 to 2000 ppm of potassium sorbate. What is sold as food has a higher sorbic acid content than spray solutions of potassium sorbate require for controlling plant pathogens. These rowan berries have been consumed by humans and wildlife since prehistoric times and are still readily available for human consumption **[19].** You can go online right now and order rowan berry jam or liqueur or dried berries, and you can feel safe eating the sorbic acid in it without worry of genotoxicity.

The 2023 NOSB is concerned that non-renewable fossil fuels are consumed in the manufacturing of potassium sorbate. The organically approved petroleum oil sprays that can be replaced with potassium sorbate are actual petroleum oils and it takes energy to refine crude oil to create these oils. Mineral oils and paraffinic oils are names that sound warm and fuzzy, but they are biproducts of refining crude petroleum oil into gasoline. Even through it may require less energy to produce a kg of highly refined oil than a kg of potassium sorbate, the typical application rate of potassium sorbate uses so much less material per acre that 10x less fossil fuel is likely consumed per acre per treatment, and even at the highest application rate, potassium sorbate still uses 2x less fossil fuel per acre than a mineral oil **[see Appendix D; Reference 20]**. As an alternative to these highly refined petroleum oils, potassium sorbate greatly reduces the use of fossil fuels.

Copper and micronized sulfur products take energy to mine and to mill, and are synthetically derived, but likely represent a lower fossil fuel impact than most pesticides [1]. They, along with petroleum oils and other chemicals are approved synthetic active ingredients for organic pesticide under **7 CFR § 205.601** of the **Organic Foods Production Act of 1990**. They also have some serious negative impacts on human health and the environment [Petition Sec. B.13].

The 2023 NOSB panel believes that potassium sorbate is not compatible with biological controls. I am not sure why the panel came to such a conclusion. Potassium sorbate as a fungicide is as compatible as it gets when it comes to biological pest control [1]. Potassium sorbate is not a contact insecticide or miticide. It does not indiscriminately kill beneficial insects and mites like organic approved sulfur and petroleum oils do [1]. When growers use organic sulfur and petroleum oils to control plant diseases, they are also killing beneficial insects and mites [1]. Potassium sorbate cost effectively controls these same diseases, yet preserves the beneficial insects and mites. I've seen this first hand, many times and there is no reason to believe it would have any pesticidal activity upon them [1].

For controlling soil pathogens, potassium sorbate as a soil drench would probably alter soil biology, as would the addition of any other fungicidal drench [1]. That is the point of adding a fungicide to the soil. Even adding beneficial soil fungi and bacteria to soils changes the soil biology [1]. A good strategy for controlling soil pathogens starts with creating soil biology favorable for plant growth and inhibitory to plant pathogenic organisms. Potassium sorbate as a foliar spray works complimentary to the soil biology [1].

Note: this petition is for the organic use of foliar applied potassium sorbate, not for use as a soil drench. The petitioner does not see a big need for using potassium sorbate as a soil drench, though it is very unlikely such usage would cause any lasting harm [1].

Table 1--Matrix Addressing Past NOSB/TAP Concerns on Potassium Sorbate

Past NOSB/TAP Concern	Petitioner's Response	Supporting Citations
2002: Specific polymer not identified	Polymers in *All Phase* are fully disclosed and are approved as inert pesticide ingredients for organic food production. Polymer concerns are irrelevant if they meet NOP inert ingredient standards.	All Phase label (2)
2002: Target pests and mode of action not specified	Label specifies targets including **peach leaf curl, brown rot, and powdery mildew**. Documented multiple modes of action: inhibits cellular metabolism, compromises spore germination. Sulfur, by contrast, has no documented mode of action.	All Phase label (2); Petition Sec. B.12
2002: Justification for use incomplete	Section B.13 provides a complete justification, emphasizing KS as the only cost-competitive alternative to sulfur, copper, and petroleum oils — the "big three" organic pollutants.	Petition Sec. B.13
2002: Many alternatives exist	Alternatives exist but are either unreliable in university trials or significantly more expensive. Cultural practices alone cannot replace fungicides. Sulfur, copper, and oils remain dominant because they work and are affordable — KS matches efficacy without their environmental and health hazards.	Petition Sec. B.13
2002: KS is synthetic	KS is classified as synthetic under NOP rules, but is chemically identical to sorbic acid naturally found in rowan berries. Petition seeks inclusion on the **Approved Synthetics List** under §205.601.	Rowan berry composition (19)
2002: Inconsistent with organic practices	KS better aligns with OFPA's mandate to conserve biodiversity and ecological balance by reducing use of sulfur, copper, and petroleum oils that harm beneficial organisms, pollute the environment, and impact worker health.	7 U.S.C. § 6502(21); Petition Sec. B.13
2023: Many alternatives and cultural practices exist	Presence of alternatives has not significantly reduced sulfur/copper/oil reliance. Mycofungicides have inconsistent results; essential oils are costly; copper is developing resistance and accumulates in soils. KS offers a new chemistry for rotation and resistance management.	Petition Sec. B.13
2023: Need more info on interactions, soil persistence	Foliar deposition is minimal: max 0.0167 g/ft² even if all spray reaches soil. Half-life: 17 days (soil), 9 days (water), 2.6 hrs (air). Breaks down to CO_2 and water, no accumulation.	USDA half-life data (8)
2023: Concern over KOH byproduct	KOH is not a known breakdown product of KS in soil. Even at maximum application rates, pH impact is negligible.	pH impact calculation; All Phase potassium content (19)
2023: Possible DNA mutagenicity	KS is GRAS per 21 CFR § 582.3640. No in vivo animal studies show genotoxicity. In vitro effects occur only at unrealistically high doses (~25 g acute intake). Comparable vitamins show similar in vitro genotoxicity but are anti-genotoxic at dietary levels. Low doses may be anti-inflammatory.	Pongsavee & Mishra (13); Anti-inflammatory study (18); Vitamin C/D/B1 studies (15, 16, 17)
2023: Not from renewable resources	KS production uses far less fossil fuel per acre than organic petroleum oils (10× less at typical rates, 2× less at highest rates). Sulfur and copper are also mined and non-renewable.	Fossil fuel comparison (20)
2023: Not compatible with biological controls	KS does not harm beneficial insects or mites, unlike sulfur and oils. Compatible with IPM programs; All Phase is non-toxic to honeybees (EPA test). Foliar KS can protect roots via systemic action without disturbing soil biology.	Bee toxicity test (9); Systemic movement study (10)

B.8 – Regulatory Authority

Potassium sorbate is listed by the EPA as a FIFRA 25(b) active pesticide ingredient (40 CFR 152.25(f)) **[21],** exempt from EPA residue tolerances (40 C.F.R. § 180.1233) **[22]**. Potassium sorbate is on EPA List 4 of Inerts of Minimal Concern **[23]** (52 Fed. Reg. 13,305) and is acceptable by OMRI as an inert ingredient for pesticides used for organic farming. The FDA classifies potassium sorbate as GRAS for human consumption **(**21 CFR § 582.3640**)**.

Item B.9—Chemical Abstracts Service (CAS) Number and Product Labels

CAS 24634-61-5

All Phase Label – Appendix B

KS SDS – Appendix C

Item B.10—Physical and Chemical Properties

B.10.A.—Chemical interactions with other substances used in organic production.

Incompatible with strong acids, strong bases, strong oxidizing agents and strong reducing agents [24]. Potassium sorbate is compatible with weak bases such as potassium bicarbonate and weak acids such as citric acid, which can improve the efficacy of potassium sorbate [1]. Potassium sorbate is deactivated when tank mixed with a horticultural oil [1].

B.10.B. Toxicity and environmental persistence.

Potassium sorbate has a long history of use as a food preservative and is recognized as GRAS by the FDA **(**21 CFR § 582.3640) and is exempted from the requirement of establishing a residue tolerance (40 C.F.R. § 180.1233).

Potential Health Effects [24]

Acute oral toxicity: LD50: > 10,000 mg/kg rat (Reference substance: Sorbic acid)
Acute dermal toxicity: LD50: 2,000 mg/kg rat (Reference substance: Sorbic acid)
Acute inhalation toxicity: LC50 (4H): >5.15 mg/l
Skin corrosion/irritation: Not irritating (rabbit)
Skin Sensitization: nonsensitizer (guinea pig)
Serious eye damage/eye irritation: irritant (rabbit eye)
Carcinogenic effects: No evidence of carcinogenicity (mice)
In vitro Mutagenicity: Ames Test: negative
Chromosome aberration test: weak positive without metabolic activation
In Vivo Mutagenicity: Mammalian Erythrocyte Micronucleus Test in mice: negative.
Reproductive toxicity: No toxicity to reproduction.
Developmental effects: No developmental or reproductive effects (rat)
Repeated exposure: No consistent differences between treated and control (rat)

Ecological Information [24]

Acute fish toxicity: LC50: > 1,000 mg/l (96h) (rainbow trout)
Acute daphnia toxicity: EC50: 982 mg/l (48h) (*Daphnia magna*)
Toxicity to bacteria: EC50 (3h): > 100 mg/L (in activated sludge)
Biodegradation: Readily biodegradable
The United States Department of Agriculture (USDA) shows half-lives for potassium sorbate of 17 days in the soil, 9 days in water, and 2.6 hours in the air **[8]**

B.10.C. Environmental impacts from use and/or manufacture of potassium sorbate

No adverse environmental effects are expected from the use of potassium sorbate at requested foliar application rates. The Environmental Protection Agency includes potassium sorbate in a list of chemicals considered to pose a minimum risk to humans and the environment and eligible for use in Minimum Risk Pesticides (40 CFR 152.25(f)). As discussed in addressing the concerns of previous reviews, most of the potassium sorbate from a pesticide application is going to remain on the foliage, but even if every gram of the highest application rate (1,100 gm) ended up on the soil, that equates to .025 grams of potassium sorbate per square foot of soil. If that 0.025 grams were to diffuse into a cubic foot of water it would equate to 6.6 ppm (0.00066% by wt.) of potassium sorbate. In this example the unrealistically high deposition of potassium sorbate on the soil from a foliar application is insignificant to soil biology [1].

Potassium sorbate has no contact insecticidal activity, so no impact on beneficial insects and mites [1].

Potassium sorbate takes energy to manufacture as do all pesticides. In the case of potassium sorbate, it takes 4 to 6 kg of crude oil to produce 1 kg of potassium sorbate. That may sound like a lot, but because of high efficacy at low rates, a typical application requires the consumption of ten times less crude oil (0.7 –1.0 kg/acre) than a typical mineral oil application (7.8-975 kg acre) [**Appendix D**].

Potassium sorbate in the field produces no VOCs, but VOCs were generated in the manufacturing of that potassium sorbate. Modern production facilities employ condensers, scrubbers, and thermal oxidizers that can reduce VOC release by >95%. With effective controls, VOCs reaching the atmosphere can be virtually eliminated. When considering a typical field application rate for potassium sorbate of 175 g/acre, figure zero VOCs emitted in the field and 0-2.6 g emitted to the atmosphere at the production facility (depending upon abatement efficiency). Compared with VOC emissions from mineral oil that occurs mainly in the field, typical application rates emit 0.66 to 3.93 kg of VOCs per treated acre. Mineral oil therefore releases approximately 250× to >5,000× more VOCs to the atmosphere per acre than KS under comparable use conditions [**Appendix L]**.

Potassium sorbate is about 26% potassium by weight. Potassium is mined through a process of solution mining and evaporation. Solution mining typically causes less surface disturbance than copper or sulfur mining but requires considerably more water. Crops require this nutrient, so regardless if the potassium is replaced with sulfate of potash or potassium sorbate the environmental impact from mining the mineral is the same. Foliar application rate of potassium sorbate (175 grams/acre typical) are not providing excessive amounts of the heavy metal. Even crops like lettuce with a low demand for potassium require at least 9 kg/acre of potassium to preserve fertility. Fungicidal applications of copper on the other hand are typically at rates that exceed crop demands [Petition Sec. B.13].

B.10.D. Effects on human health

Potassium sorbate is an approved food additive, regularly consumed at concentrations higher than required for foliar applications. In 60 years as a widely consumed and studied food preservative, studies have not shown any adverse effects related to cancer or reproductive health from this consumption and only mild sensitivities and or allergic reactions in a few individuals.

No adverse effects on human health are expected and a positive net effect on human health is expected from a reduction in use sulfur, copper and mineral oils [Petition Sec. B.7B] [Petition Sec. B.13].

B.10.E. Effects on soil organisms, crops, or livestock.

No adverse effects are expected from foliar applications [Petition Sec. B.7B] [Petition Sec. B.13].

Item B.11—Safety Information

Potassium sorbate is considered an eye irritant. No other safety concerns.

[Petition Sec. B.10]

SDS Potassium Sorbate [Appendix C]

No NIEHS substance report for KS

GreenScreen® Certified Assessment (2024) found moderate eye irritation, low aquatic toxicity (acute and chronic), low bioaccumulation potential, and no major systemic toxicity or carcinogenic concerns based upon available data **[69]**

Item B.12—Research Information

B.12.1 Modes of Action for Potassium Sorbate

Potassium sorbate, the potassium salt of sorbic acid, is a widely used preservative in the food, cosmetic, and pharmaceutical industries. It inhibits the growth of various microorganisms, including molds, yeasts, and some bacteria, thus extending the shelf life of products. Its efficacy and safety make it a popular choice for preservation. This section outlines the modes of action through which potassium sorbate exerts its antimicrobial effects.

1. **Disruption of Cell Membranes [25] [28)**

Potassium sorbate exerts its preservative action by interacting with the microbial cell membrane, altering its permeability:

- Mechanism:
  - Sorbic acid, the active form of potassium sorbate at acidic pH, penetrates the cell membrane of microorganisms in its undissociated form.
  - Inside the cell, the acidic environment disrupts the membrane's integrity, leading to leakage of essential ions and metabolites.
- Impact: Loss of membrane potential impairs the microorganism's ability to maintain homeostasis, effectively inhibiting growth or leading to cell death.

2. **Inhibition of Enzymatic Activities [26] [28]**

Potassium sorbate interferes with key enzymatic processes necessary for microbial metabolism:

- Mechanism:
  - Sorbic acid affects enzymes involved in energy production and synthesis pathways, such as dehydrogenases and decarboxylases.
  - The interaction with sulfhydryl (–SH) groups of enzymes leads to their inactivation.
- Impact: Disruption of enzymatic functions impairs energy generation, effectively halting microbial growth.

3. **Acidification of the Cytoplasm [27] [28]**

Potassium sorbate lowers the intracellular pH, creating an inhospitable environment for microbial survival:

- Mechanism:
  - At low pH, potassium sorbate exists predominantly in its undissociated form, which can diffuse into the cell.
  - Once inside, the sorbic acid dissociates, releasing hydrogen ions (H^+) that acidify the cytoplasm.
- Impact: The acidification disrupts cellular processes that depend on an optimal pH, such as DNA replication, protein synthesis, and metabolic reactions.

4. **Inhibition of Spore Germination [28]**

Potassium sorbate is effective in preventing the germination of fungal and bacterial spores:

- Mechanism:
  - Sorbic acid impairs the uptake of essential nutrients required for spore activation.
  - It also affects the hydration of spores, a critical step for their transition to a vegetative state.
- Impact: Spores remain dormant, unable to propagate or cause spoilage.

B.12.2—Pathogens Controlled in Field Trials of KS Pesticide (All Phase)

Field Trial Results of All Phase (34.7% potassium sorbate)

Dormant spray applications of All Phase showed superior efficacy for controlling Peach Leaf Curl to the organic approved alternative of dormant sprays of LiquiCop with mineral oil **[see Appendix D; Reference 29]**.

Field applications of All Phase on peach trees showed good efficacy for controlling powdery mildew and brown rot. Results also found that combining All Phase with an oil nullified the efficacy of potassium sorbate **[Appendix E] [Appendix F] [30]**

Cal Poly Strawberry Center found that weekly sprays of All Phase at 1/3 lb/acre plus a surfactant provided comparable results to weekly applications of 5 lbs/acre of sulfur for controlling powdery mildew in strawberries **[Appendix G] [31]**.

The Cal Poly Strawberry Center found that All Phase applied weekly at a rate of 5 lb/acre with a surfactant had comparable results to weekly sprays of the synthetic pesticide, Luna Sensation, at 7.6 fl oz/acre for controlling powdery mildew of strawberry **[Appendix H] [32]**. This is the absolute high-end rate for All Phase as some spotting was observed on foliage.

Bi-weekly applications of All Phase to hops at 1.6 lbs/acre with a surfactant were as effective as the industry-standard fungicide tank mix in suppressing downy mildew in hops under field conditions. It completely prevented foliar symptoms across five evaluation dates without causing phytotoxicity, even under environmental stress **[Appendix I] [33]**.

Weekly sprays of All Phase at 1.8 lbs/acre without the addition of a surfactant suppressed powdery mildew in chardonnay grapes comparable to a bi-weekly spray rotation that included sulfur with Rally, followed by Quintec with a wetting agent, followed by Pristine with a wetting agent **[34]**.

All Phase was also shown to reduce severity of almond scab in a field trial conducted by Professor James Adaskaveg at UC Davis **[35]**.

B.12.3 Plant Pathogens Controlled by KS in Scientific Literature

1. Fungal Pathogens

Botrytis cinerea (36) (37)
Penicillium spp. (38)
Alternaria alternata (39)
Fusarium oxysporum (10) (40)
Verticillium sp. (10)
Pythium sp. (10)
Rhizoctonia sp. (10) (40)
Macrophomina phaseolina (40)
Sclerotinia sclerotiorum (40)
Rhizoctonia solani (10) (40)

2. Bacterial Pathogens

Pseudomonas spp. (41)(42)
Erwinia spp. (43)

B.12.4 Environmental Testing of All Phase (KS AI)

Coturnix quail chicks fed a diet of 0.6 grams of All Phase per 100 grams of feed showed no differences between chicks fed uncontaminated feed per standardized EPA testing [44].

Honey bees were unaffected by All Phase per standardized EPA testing **[9]**.

Item B.13—Petition Justification Statement

A. Inclusion of a Synthetic on the National List (7 C.F.R. §§ 205.601, 205.603, 205.605(b))

• Explain why the synthetic substance is necessary for the production or handling of an organic product.

The purpose of this petition is to reduce the use of organic pesticides that violate the principles of the Organic Foods Production Act (OFPA) of 1990 by providing potassium sorbate as a healthier and cost-effective alternative.

Regulations Guiding Decisions of the NOP
7 CFR Part 205.2 of the OFPA in its definition of organic production states: **"**respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote **ecological balance**, and conserve biodiversity." 7 CFR Part 205.200 of the OFPA states: **"Production practices** implemented in accordance with this subpart **must maintain or improve the natural resources of the operation, including soil and water quality."** NOSB evaluation criteria (7 U.S.C. §6518(l)): The Board must consider "**the effect of the substance on human health**" and "**its compatibility with a system of sustainable agriculture**.

Human health and environmental stewards are guiding principles of the OFPA, and that certainly is the public perception and what the guiding principle should be. In evaluating this petition, please consider the overall impact that the inclusion of potassium sorbate as an approved synthetic active ingredient in organic pesticides would have on human health and the environment, and whether that effect is a net positive or net negative compared with the current state of organic farming.

Organic farming is arguably no more sustainable and no better for the environment and or to the health of farming communities than conventional farming practices [1]. This shouldn't be debatable, but it is. Organic farming relies way to heavily on the Big Three Polluters: sulfur, petroleum oils, and copper. This is not good environmental stewardship. The only way organic farmers are going to reduce their reliance upon the Big Three Polluters is through legislation (not good for farmers), a mandate to curtail usage by the NOP (hard on farmers), or by giving farmers options that are actually environmentally sound, and that are affordable and reliable (good for farmers) [1]. Potassium sorbate is such an option.

B.13.1 Cost Effectiveness of KS (All Phase) Compared to Organic Alternatives

The most commonly used organic pesticides: sulfur, petroleum oils, and copper are arguably the most cost-effective pest control options available to farmers. That's why they're the most commonly used pesticides. That doesn't mean they're the healthiest for farming communities and the environment, though. To get farmers to voluntarily reduce their use of these harmful products you have to provide them with economically viable alternatives. So, how does the cost effectiveness of potassium sorbate as a pesticide stack up? To compare, we will look at All Phase (34.7% potassium sorbate). All Phase is formulated to maximize the performance of potassium sorbate while putting the least amount of active ingredient into the environment. The pricing for All Phase is for an 8-lb bucket of the material that even the smallest of farmers can afford to purchase from the manufacturer's website and includes shipping. The pricing for the other materials in this analysis is estimated for what larger growers can get those materials for and does not account for shipping. Not that smaller growers can easily pay double the prices used in this analysis for sulfur, copper, and petroleum oils.

Peach Leaf Curl (UC Davis Field Trial) [29]

In a UC Davis field trial for controlling peach leaf curl, All Phase was applied at 400 g/acre with the surfactant Kinetic (6 oz/acre) on 12-8-22 and 3-2-23. All Phase costs $25/lb, so 400 g (0.88 lb) costs $22. Kinetic costs $35/gal so $1.64/application. Total cost is $23.64/acre/application. With two applications, the season cost for All Phase is $47.68/acre. The copper-based option, MasterCop, was applied once on 12-8-22 at 6 pints/acre ($18/gal) plus 1.5 gal/acre of Omni Oil ($12/gal), for a total of $30/acre for that single treatment. While the copper option was slightly cheaper overall, All Phase provided 39% fewer infections than the copper/oil treatment and without the long-term soil contamination risks.

Hops Downy Mildew (Collins Agricultural Consultants Field Trial, 2021) [33]

In Oregon City, OR, All Phase was applied six times from April 8 to August 12 at 15 g/gallon with the surfactant Preference (10 ml/gallon) in 50 gallons/acre. All Phase was applied at 750 g/acre/application (1.65 lb), costing $41.25/acre/application and the surfactant added an additional $3.97/acre. The total cost of per application is $45.22. The total seasonal cost for six applications is $271.32/acre. No disease symptoms were observed in treated plots, while untreated controls developed infections. In comparison, copper regimens for hops typically involve multiple applications of copper hydroxide or copper sulfate at 2–3 lb metallic copper/acre per spray, costing significantly less per application but posing long-term soil accumulation and toxicity risks.

Strawberry Powdery Mildew (Cal Poly SLO Field Trial) [32]

In a Cal Poly SLO field trial, All Phase at 1/3 lb/acre had slightly lower incidence/severity than sulfur (not statistically significant). At $25/lb, this rate costs $8.33/acre/application. The recommended 1 lb/acre rate costs $25/acre. Micronized sulfur (~$3/lb) applied at 5 lb/acre costs $15/acre. Compare with Stylet Oil (~$16/gal) at 1 gal/acre costs $16/acre. Copper sulfate (~$2/lb) at 2 lb/acre costs $4/acre but has poor efficacy against powdery mildew, with UC Davis trials and Cal Poly ratings showing little to no control. While copper is the cheapest, it is not cost-effective for controlling this disease, because it lacks good efficacy.

Brown Rot Peaches (UC Davis Field Trial) [30]

All Phase showed efficacy in controlling brown rot at a rate of 24 oz/acre ($37.50/acre). Neither sulfur or mineral oils have any efficacy against brown rot. Copper sulfate can be applied at 2 to 2.8 lbs/acre ($5 - $7.50/acre). In this example copper is again the most cost-effective option, but again the copper option is loading more copper into the environment.

Cost Effectiveness Conclusions

Where copper has good efficacy, it is likely the most cost-effective option for farmers to control plant pathogens, but it is perhaps the pesticide most in need of curtailing usage in order to have a sustainable farm and to protect soil and water [1].

Potassium sorbate is cost competitive with sulfur and highly refined petroleum oils for controlling plant pathogens and though more expensive, still cost competitive with copper for controlling peach leaf curl.

B.13.2 The Need to Reduce Usage of Sulfur, Copper, and Petroleum Oils

B.13.2.1 Sulfur

Sulfur is the most used agricultural pesticide in terms of amount applied and acres applied to. In 2022, close to 39 million pounds of it were applied in California agriculture for use as a fungicide/insecticide [**6]**.

Despite such heavy usage, elemental **sulfur has no documented mode of action** as either an insecticide or a fungicide. None. The labels don't state the mode of action, safety data sheets don't address the mode of action, and the scientific literature doesn't describe a mode of action. Sulfur dioxide is a gas that is generated from a dusting or spraying of micronized sulfur on a crop, it is the active component, and I'll prove it to you **[1]**.

Many who have worked in or walked by agricultural fields following a sulfur application have detected an odor they attribute to sulfur. But sulfur has no odor, either as a solid or as sulfur vapor. Most any general chemistry text will tell you this. So, what are people smelling? Hydrogen sulfide? No. Hydrogen sulfide gas smells like rotten eggs and sewage and forms in anaerobic environments where sulfur is reduced by microbial organisms. Sulfur sprayed or dusted on the surface of foliage is exposed to a highly aerobic environment. **What people smell following a sulfur application is sulfur dioxide** (a pungent, acrid, burnt match odor). Sulfur dioxide is an inorganic pesticide with multisite modes of action against microorganisms and is a group code M2 fungicide **[45]**. Sulfur dioxide provides modes of action for a sulfur application, the gassing off to sulfur dioxide explains the disappearance of sulfur from leaf surfaces, and sulfur dioxide explains having the odor of sulfur dioxide in fields following applications.

The fate of foliar applied sulfur following an application is not well documented in scientific literature, but the University of California acknowledges the weathering and oxidation of foliar applied sulfur in their modeling of grapevine powdery mildew on the UC IPM website, stating, "If possible, sulfur should be applied in the evening after temperatures drop below 90 F to allow **slow oxidation** during the night, thus avoiding some leaf burn which occurs during the hotter hours."**[46]**.

Micronized sulfur manufacturers avoid mentioning sulfur's oxidation to sulfur dioxide because it could drastically change its regulatory classification, perceived risk, and allowable uses **[1]**. By maintaining the fiction that sulfur remains elemental post-application, the industry sidesteps worker protections, air monitoring, and

label restrictions that would otherwise apply to a material releasing toxic gas under field conditions **[1]**. A flier from one micronized sulfur manufacturer even claims that their micronized sulfur sublimates to sulfur vapor which is then reduced to hydrogen sulfide gas, which then provides fungicidal activity **[47]**. The truth is that sulfur vapor in an oxygen rich environment is going to oxidize to sulfur dioxide, and hydrogen sulfide gas forms when sulfur is digested by sulfur-reducing-bacteria in an anaerobic environment **[48]**. Any hydrogen sulfide gas released into an oxygen rich environment is going to rapidly oxidize to sulfur dioxide (Figure 1) **[48]**.

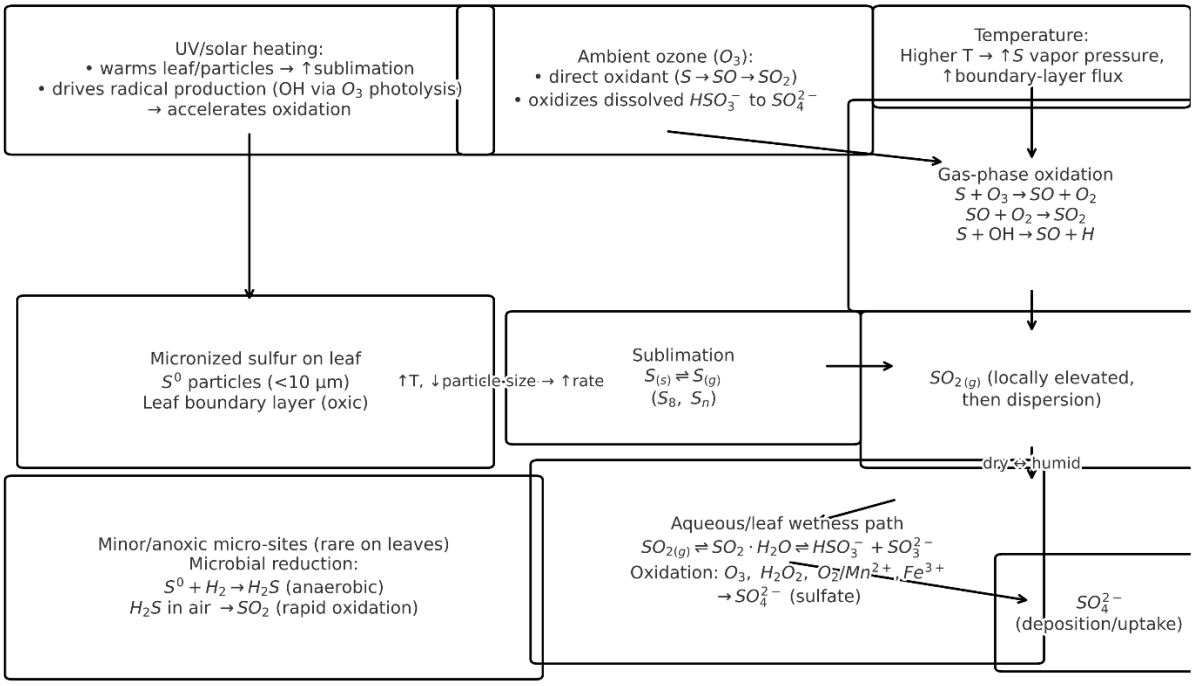


Figure 1. Fate of micronized sulfur applied to a leaf surface. Dominant pathway in oxic canopy: solid S^0 → sublimation (S_8, S_n) → gas-phase oxidation (SO_2) → sulfate via gas/aqueous oxidation. Minor pathway: microbial reduction to H_2S occurs in anoxic micro-sites; in air, H_2S is rapidly oxidized. Created by GPT-5 Thinking (2025).

Figure 1 Fate of Micronized Sulfur

Sources for Figure 1 (Fate of Micronized Sulfur)

1. **Gas-phase S → SO/→ SO_2 kinetics** (rate constants for S, SO reactions with O_3/OH and related sulfur species):
Westley F. *Tables of Recommended Rate Constants for Gas-Phase Chemical Reactions* (NBS NSRDS-67). U.S. Dept. of Commerce/NIST; 1980. PDF. GovInfo

2. **Aqueous oxidation of dissolved SO_2 (S(IV)) to sulfate** — laboratory/cloud studies (O_3, H_2O_2, radicals) and pH effects:
Hoyle CR, et al. *Aqueous phase oxidation of sulphur dioxide by ozone in cloud droplets.* **Atmos Chem Phys**. 2016;16:1693–1703. Open access. ACP
Liang J, et al. *A study of sulfur dioxide oxidation pathways over a range of atmospheric conditions.* **J Geophys Res**. 1999;104(D9):13749–13773. PDF. Stanford University
Pattantyús-Ábrahám AK, et al. *Review of sulfur dioxide to sulfate aerosol chemistry at coastal-marine sites.* 2018. PDF. SOEST

3. **Atmospheric fate of hydrogen sulfide (rapid oxidation to SO_2/sulfate; typical ambient levels)**:
ATSDR. *Toxicological Profile for Hydrogen Sulfide and Carbonyl Sulfide.* U.S. DHHS/CDC; 2016 (profile PDF set). ATSDR+3ATSDR+3ATSDR+3NCBI

4. **Anoxic, microbial reduction of elemental sulfur (S^o) to sulfide (H_2S)** — foundational reviews & culture studies:
Hedderich R, Fischer E. *Anaerobic respiration with elemental sulfur and with disulfides.* **FEMS Microbiol Rev.** 1998;22:353–381. PDF. Oxford Academic
Barton LL, Fardeau ML, Fauque GD. *Hydrogen sulfide: a toxic gas produced by dissimilatory sulfate and sulfur reduction and consumed by microbial oxidation.* In: **Metal Ions in Life Sciences** Vol. 14. 2014. Open PDF. Bradley.Lusk #ScienceTheEarthPubMed
Lovley DR, Phillips EJP. *Novel processes for anaerobic sulfate production from elemental sulfur by sulfate-reducing bacteria.* **Appl Environ Microbiol.** 1994;60:2394–2399. Open access. PMC

Figure created by GPT-5 Thinking (2025).

Figure 1 describes the fate of sulfur following a pesticide application based upon chemistry and the best available science [1]. Sublimation is the first step. Most people who have taken a high school level chemistry class were taught that solid water (ice) can go directly from a solid state to a gas in a process called sublimation. If you double the surface area of a given mass of water-ice exposed to the air you double the rate of sublimation, and if you increase the surface area of a given mass of water-ice by a thousand times, you increase the rate of sublimation a thousand-fold. Sulfur manufacturers understand this and can mill sulfur to fine particle sizes (down to 3 microns in diameter or less **[47]**) to increase the surface area of a given mass and to provide for more uniform distribution when applied to crops. Ten pounds of sulfur per acre is a common application rate. A ten-pound cube of sulfur has a surface area of 153.1 in2 **[49]**. Milling it to 3 micrometer sized cubes increases the surface area of the mass by 44.3 million times **[49]**. With such a large surface area per mass of sulfur, sublimation occurs rapidly, with reapplications commonly required every 7 to 10 days to account for weathering to sulfur dioxide and for protecting new growth **[50] [1]**.

Like water-ice, sulfur sublimates from a solid to a vapor. Roy P. Tucker of UC Berkeley laid the groundwork of our understanding of sulfur sublimation at ambient temperatures (25 to 50 °C) **[46][51]**. In practice, many licensed Pest Control Advisors (PCAs) know that sulfur applications for pesticidal purposes are ineffective when temperatures are below 68 °F, because sublimation and the subsequent oxidation to sulfur dioxide occurs too slowly **[1]**. PCAs also know, and it is even acknowledged on pesticide labels, that at higher temperatures (>85-90 °F) sulfur applications can burn foliage [**51]**. Pesticide labels are careful to avoid mentioning why this occurs, but the University of California attributes the phytotoxicity from sulfur applications to the excessive **oxidation** of sulfur at high temperatures **[46]**.

Clear chemical pathways are present in agricultural fields for the oxidation of sulfur vapor to sulfur dioxide **(Figure 1)**. Sunlight and ozone can break bonds in sulfur vapor and drive the oxidation to sulfur dioxide. When sulfur is oxidized to sulfur dioxide, it takes on two oxygen molecules which effectively doubles its molecular weight. Ten pounds of sulfur added to an acre can potentially generate twenty pounds per acre of sulfur dioxide and that 39 million pounds of sulfur added in one year in California could potentially convert to 78 million pounds of sulfur dioxide. Realistically, some field applied sulfur will be absorbed into the biomass of the plants or go along a different pathway, but most is directed to a sulfur dioxide phase in the presence of oxygen **[1]**.

Sulfur dioxide is the most obvious active ingredient in a sulfur application **[1]**. The number one used organic pesticide is generating massive amounts of sulfur dioxide. Sulfur dioxide is a gas. It cannot be detained on site. It drifts. And, why should we be concerned? Because, sulfur dioxide has a number of human health and environmental health concerns and is a toxic gas on California's Proposition 65 List known to cause reproductive harm **[52]**. The following is a summary of the justification for including sulfur dioxide on the Prop 65 List [52].

Summary of California Prop 65's Justification for Listing SO2 as a Reproductive Hazard to Humans

Genotoxicity

- Sulfur dioxide is **genotoxic** in multiple in vitro and in vivo assays:
  - Induces **DNA strand breaks**, **chromosomal aberrations**, and **sister chromatid exchanges**.
  - Positive results have been observed in **human lymphocytes**, **Chinese hamster ovary cells**, and other mammalian cell cultures.
  - **Mechanisms** include oxidative stress and formation of sulfite radicals, which can damage DNA.

Developmental Toxicity

- Rodent studies show that inhalation of sulfur dioxide during gestation causes:
  - Reduced fetal body weight
  - Skeletal abnormalities (e.g., rib deformities, delayed ossification)
  - Increased resorptions and decreased litter sizes
- Effects occur even at relatively low exposure levels (e.g., 5 ppm in rats).
- These effects are more severe when exposure occurs during **organogenesis**.

Reproductive Toxicity

- In male rodents:
  - Sulfur dioxide exposure impairs sperm quality, reducing motility and increasing abnormal forms.
  - Associated with decreased testis weight and histopathological changes.
- In female rodents:
  - Associated with disrupted estrous cycles, decreased ovarian weight, and fewer implanted embryos.
- Some epidemiologic studies suggest links between ambient SO_2 exposure and:
  - Spontaneous abortions (SO2 exposure 10 to 30 ppb)
  - Low birth weight (SO2 exposure 10 to 30 ppb)
  - Preterm births (SO2 exposure 10 to 30 ppb)
  - Congenital heart defects
- Men exposed to SO2 occupationally or environmentally at levels as low as 15.3 ppb showed:
  - Decreased sperm count and motility b
  - Increased abnormal sperm morphology
- Women exposed to SO_2 at those same low levels showed:
  - Altered menstrual cycles
  - Lower rates of conception
  - Greater likelihood of delayed pregnancy or infertility

Most people are unable to detect the odor of sulfur dioxide at concentrations of between 0.4 and 5 ppm [**53],** which is well above levels known to cause reproductive harm. We also can become nose blind to sulfur dioxide as we do with other pervasive odors in our environment, so our noses are unreliable in letting us know if we are in a sulfur dioxide rich environment that could harm us. Workplace exposure limits [53] are: **1**. OSHA—5 ppm averaged over and 8-hour work shift (maximum legal exposure). **2**. NIOSH—2 ppm averaged over a 10-hour work shift and 5 ppm not to be exceeded during any 15-minute work period. 3. ACGIH—Threshold limit value is 0.25 ppm averaged over an 8-hour work shift.

Sulfur dioxide is also well documented to irritate skin, eyes, nose and throat, and cause respiratory distress **[53]**.

Pesticide labels for micronized sulfur do not warn of the toxic gas generated from applications. Micronized sulfur is also given a certification of approval for use in organic food production. These two factors keep the farming community uninformed of the real hazards associated with sulfur use [1].

Here is an alarming study. The University of California, Berkely, followed the families of farmworker in the Salinas Valley for ten years and found a strong correlation between agricultural sulfur pesticide applications and a significant reduction in pediatric lung function along with an increase in asthma in children living within 1 km of the applications sites **[54]**. It wasn't until beyond 3 km from application sites that no cause and effect was detected [54]. Sulfur dioxide exposure explains all the symptoms seen in affected children, and because it's a gas that cannot be confined to the application site, it explains how sulfur applications could consistently affect children living so far from the application sites.

The California Department of Pesticide Regulation maintains a database of illnesses and injuries associated with exposure to pesticides and every year sulfur is contributing to these injuries, with respiratory distress the most commonly reported symptom **[55]**. All other injuries reported are consistent with sulfur dioxide exposure [55].

We know that agricultural sulfur applications are affecting the lungs of farmworkers in the field, and the lungs of children living within a kilometer of application sites. This sort of effect where people or property away from application sites are impacted by pesticide applications is known as drift. What we don't know and that has never been studied is the reproductive harm these sulfur applications are having on farmworkers and the surrounding community. Studies have attributed reproductive harm to sulfur dioxide levels as low as 1 ppb **(52).** Where it requires exposure in the parts per million to have affected the lungs of children living a kilometer away, how far might sulfur dioxide levels in the low parts per billion extend beyond application sites?

California Food and Agricultural Code (FAC §12972) states: "No pesticide... shall be applied, stored, or used in a manner that results in **drift** at levels that **endanger people or the environment**." It may not even be possible to use micronized sulfur in a manner that doesn't endanger people and the environment.

We know that foliar applied sulfur in agriculture, even when applied in conformance with labeled instructions, is hurting people [54], but is it also hurting the environment?

Agriculture is the largest contributor of sulfur into the environment of any industry [56]. Much of this sulfur is in the form of sulfate salts used to fertilize plants and is needed, but a lot of this sulfur is contributing to sulfur dioxide in the air, to acid rain, to methylmercury formation in bodies of water, and to eutrophication of lakes [56].

As stated previously, micronized sulfur is the most widely used pesticide in agriculture, organic or otherwise, in terms of amount applied and acres applied too. Though micronized sulfur and its active biproduct, sulfur dioxide, are "natural", the continued use of micronized sulfur in such large quantity conflicts with human and environmental health and is in conflict with the principles of the OFPA [1].

The sulfur dioxide that micronized sulfur generates also appears to conflict with California law concerning drift (FAC §12972). It's continued use could be curtailed though legislation beyond the authority of the NOP and leave organic growers in a bind.

Organic growers need a good and cost-effective alternative to using micronized sulfur. Potassium sorbate is a cost-effective alternative that can completely replace sulfur as a fungicide, a fungicide that doesn't drift off as a toxic gas, that has a long history of safe human consumption, that breaks down quickly in the environment,

that works well with biological pest control, and though synthetically derived it is a natural substance that is being put into the environment.

B.13.2.2— Mineral/Paraffinic Oils

In California 34.5 million pounds of petroleum oils were sprayed as insecticide/miticides in 2022. That's how they classify the usage, but a good share of the usage was for controlling powdery mildew in vineyards [1]. Of the Big Three Polluters, mineral oils or paraffinic oils are perhaps the least hazardous to humans and the environment [1]. These oils start off as natural crude oil and through distillation and refinement end up as non-natural-highly-refined oils. Organic JMS Stylet-Oil is a product I've used and found effective in controlling powdery mildews and spider mites. According to the toxicological information on the product's Safety Data Sheet **[57]**:

1. Repeated and/or prolonged exposure may cause **irritation to the skin, eyes or respiratory tract**
2. No component of this product at levels **greater than 0.1% is identified as a carcinogen** by ACGIH or the International Agency for Research on Cancer (IARC)
3. No component of this product at levels **greater than 0.1% is identified as a carcinogen** by the U.S. National Toxicology Program (NTP) or the U.S. Occupational Safety and Health Act (OSHA).
4. The **DMSO** extract by IP-346 of the oil is less than 3% (Typical 0.2% with Maximum 0.5%0. Consequently, it is not classified as a carcinogen.
5. MUTAGENIC EFFECTS: No component of this product at levels greater than 0.1% is classified by established regulatory criteria as a **mutagen**.
6. TERATOGENIC EFFECTS/DEVELOPMENTAL TOXICITY: No component of this product at levels greater that 0.1% is classified by established regulatory criteria as **teratogenic** or embryonic.
7. REPRODUCTION TOXICITY: No component of this product at levels greater than 0.1% is classified by established regulatory criteria as a **reproductive toxin**.

In regard to bioaccumulation potential the SDS states, "Has the potential to bioaccumulate, however metabolism or physical properties may reduce the bio concentration or limit bioavailability." [57].

According to its SDS, Organic Stylet Oil contains less than 0.1% of any component that has been identified as a carcinogen, mutagen, teratogen, or reproductive toxin **[57**]. This implies that it does contain a component or multiple components that possess the afore mentioned undesirable properties at levels possibly as high as 0.1%. Having assurances that a product I'm working with contains carcinogens, mutagens, teratogens, and reproductive toxic components at a concentration of less than 0.1% isn't all that reassuring, especially when accompanied with DMSO. 0.1% of something is the equivalent of 1,000 ppm and many organic compounds are active fungicides and bactericides and teratogens and reproductive toxins at concentrations well below this concentration. The SDS for Stylet Oil also states that less than 3% of the oil is DMSO [57]. That stands for dimethyl sulfoxide. DMSO is a potent transdermal penetration enhancer. It has been shown to dramatically increase the cutaneous absorption of various compounds by over 100-fold compared to aqueous vehicle alone. While DMSO itself is not classified as a carcinogen, its ability to transport other agents through the skin poses a potential safety hazard if such agents it is coupled with are carcinogenic or toxic **[58] [59][60]**. In this product, DMSO is present with an unnamed ingredient or ingredients that we will call X and that is a carcinogenic, teratogenic, mutagenic, and a reproductive toxin. Now, consider that a typical scenario for using such a highly refined petroleum oil is to mix 2 gallons in 100 gallons of water and to spray it over an acre. At

max this one application would load the treated acre with 195 grams (0.43 pounds) of DMSO and 6.5 grams of X. While such residuals will probably breakdown quickly and have an insignificant overall effect on human health and the environment, 34.5 million pounds of these oils are being applied every year in California alone.

Petroleum oils sprays generate volatile organic compounds (VOCs). The California Department of Pesticide Regulation estimates that on average 1.53% of these oils are converted to VOCs [61]. This means that the 34.5 million pounds of these oils applied in California in 2022 contributed approximately 527,850 lbs of VOCs into the atmosphere throughout the state **[62]**.

We know that micronized sulfur produces a toxic gas that drifts offsite, but is replacing those sulfur sprays with mineral oil that much better? It would be best to reduce usage of both of these pesticides. By switching from sulfur with one spray to mineral oil with the next, farmers would cut their use of both materials in half, which is probably better for the environment than putting twice the amount of just one of these materials into the environment [1].

Sulfur and these highly refined petroleum oils are incompatible, so farmers tend to use one or the other. Potassium sorbate can safely be used in rotation with sulfur and petroleum oils. For example, let's say there is high disease pressure favoring powdery mildew in a vineyard. A grower could have a weekly spray schedule starting with mineral oil, followed by potassium sorbate, followed by sulfur, followed by potassium sorbate, followed by mineral oil, et cetera, for as long as environmental conditions favor disease. In this way the farmer is going after the pathogen with alternating modes of action (that's a preferred pest control strategy) and minimizing the usage of sulfur and mineral oil [1]. The dose is what makes the poison. If a grower only needed to spray sulfur or mineral oil a couple of times a year, there would be much less chance of causing human health or environmental concerns. Such a pest control practice is clearly more in line with the goals of the OFPA than current practices [1].

It is well known that mineral oils kill beneficial insects and targeted mites exposed to sprays. Its usage generally upsets the field ecology and can lead to a rebound effect where the pest comes back worse than ever because of having killed off the beneficial organisms that had been inhibiting an outbreak of the pest [1]. Let's say you have predatory mites holding spider mites in check, but you also have conditions favorable for powdery mildew. You need to spray a fungicide. Sprays of sulfur or mineral oil will tend to kill off your beneficial mites, and then, if you stop spraying, spider mites can return with a vengeance. Now, let's say you decide to spray with potassium sorbate. You do that for a few weeks until conditions no longer favor the disease and then you stop spraying. You don't get a rebound effect with the spider mites, because you haven't killed off the predatory mites.

While mineral oils are probably safer for humans and the environment than micronized sulfur applications, the indiscriminate killing of field biology and spreading of petroleum oil through agricultural fields along with the X component of these oils coupled with DMSO, and the production of unhealthy VOCs, seems considerably less compatible with the goals of the OFPA than potassium sorbate [1]. Potassium sorbate produces no carcinogens, no VOCs, no nasty biproducts, it does not kill beneficial insects and is a cost-effective alternative to these highly refined oils.

B.13.2.4—Copper

In 2022, copper sulfate was the most widely used agricultural fungicide in California, ranked by acres treated (1,800,542) and pounds applied (6,010,805) **[6]**. Copper is an essential nutrient for plants and humans, but excessive exposure can have damaging effects to humans and the environment.

The US EPA has established a goal for keeping copper in drinking water below 1.3 ppm, finding potential harm to humans from exposure to copper above the threshold: 1. Short periods of exposure can cause gastrointestinal disturbance, including nausea and vomiting. 2. Use of water that exceeds the Action Level over many years could cause liver or kidney damage. 3. People with Wilsons disease may be more sensitive than others to the effect of copper contamination and should consult their health care provider **[63]**.

One pound of copper sulfate contains 180 grams of copper and can bring 36,138 gallons of copper free water up to 1.3 ppm [1].

A pesticide label for Copper Sulfate **(64)** states in regard to controlling Peach Leaf Curl:

"Prepare a 10-10-100 Bordeaux mixture. Apply at leaf fall or as a dormant spray in late fall or early spring before buds begin to swell. DO NOT apply more than 32 lbs (8 lbs metallic copper) per acre per application. Minimum retreatment interval is 7 days. DO NOT exceed 128 lbs (32 lbs metallic copper) per acre per year."

According to 7 CFR § 205.601(i)(2), fixed coppers may be used in organic production with restrictions, provided that copper accumulation in the soil is minimized. In the afore mentioned spray application, 8 lbs of metallic copper is added per acre from just one application. Crops don't utilize nearly that much copper. The only way that that one application doesn't cause copper to build up in the soil is if the copper leaches into water sources or blows away with dust. Why doesn't the NOP require water quality monitoring requirement in addition to soil monitoring?

Mature peach trees only remove 0.05 to 0.1 lbs Cu/acre/year via harvested fruit and pruned biomass **[65]**. **Copper is a forever chemical**. It does not breakdown. If you are an organic peach grower and you do just one dormant spray to prevent Peach Leaf Curl per season, you may add up to 8 lbs of metallic copper per acre per year when using the labeled rate of this copper sulfate product [64]. The excess copper is either going to accumulate in the soil or leach from the site into ground and surface waters. Where else is it going to go? And the NOP already knows that copper is a problem, as they have imposed restrictions on organic copper use to minimize accumulation in the soil. "Minimize" is a vague term and minimizing the impact to surface and ground waters should have been included in the restrictions as well [1]. An organic grower may be able to "minimize" their copper use to using the least amount necessary to prevent a disease like Peach Leaf Curl, but that amount is still going to be well above what is sustainable. And even if a grower could minimize copper accumulation in their soil to levels that would not impact soil biology for 500 years, that's still not acceptable. It is impossible to use copper fungicides on an annual basis and have a sustainable farm, because effective dosages leave more copper than crops consume [65]. Ultimately, having a sustainable farm is more important than any certification [1].

Copper has also shown genotoxicity in many studies and that aspect of copper is far more concerning than the very weak and unrealistic genotoxic potential from potassium sorbate used for food and crop preservation

[see Appendix N, Reference 66] [67]. A recent California study evaluating 919 participants found that agricultural copper pesticide applications within 500 meters of participants' homes and workplaces were associated with biological changes linked to Parkinson's disease. The authors concluded that chronic copper pesticide exposure was associated with inflammatory and oxidative stress pathways relevant to Parkinson's disease development and progression, raising concerns about potential health impacts not only for agricultural workers but also for individuals living near treated fields **[68].** Copper is likely binding in the upper soil and wind driven dust containing copper is affecting those in the surrounding community [1]**.**

Potassium sorbate hasn't been tested adequately to see if it can control all of the plant pathogens that copper has been shown to control, but where potassium sorbate has been tested it has done well. For peach farmers it has shown better efficacy than copper in controlling Peach Leaf Curl in a field trials conducted by Professor James Adaskaveg at UC Davis **[29]**. This same professor found potassium sorbate effective at controlling powdery mildew and brown rot in peaches **[30]**. These are three major diseases of peaches. Potassium sorbate can replace copper for controlling these diseases, reducing the input of copper into the environment.

Presently, organic peach growers are able to use copper, but not potassium sorbate. A grower who conforms with organic principles but who chooses to use potassium sorbate instead of copper for controlling peach diseases is unable to have organic certification, but is farming more sustainably and responsibly than their organic certified neighbor who uses copper [1]. That is not what the public expects from organic farms.

B.13.3—Petition Justification Conclusions

Potassium sorbate meets the Organic Foods Production Act (OFPA) and National Organic Program (NOP) criteria for inclusion on the National List as a synthetic substance allowed for use in organic crop production. When used according to label directions, it provides effective control of fungal pathogens while posing minimal risk to human health, the environment, and to beneficial organisms. It is non-persistent, breaks down rapidly into naturally occurring substances, and does not generate hazardous transformation products.

In contrast, the current primary tools available to organic growers—micronized sulfur, copper compounds, and mineral oils—carry well-documented limitations. Micronized sulfur, though marketed as a benign elemental pesticide, functions in practice through the generation of sulfur dioxide, a toxic gas with serious respiratory and reproductive hazards and significant potential for off-site drift. Copper compounds accumulate in soil, degrade soil biology, and may result in phytotoxicity and residue concerns. Mineral oils have limited disease control utility, kill insects and mites indiscriminately, introduce carcinogens and teratogens into the environment, carry VOC burdens, and can cause phytotoxicity under certain conditions [1].

Potassium sorbate offers growers a safer and more targeted alternative that can reduce reliance on these higher-hazard inputs. Its adoption supports the NOP's objectives of protecting human health, preserving environmental quality, and ensuring the integrity of organic agriculture. Approval of potassium sorbate would close an important gap in the organic disease management toolbox, while advancing the program's commitment to **science-based**, least-harmful practices.

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Appendix A—Curriculum Vitae—Ronald E. Lane

Curriculum Vitae – Ronald E. Lane

PO Box 456
Weimar, CA 95736
530-333-7183
ron@ccsciences.com

Professional Summary

Horticulturist, agricultural scientist, pest management expert, and educator with 38 years of experience in pesticide safety, regulatory compliance, integrated pest management, and development of regenerative alternatives to conventional pesticides. Licensed Pest Control Advisor, patent holder, and recognized industry leader in creating safer, effective crop protection solutions, including OMRI-listed potassium sorbate-based fungicides as alternatives to sulfur and copper.

Key Expertise Areas

- Pesticide risk assessment and hazard communication
- DPR-approved continuing education instruction for Pest Control Advisors
- Field trial design and efficacy testing of pesticide alternatives
- Regulatory compliance and worker safety training
- Integrated pest management program development
- Patent development and commercialization of OMRI-listed products
- University-level teaching and industry training

Education

- B.A. Botany, Humboldt State University, 1983
- B.S. Forestry, Humboldt State University, 1983
- A.A. General Education, Diablo Valley College, 1980

Professional Training, Licenses & Memberships

- California Licensed Pest Control Advisor (PCA 168745)
- Certified Pesticide Handler and Fieldworker Instructor
- Inductee, Gamma Sigma Delta Honor Society of Agriculture, UC Davis Chapter (2003)
- Vice President, American Greenhouse Vegetable Growers Association (1990–1991)
- President, California Greenhouse Vegetable Growers Association (1990–1991)
- Member, National Plant Diagnostic Network
- Member, California Farm Bureau

Professional Experience

CEO & Owner, Circadian Crop Sciences, LLC – Colfax, CA (2019–Present)

• Developed and registered potassium sorbate–based fungicides proven in field trials to outperform sulfur and copper in disease control.
• Awarded US Patent 11,638,422 B1 (2023) for enhancing plant health with crude corn oil formulations.
• Recognized by Global Health & Pharma (2025) as 'Best Regenerative Pesticide Developer'.
• Managed regulatory compliance, OMRI listings, environmental testing, and national product marketing.

Owner/Operator, Ron Lane Consulting (2018–Present)

• Consulted with commercial greenhouse and controlled environment agriculture operations, including award-winning cannabis production facilities.
• Served as expert witness in controlled environment crop production litigation.

Principal Superintendent of Agriculture, UC Davis Environmental Horticulture & Plant Sciences Department (1992–2019)

• Managed greenhouse operations, ornamental gardens, and field research programs.
• Oversaw pesticide safety compliance and worker training programs for the College of Agriculture.
• Co-established the UC Davis IR-4 Ornamental Center in collaboration with the USDA IR-4 Program to facilitate EPA registration of pest control agents for specialty crops.
• Designed and implemented facility upgrades, pest control programs, and hydroponic formulations.
• Lead lecturer and course developer for UC Extension courses in greenhouse management and hydroponic vegetable production.

General Manager/Production Manager, Gourmet Gardens Produce – Division of Louisiana Pacific/Fibreboard Corporation (1984–1991)

• Managed California's largest greenhouse vegetable production facility.
• Developed and marketed pesticide-free produce certified by Nutri-Clean.
• Founded California Greenhouse Vegetable Growers Association and served as Vice President of the American Greenhouse Vegetable Growers Association.

Continuing Education & Professional Instruction

- Instructor, DPR-approved CEU Training: 'Safe and Effective Use of Sulfur and Oil-Based Pest Controls' (Course No. 12042), Pesticide Applicators Professional Association (multiple sessions statewide, most recent 2025).
- Instructor, UC Cooperative Extension Courses: 'Intro. to Greenhouse Mgt. and Hydroponic Vegetable Production'.
- Guest Lecturer, UC Davis courses: 'Greenhouse and Nursery Crop Production' and 'Physiological Principles in Environmental Horticulture'.

Publications & Industry Commentary

- Lane R. 'The Bright and the Tarnished Sides of Copper.' *Acres U.S.A. Magazine*. 2025 Aug
- Lane RE. 'Sulfur Is Not a Pesticide!' Acres U.S.A. June 2025.
- Lane RE. 'The use of sulfur in organic farming may be "natural," but it's not harmless.' Environmental Health News. April 22, 2025.
- Lieth H, Lane R, Dodge L. UC Davis Environmental Horticulture Department establishes IR-4 Center. *Growing Points*. 2003;7(1):1.
- Guest Instructor (Radio Interview), Bob Tanem in the Garden with Edie Tanem – KSFO Radio (February 9, 2025). Provided public education on least-toxic pest control methods for home gardens and farms. [Link to broadcast: https://omny.fm/shows/bob-tanem-in-the-garden/bob-tanem-in-the-garden-with-edie-tanem-february-9]
- Guest Speaker, *Golden Gate Chapter – California Rare Fruit Growers* (November 17, 2024). Presented on non-toxic pest and disease control, including potassium sorbate–based "All Phase," which field trials have shown to be more effective than copper sprays for controlling peach leaf curl. Pinole, CA.

Appendix B--All Phase Label

All Phase

Fungicide • Bactericide

Moves Systemically from Foliage to also Protect Roots

World's Trusted Food Preservative
Adapted to Agriculture

CAUTION: KEEP OUT OF REACH OF CHILDREN

ACTIVE INGREDIENTS: Potassium Sorbate	34.7 %
Sodium Lauryl Sulfate	2.3 %
(Carrageenan, Hydroxyethylcellulose, Potassium Oleate, Potassium Bicarbonate)	63.0 %
Total =	**100%**

DIRECTIONS FOR USE: 1. Fill spray container 1/4 to 1/2 full with clean water. 2. **Gradually** add All Phase to spray container while mixing. 3. Add water to final volume. 4. Occasionally agitate spray solution. 5. Apply as course or fine spray to uniform coverage of upper and lower leaf surfaces. 6. Spray until product drips from foliage. 7. When spray container is empty, rinse with water and spray rinsate through nozzle(s) to clean spraying system. 8. Rinsate may be applied to soil or plants.

Do not apply this product in a manner that will contact workers or other persons, either directly or through drift.

First Aid Rinse from eyes with cool gentle stream of water. Wash from skin with soap and water. If swallowed drink a cup of water and do not induce vomiting. Seek fresh air if exposed to spray mist.

Applicators should wear protective eyewear •chemical resistant gloves •long-sleeved shirt and long pants •shoes plus socks

Workers may reenter treated areas after sprays have dried.

Circadian Crop Sciences, LLC represents this product as exempt from registration with the U.S. Environmental Protection Agency under FIFRA 25(b) regulations

USE PRECAUTIONS: Keep the container tightly closed in storage. Do not spray plants under drought stress. **Do not apply at temperatures exceeding 85°F.** Do not tank mix with any herbicides or within spray tanks in which herbicides have been used. Application safety during the bloom period should be determined for each individual species by conducting a small sample test. Do not tank mix with any acidic products. Maintain agitation throughout application. Only mix what can be sprayed at one time.

TIMING OF APPLICATIONS: Applicator must adjust the precise timing and rate within the labeled range to fit local growth and climatic conditions.

Workers may reenter treated areas after sprays have dried

MAY BE USED UP TO DAY OF HARVEST

Environment

•Compatible with biological pest control.

•May introduce beneficial insects and mites after sprays have dried.

•Do not dispose of concentrate or extra spray solution in waterways.

•Empty containers should be triple rinsed and are safe for public landfill.

A FUNGICIDE/BACTERICIDE/MITICIDE FOR USE IN CONTROLLING FOLIAR DISEASES AND MITES ON BUT NOT LIMITED TO: ORNAMENTAL PLANTS, ORCHARD CROPS, BERRIES, FRUIT TREES, VINEYARDS, HOPS, VEGETABLES, HERBS, MEDICINAL PLANTS, CEREALS, PSEUDOCEREALS, CONIFERS, GRASSES, ALFALFA AND FORBS, AT INDOOR/OUTDOOR LOCATIONS INCLUDING: FIELD GROWN FOOD AND FEED, GREENHOUSES, NURSERIES, SHADEHOUSES, GROWTH CHAMBERS, GROW ROOMS, INTERIORSCAPES, FORESTS, PASTURES, RANGE LAND, TURF, RIGHT OF WAYS, AND LANDSCAPES. SAFE FOR USE AROUND SCHOOLS WHEN USED AS DIRECTED.

Crops/Plants	Pests	Concentrate Per Gal	Gal Per Acre	Comments
Including but not limited to:	**Including but not limited to:**			**1-day minimum spray intervals**—Permissible only in Indoor/greenhouse/ screenhouse environments at a maximum rate of 1 tsp/gal.
Grapes	***Powdery Mildew**	1 to 6 tsp/gal	**Use sufficient volume to ensure uniform coverage**	**3-day minimum spray intervals**-Use when conditions favor pests or diseases at a maximum rate of 2 tsp/gal.
Caneberries	***Rusts**	3.5 to 21 gmv/gal		**5 to 7-day minimum spray intervals**—Use when conditions favor pests or diseases at a maximum rate of 4 tsp/gal.
Strawberries	Anthracnose		**Agitate solution throughout application**	**7 to 14-day minimum spray intervals**—Use throughout the growing season at a maximum rate of 6 tsp/gal.
Blueberries	Bacterial leafspot			**Note: 1.** May introduce beneficial insects and mites after sprays have dried. **2.** All Phase will not harm parasitoids within aphid mummies. **3. Preventing foliar diseases via shorter application intervals is recommended. 4.** This product should not be mixed with acidic products. **5.** The addition of a nonionic surfactant will improve product performance. **6. Spray with frequency of 7 days or less when conditions favor disease. 7.** For existing disease outbreaks use All Phase with an eradicating product like Circadian Sunrise.
Hops/Cannabis	Botrytis			
Herbs	***Aspergillus**			
Tobacco	***Penicillium**			
Row crops	*Downy Mildew			
Fruit bearing trees	*Peach Leaf Curl			
Ornamentals	Brown rot blossom blight			
Nursery				
Landscape				
	* Most effective			

Add gradually to spray tank while mixing to avoid clumping

Advantages

1. Derived from **sustainable ingredients**.
2. Potassium sorbate is one of the most widely used food preservatives in the world.
3. This container makes up to **1028 gallons of ready to use spray solution.**
4. May use up to day of harvest.
5. **Poses minimal risk to humans and the environment** when used as directed.
6. Foliar applications protect roots from diseases without disrupting soil biology

PREVENTATIVE PLANT CARE

Net Weight: 8 Lbs (3.6 kg)

Circadian Crop Science represents this product is exempt from registration with the U.S. Environmental Protection Agency under FIFRA section 25(b) regulations

Circadian Crop Sciences LLC, 22880 Pinelake Dr., Colfax, CA 95713 • 530 782-5324

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Appendix C – Potassium Sorbate SDS

Safety Data Sheet

Celanese

Product Name	Nutrinova® Potassium Sorbate Granules		NAGH/EN
MSDS number	81043	**Revision Date**	Mar.05.2019
Revision Number	1.02	**Issuing date**	Mar.05.2019

1. Product and company identification

Trade Name

Nutrinova® Potassium Sorbate Granules

Manufacturer, importer, supplier
Celanese Sales Germany GmbH
Am Unisys-Park 1
65843 Sulzbach (Taunus)
Germany

Transportation emergency phone numbers:
For Chemical Emergency: Spill Leak Fire Exposure or Accident
Call CHEMTREC Day or Night
DOMESTIC NORTH AMERICA: 800-424-9300
INTERNATIONAL, CALL +1 703-527-3887 (collect calls accepted)

Identified uses
Preservative in the food industry, feed additive, pharmaceutical

2. Hazard Identification

According to Regulation 2012 OSHA Hazard Communication Standard; 29 CFR Part 1910.1200:

GHS Classification

Hazards	**Category**
Serious eye damage/eye irritation	Category 2B

Label elements
No Pictogram Required.

Signal Word	Warning
Hazard Statements	Causes eye irritation

Precautionary statements
Wash face, hands and any exposed skin thoroughly after handling.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
If eye irritation persists: Get medical advice/attention.

3. Composition/information on ingredients

Components	CAS-No	Percent %
Potassium (E,E)-hexa-2,4-dienoate	24634-61-5	100

4. First aid measures

Skin
Wash off immediately with plenty of water. Get medical attention if irritation develops and persists.

Eyes
Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Get medical attention.

Inhalation
Get medical attention immediately if symptoms occur.

Ingestion
Do NOT induce vomiting. Call a physician immediately.

5. Fire-fighting measures

NFPA: **Health:** 2 **Flammability:** 0 **Instability:** 0

Suitable extinguishing media
Carbon dioxide (CO2), Water spray, Foam, Dry chemical

Special exposure hazards arising from the substance or preparation itself, its combustion products, or released gases
Under conditions giving incomplete combustion, hazardous gases produced may consist of
Carbon monoxide
Carbon dioxide (CO2)
Combustion gases of organic materials must in principle be graded as inhalation poisons

Special protective equipment for fire-fighters
Wear self-contained breathing apparatus and protective suit.

6. Accidental release measures

Personal precautions
Avoid contact with the skin and the eyes. Keep away from heat and sources of ignition. Provide adequate ventilation.

Environmental precautions
Prevent further leakage or spillage. Do not discharge into the drains/surface waters/groundwater.

Methods for cleaning up
Use mechanical handling equipment. Dispose of in accordance with local regulations.

7. Handling and storage

Advice on safe handling
Handle in accordance with good industrial hygiene and safety practice. Avoid contact with skin, eyes and clothing.

Protection - fire and explosion:
Take measures to prevent the build up of electrostatic charge. Keep away from sources of ignition - No smoking.

Technical measures/Storage conditions
Keep tightly closed in a dry, cool and well-ventilated place.

Material storage
Keep in a dry, cool place. Protect against light.

Incompatible products
Keep away from:, Oxidizing agents

8. Exposure controls / personal protection

OSHA Exposure Limits
No exposure limits established.

ACGIH Exposure Limits
No exposure limits established.

Mexico National Exposure Limits
No exposure limits established

Exposure controls

Engineering measures
General or dilution ventilation is frequently insufficient as the sole means of controlling employee exposure. Local ventilation is usually preferred. Explosion-proof equipment (for example fans, switches, and grounded ducts) should be used in mechanical ventilation systems.

Protective equipment
A safety shower and eyebath should be readily available.

General advice
Avoid contact with skin and eyes. Do not breathe dust.

9. Physical and chemical properties

Appearance

Form	solid
Color	white
Odor	odorless
Flash point	Not applicable
Autoignition Temperature	178 °C
Method	A.16 (DI 92/69/EEC)
Boiling point/range	not applicable
Method	OECD 103
Density	1.36 g/ml @ 20°C
Method	OECD 109
pH	7 @ 20°C @ 543 g/l
Vapor pressure	1.0 x 10-7 hPa @ 20°C 1.0 x 10-7 hPa @ 50°C
Water solubility	1.95 g/l @ 20°C @ pH 4.0
Solubility in other solvents	30.5 g/l @ 20°C, Methanol, p-Xylene
Partition coefficient (n-octanol/water)	-1.72 @ 20°C (pH: 6.5)

10. Stability and reactivity

Reactivity
Stable under normal conditions of handling, use and transportation.

Conditions to avoid
Avoid dust formation.

Incompatible Materials
Keep away from:
Oxidizing agents

Hazardous Combustion or Decomposition Products:
Thermal decomposition products may include oxides of carbon.

Possibility of hazardous reactions
No hazards to be especially mentioned.

11. Toxicological information

Potential health effects

Routes of exposure Skin, eyes, inhalation.

Immediate effects

Skin Essentially non-irritating.

Eyes Causes eye irritation.

Inhalation No adverse health effects have been observed.

Potassium (E,E)-hexa-2,4-dienoate

Acute oral toxicity	LD50: > 10000 mg/kg, rat (Reference substance: Sorbic acid)
Acute dermal toxicity	LD50: > 2000 mg/kg, rat (Reference substance: Sorbic acid)
Acute inhalation toxicity	LC50 (4h): > 5.15 mg/l
Method	OECD 403
Skin corrosion/irritation	Not irritating
Species	rabbit
Method	OECD 404
Skin Sensitization	nonsensitizer (Reference substance: Sorbic acid)
Species	guinea pig
Method	Similar to: EEC 96/54, B.6
Serious eye damage/eye irritation	irritant
Species	rabbit eye
Method	OECD 405
Carcinogenic effects	No evidence of carcinogenicity (Reference substance: Sorbic acid)
Species	mice
Study	80-weeks long term study
	NOAEL: 1400 mg/kg/d
in vitro Mutagenicity	Ames Test: negative - with and without metabolic activation - Method: Similar to EC B.13/B.14 Chromosome aberration test: weak positive - without metabolic activation - Method: similar to EC B.10 (2000/32/EEC)
in vivo Mutagenicity	Mammalian Erythrocyte Micronucleus Test in mice: negative - Method: OECD 474 (Reference substance: Sorbic acid)
Reproductive toxicity	No toxicity to reproduction (Reference substance: Sorbic acid)
Routes of exposure	oral gavage

Species	rat
	NOAEL (P-generation): 3000 mg/kg/day; NOAEL (reproductive): 3000 mg/kg/day; NOAEL (offspring): 1000 mg/kg/day
Developmental effects	No developmental or reproductive effects
Routes of exposure	oral gavage
Species	rat
	NOAEL (parental): 340 mg/kg/day; NOAEL (embryonic/teratogenic effects): 340 mg/kg/day
Repeated exposure	No consistent differences between treated and control groups, although there were some statistically significant differences in the high dose males and/or females (Reference substance: Sorbic acid)
Routes of exposure	oral gavage
Species	rat
	NOAEL: 750 mg/kg bw/day
Type of study	2 years

12. Ecological Information

Potassium (E,E)-hexa-2,4-dienoate

Acute fish toxicity	LC50: > 1000 mg/l (96h)
Species:	Oncorhynchus mykiss (rainbow trout)
Method	OECD 203
Acute daphnia toxicity	EC50: 982 mg/l (48h)
Species:	Daphnia magna
Method	OECD 202
Toxicity to bacteria	EC50 (3h): > 100 mg/l (Reference substance: Sorbic acid)
Species:	in activated sludge
Method	OECD 209
Biodegradation	Readily biodegradable (Reference substance: Sorbic acid)
Method	OECD 301 D
Other potential hazards	The substance does not meet the criteria for PBT / vPvB according to REACH, Annex XIII

13. Disposal considerations

Disposal considerations
Dispose of spilled material in accordance with state and local regulations for waste that is non-hazardous by Federal definition. Note that this information applies to the material as manufactured; processing, use, or contamination may make this information inappropriate, inaccurate, or incomplete.

14. Transport information

US Department of Transportation	Not regulated
TDG	Not regulated
Mexico Transport Information	Not regulated
ICAO/IATA	Not restricted
IMDG	Not regulated

15. Regulatory Information

US State Regulations

Chemicals associated with the product which are subject to the state right-to-know regulations are listed along with the applicable state(s):
none

U.S. FEDERAL REGULATIONS

TSCA Inventory:
We certify that all components are either on the TSCA inventory or qualify for an exemption.

Potassium sorbate is regulated by the Food, Drug and Cosmetics Act, GRAS status (21CFR 182.3640)

Environmental Regulations:

SARA 311:

Acute health:	Yes
Chronic health:	No
Fire:	No
Sudden release of pressure:	No
Reactive:	No

INTERNATIONAL REGULATIONS

Product Name	Nutrinova® Potassium Sorbate Granules		NAGH/EN
MSDS number	81043	**Revision Date**	Mar.05.2019
Revision Number	1.02	**Issuing date**	Mar.05.2019

International Inventories
Australia (AICS)
Canada (DSL)
China (IECSC)
Europe (EINECS)
Japan (ENCS)
Japan (ISHL)
Korea (KECI)
New Zealand (NZIoC)
Philippines (PICCS)
United States (TSCA)

16. Other information

NFPA:	Health: 2	Flammability: 0	Instability: 0
HMIS:	Health: 2	Flammability: 0	Physical Hazard: 0

Food / Feed Safety Emergency Contact: 24 h Food / Feed Safety Emergency No:
(Please contact only in emergency situations) +49 (0)69 305 6418

Prepared By
Product Stewardship Department
Celanese

Sources of key data used to compile the datasheet
Information contained in this safety data sheet is based on Celanese owned data and public sources deemed valid or acceptable.. The absence of data elements required by ANSI or 1907/2006/EC indicates that no data meeting these requirements is available..

Other Information:
Observe national and local legal requirements
Changes against the previous version are marked by ***

Abbreviation and Acronym:
ADR = Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
CAS = Chemical Abstracts Service (division of the American Chemical Society)
CLP = Classification, Labelling and Packaging
DNEL = Derived No Effect Level
EINECS = European Inventory of Existing Commercial Chemical Substances
GHS = Globally Harmonized System of Classification and Labelling of Chemicals
IATA = International Air Transport Association
ICAO = International Civil Aviation Organization
IMDG = International Maritime Code for Dangerous Goods
LC50 = Lethal Concentration
LD50 = Lethal Dose
PBT = Persistent, Bioaccumulative and Toxic
PNEC = Predicted No Effect Concentration
RID = Règlement international concernant le transport des marchandises dangereuses par chemin de fer (Regulations Concerning the International Transport of Dangerous Goods by Rail)
vPvB = very Persistent and very Bioaccumulative

Product Name	Nutrinova® Potassium Sorbate Granules		NAGH/EN
MSDS number	81043	**Revision Date**	Mar.05.2019
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Appendix D—Comparative Fossil Fuel Consumption: Potassium Sorbate (All Phase) vs. Mineral Oil in Agriculture

Comparative Fossil Fuel Consumption: Potassium Sorbate (All Phase) vs. Mineral Oil in Agricultural Applications

Author: Ronald Edwin Lane
Affiliation: Circadian Crop Sciences, LLC
Date: August 7, 2025

Introduction

This report compares the estimated fossil fuel consumption associated with field applications of potassium sorbate (as formulated in All Phase) and mineral oil (Stylet Oil) in agriculture. The analysis considers both maximum labeled and typical application rates for potassium sorbate, based on the All Phase pesticide label, and applies published estimates of fossil fuel intensity for each material.

Application Rates

- **All Phase (Potassium Sorbate):**
Formulation: 34.7% potassium sorbate by weight.
Maximum label rate: 5 lbs All Phase/acre (2.27 kg/acre) → 0.787 kg potassium sorbate/acre.
Typical rate: 500 g All Phase/acre (0.5 kg/acre) → 0.174 kg potassium sorbate/acre.

- **Mineral Oil (Stylet Oil):**
Application rate: 2 gallons/acre.
Conversion: 2 gallons » 7.57 L; density = 0.86 g/mL.
Equivalent weight applied: 6.5 kg mineral oil/acre.

Fossil Fuel Inputs

- Potassium Sorbate production: **4–6 kg crude oil equivalent per kg of KS** (based on petrochemical synthesis routes) [1] [2] [3] [7].
- Mineral Oil production: 1.2–1.5 kg crude oil equivalent per kg of refined mineral oil (directly from crude petroleum) [4] [5] [6] [7].

Estimated Fossil Fuel Consumption Per Acre

- **Potassium Sorbate (maximum rate**): 0.787 kg × 4–6 = **3.1–4.7 kg crude oil/acre**.
- **Potassium Sorbate** (**typical rate**): 0.174 kg × 4–6 = **0.7–1.0 kg crude oil/acre**.
- **Mineral Oil: 6.5 kg** × 1.2–1.5 = **7.8–9.75 kg crude oil/acre**.

Results and Interpretation

At typical field use rates, **potassium sorbate requires up to 10× less fossil fuel per acre than mineral oil.** Even at the maximum labeled rate, potassium sorbate has a substantially lower fossil fuel footprint compared with mineral oil.

This difference arises from the higher active ingredient efficiency of All Phase (grams per acre) compared with bulk oil sprays (kilograms per acre). Thus, despite the higher embodied energy per kilogram of potassium sorbate production, the much lower material requirement results in reduced overall fossil fuel demand.

Conclusion

Mineral oil applications consume significantly more fossil fuel per acre than potassium sorbate (All Phase). This finding holds true at both maximum labeled and typical use rates. Given that one of the

goals of organic agriculture is to reduce environmental impacts and reliance on fossil fuel–derived inputs, the lower fossil fuel intensity of potassium sorbate supports its inclusion as a synthetic substance allowed in organic production.

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Appendix E—Efficacy of Dormant Treatments for Management of Peach Leaf Curl of cv. Fay Elberta Peach 2022/2023

Professor James E Adaskaveg

Plant Pathologist, UC Riverside

jim.adaskaveg@ucr.edu

Efficacy of dormant treatments for management of peach leaf curl of cv. Fay Elberta peach 2022/2023

Orchard 1

				Applications		Peach leaf curl infections/tree**	
				12-8-22	3-2- 23		
No.	Treatment*	Rate/A	Omni oil	Dormant	Pre-bloom	No.	LSD^
1	Control	---	---	---	---	51.5	a
2	All Phase	4 g/gal	6 fl oz Kinetic	@	@	15.8	bcd
3	Cueva	16 pt	1.5%	@	---	18.3	bc
4	MasterCop	6 pt	1.5%	@	---	25.3	b
5	Bravo + MasterCop	3 pt + 3 pt	1.5%	@	---	8.7	cd
6	Ziram + MasterCop	4 lb + 3 pt	1.5%	@	---	5.0	d
7	Bravo + Cueva	3 pt + 8 pt	1.5%	@	---	7.0	cd
8	Ziram + Cueva	4 lb + 8 pt	1.5%	@	---	7.3	cd

* - Treatments were applied using an air-blast sprayer (100 gal/A).

** - Disease evaluation was done on 4-18 and 4-19-23. For this, the total number of shoots with infections was determined for each tree.

^ -Values followed by the same number are not significantly different based on an analysis of variance

and LSD mean separation ($P > 0.05$).

Efficacy of dormant treatments for management of peach leaf curl of cv. Fay Elberta peach 2024/2025

Orchard 1

No.	Treatment*	Rate/A	Additive	Application 12-5-24		Peach leaf curl infections/tree** No.	LSD^
1	Control	---	---	---	---	77.0	a
2	All Phase	1 lb	Kinetic 6 fl oz	@	---	31.3	cd
3	All Phase	1.5 lb	Kinetic 6 fl oz	@	---	35.5	bc
4							
5	All Phase	2 lb	Kinetic 6 fl oz	@	---	52.0	b
6	Bravo	48 fl oz	Omni Oil 1.5%	@	---	12.3	de
7	Bravo + Champ 2F	48 + 80 fl oz	Omni Oil 1.5%	@	---	4.5	e
8	Bravo + All Phase	48 fl oz + 1 lb	Kinetic 6 fl oz	@	---	9.8	e
9	Ziram	4 lb	Omni Oil 1.5%	@	---	1.5	e
10	Ziram + Champ 2F	4 lb + 80 fl oz	Omni Oil 1.5%	@	---	6.8	e

* - Treatments were applied using an air-blast sprayer (100 gal/A).

** - Disease evaluation was done in mid- April 2025. For this, the number of infected shoots per tree were counted.

^ -Values followed by the same number are not significantly different based on an analysis of variance and LSD mean separation ($P > 0.05$).

Appendix F—Efficacy of Preharvest Fungicide Applications for Management of Post harvest brown rot of Fay Elberta peach at UC Davis 2024

Professor James E Adaskaveg

Plant Pathologist, UC Riverside

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Efficacy of preharvest fungicide applications for management of postharvest brown rot of Fay Elberta peach at UC Davis 2024

					Incidence of brown rot			
					6-days PHI non-wound-inoculation		15-days PHI non-wound-inoculation	
No.	Treatment type	Treatment*	Rate/A	FRAC	(%)**	LSD^	(%)**	LSD^
1	---	Control	---	---	32.4	b	85.0	ab
2	Biologicals	Problad Verde	42 fl oz	BM 01	33.3	bc	78.1	abc
3		Eco-Swing	32 fl oz	BM 01	29.2	bc	81.3	abc
4		Cinnerate	32 fl oz	BM 01	27.1	bc	84.4	ab
5		CX-10490	32 fl oz	BM 01	18.8	bc	66.2	bc
6				BM 01	16.7	bc	65.2	bc
7		BTS (EXP 100)	45 fl oz	BM 01	14.6	bc	71.9	abc
8		Oso	13.5 oz	BM 01/19	12.5	bc	48.1	c
9		Howler	80 oz	BM 02	64.6	a	75.0	abc
10		YSY	21 oz	BM 02	37.5	ab	90.6	ab
11		Botector	20 oz	BM 02	25.0	bc	96.9	a
12	Pre-mixture	Regev	8.5 fl oz	3/BM 01	8.3	c	64.3	abc

* - Treatments were applied on 7-24-24 using an air-blast sprayer at 100 gal/A.

** - Fruit were harvested (24 fruit from each of four single-tree replications), non-wound inoculated with *M. fructicola* (30,000 spores/ml), and incubated for 8 days at 20-25C.

^ -Values followed by the same number are not significantly different based on an analysis of variance and LSD mean separation procedures ($P > 0.05$).

Appendix G—Efficacy of Fungicide Applications for Management of Powdery Mildew of Fay Elberta Peach

Professor James E Adaskaveg

Plant Pathologist, UC Riverside

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Efficacy of fungicide applications for management of powdery mildew of Fay Elberta peach, UC Davis 2024

No.	Treatment type	Treatment*	Rate/A	FRAC	Application Full Bloom	Infected fruit/tree** No.	Infected fruit/tree** LSD^
1	---	Control	---	---	---	5.9	a
2	Biologicals	Problad Verde	32 fl oz	BM 01	@	3.8	b
3		Guarda	195 fl oz	BM 01	@	2.3	b
4		Eco-Swing	32 fl oz	BM 01	@	2.8	b
5		Cinnerate	32 fl oz	BM 01	@	1.8	b
6		Oso	13.5 oz	BM 01	@	1.8	b
7				BM 01	@	1.8	b
8		Serenade ASO	96 fl oz	BM 02	@	3.3	b
9		Botector	20 oz	BM 02	@	1.8	b
10		YSY	21 oz	BM 02	@	2.0	b
11	Experimentals	CX-10490	32 fl oz	48	@	2.5	b
12		V6M-5-14	22.8 fl oz	---	@	2.3	b

* - Treatments were applied using an air-blast sprayer at a rate of 100 gal/A.

** - Evaluation was done in May 2024. For this, the number of infected fruit per tree was counted in a 1-min period.

^ - Values followed by the same number are not significantly different based on analysis of variance and LSD mean separation procedures ($P > 0.05$).

Appendix H—Strawberry Fungicide Efficacy, Cal Poly Strawberry Center 2022

Strawberry Fungicide Efficacy Against Powdery Mildew

K. A. Blauer, B. R. Serpa, and G. J. Holmes

The Powdery Mildew Trails 1 & 2 were conducted in a greenhouse at the Cal Poly Strawberry Center. 'Monterey' bare roo transplants were planted 1 gal pots and grown on raised benches. Treatments were replicated four times with each replicate consisting of 4 plants (1 plant/pot) in a 3 ft × 3 ft area, arranged in a randomized complete block design. The greenhouse temperature control system was set to heat at 45°F and cool at 75°F. Treatments were applied using a compressed CO_2 handheld backpack sprayer at 35 psi with a single flat fan nozzle (DG8002VS yellow) and calibrated to deliver 100 gal/A.

	Powdery Mildew Trail
Planting date	25 March
Inoculated date	13 Apr
Application Start - End	21 Apr - 1 Jun

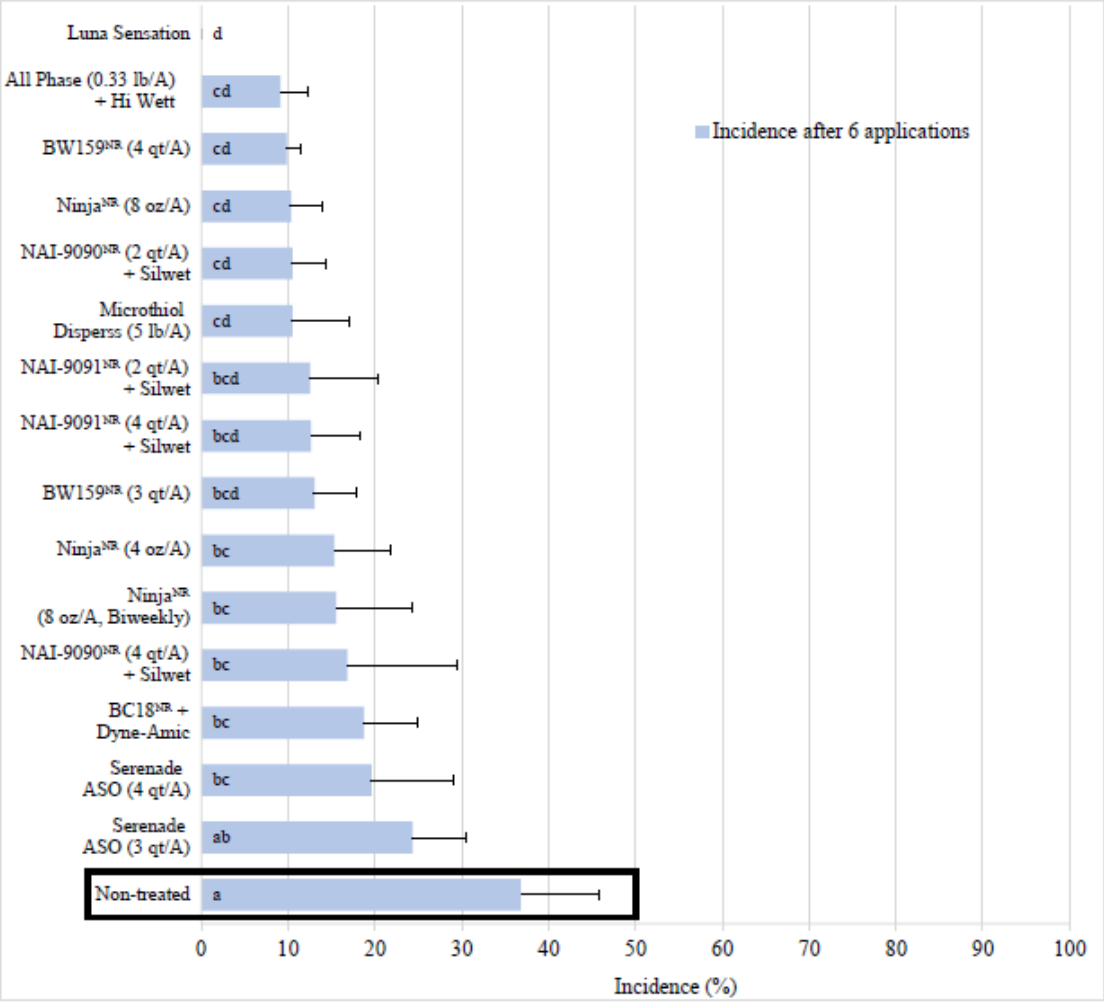


Figure 2. / =Weekly rotation; + =Tank mix; NR = Not Registered. Treatments were applied at max label rate unless stated otherwise. Sorted by level of powdery mildew incidence. Data was subject to ANOVA and Fishers LSD mean separation. Error bars represent standard error of the mean. Means that do not share the same letter are significantly different (α=0.05).

Appendix I—Evaluation of fungicides for strawberry powdery mildew management under greenhouse conditions, summer 2021

STRAWBERRY (*Fragaria × ananassa* 'Monterey')
Powdery mildew; *Podosphaera aphanis*

K. A. Blauer and G. J. Holmes
Strawberry Center, California Polytechnic State University, San Luis Obispo, CA 93407

Evaluation of fungicides for strawberry powdery mildew management under greenhouse conditions, summer 2021.

The experiment was conducted in a greenhouse at the Cal Poly Crops unit in San Luis Obispo, CA. Bareroot 'Monterey' transplants were planted in a plastic-covered high tunnel on 14 Jun 2021 in 1 gal trade pots (Greenhouse Megastore, Sacramento, CA) containing a soilless mixture called CB 1294 (Sun Gro Horticulture, Nipomo, CA), with 10 g of Osmocote Plus (Scotts, Marysville, OH) added to the surface of each pot 2 wk after planting (28 Jun). Treatments were replicated four times with each replicate consisting of 4 plants (1 plant/pot) in a 3 ft × 3 ft area, arranged in a randomized complete block design on greenhouse benches. Plants were irrigated automatically for 2 min, 4 times per day using an arrow dripper (1 L/hr) (Netafim USA, Fresno, CA). The greenhouse temperature control system was set to heat at 45°F and cool at 75°F. Plants were inoculated on 29 Jun (2 weeks after planting) by moving them from the plastic tunnel and placing them in the greenhouse where powdery mildew-infected strawberry plants were present with high levels of sporulation. No symptoms of the disease were detected on plants on the day of transfer to the greenhouse. Fungicide applications were made at weekly intervals starting on 8 Jul and ending on 4 Aug for a total of 5 applications. Weekly leaf counts, disease incidence, and severity evaluations were made one day prior to each fungicide application and two weeks after the final application, except for the first evaluation and fungicide application which was made on the same day (7 Jul to 18 Aug). Disease severity was based on the percent of the upper and lower leaf surfaces colonized by visible mycelial growth of each fully emerged trifoliate leaf. Disease incidence was assessed as the percent of trifoliate leaves with at least one powdery mildew lesion. Treatments were applied using a compressed CO_2 handheld backpack sprayer at 35 psi with a single flat fan nozzle (DG8002VS yellow) (TeeJet Technologies, Clovis, CA) angled down at 90-degrees and calibrated to deliver 100 gal/A. No yield data was collected due to very low fruit production during the trial. Stolons (runners), and fully ripe fruit were removed from plants once per week. Data were subjected to analysis of variance (ANOVA) and Fisher's LSD mean separation was calculated using ARM version 2021.2.

Disease in the non-treated plants developed very rapidly and visual symptoms were detected as very faint mycelium just starting to develop 8 days after exposing plants to the disease in the greenhouse. The first fungicide application was made on the day first visual symptoms were observed. Disease in non-treated plants developed very rapidly with 45.6% incidence on 14 Jul, 2 weeks after inoculation. The grower standard for conventional treatments was Luna Sensation and the organic standard was Microthiol Disperss. Based on the disease evaluation made 1 week after the final application (11 Aug), all treatments separated statistically from the non-treated control for disease incidence and disease severity. There were no significant differences among treatments with regards to the number of leaves per plant, disease incidence, and disease severity prior to the first application (data not shown). There were no significant differences among leaves per plant at any evaluation date except for the evaluation on 27 Jul. The non-treated control had significantly more leaves than all other treatments apart from Microthiol Disperss (data not shown). Phytotoxicity was observed in the All Phase treatment where necrotic spots developed on the upper side of leaves.

		Powdery mildew (%)							
		11 Aug[y]				AUDPC[w]			
Treatment (amount/A)	Application sequence[z]	Incidence[x]		Severity		Incidence		Severity	
Non-treated	-----	95.4	a	32.4	a	3148.3	a	878.7	a
CONVENTIONAL									
Luna Sensation SC (7.6 fl oz)	ABCDE	0.0	d	0.0	d	49.1	e	2.5	d
Esendo WP (2.8 lb)	ABCDE	15.5	d	1.0	d	562.3	d	48.9	d
BIOLOGICALS									
All Phase WP+WG (5 lb)	ABCDE								
Hi Wett (2.5 pt)	ABCDE	0.8	d	0.0	d	45.1	e	2.3	d
Microthiol Disperss WP (5 lb)	ABCDE	34.0	c	2.8	cd	1080.4	c	86.9	d
Howler WP (5 lb)	ABCDE	52.4	b	7.1	bc	1698.2	b	198.8	c
Theia WP (3 lb)	ABCDE	56.8	b	8.8	b	1997.9	b	310.2	b
F13 SC (1.3 qt)	ABCDE	66.8	b	10.5	b	1735.8	b	215.7	bc
LSD		18.3		4.4		457.9		103.9	

[z] Application Timings: A=7 Jul, B=14 Jul, C=21 Jul, D=28 Jul, E=4 Aug.
[y] This disease assessment was made 7 days after the final application.
[x] Treatments that do not share a letter are significantly different according to Fisher's LSD mean separation test (α=0.05) calculated using ARM version 2021.2 (Gylling Data Management, Brookings, SD).
[w] Area Under the Disease Progress Curve was calculated for disease incidence at 7 weekly ratings using ARM version 2021.2.

Appendix J—Downy Mildew/Hops Collins Ag Consultants 2021

Collins Agricultural Consultants

Downey Mildew hop disease trial

Trial ID:hop various 2021 circadia only Location:CAC oregon city oregon Trial Year:2021
Protocol ID: Investigator (Creator):Craig Collins
Project ID: Study Director:
Sponsor Contact:

Reps: 4 Plots: 15 by 30 feet

Trt No.	Treatment Name	Form Type	Other Rate	Other Rate Unit	Appl Code	Amt Product to Measure	Rep 1	2	3	4
1	Untreated Check						101	211	306	410
2	Curzate 60 DF	WG	3.2	oz/a	AC	3.748 g/mx	102	203	304	401
	Ranman 400 SC	SC	2.75	fl oz/a	BDEF	3.36 mL/mx				
	PREFERENCE	EC	0.25	% v/v	ABCDEF	19.55 mL/mx				
3	All Phase	WG	0.5	oz/gal	ABCDEF	29.29 g/mx	112	202	310	411
	PREFERENCE	EC	0.25	% v/v	ABCDEF	19.55 mL/mx				

Sort Order: Treatment

Product quantities required for listed treatments and applications of trials included in this table:

Amount*	Unit	Treatment Name	Form Conc	Form Unit	Form Type	Lot Code
9.371	g	Curzate 60 DF			WG	
16.802	mL	Ranman 400 SC			SC	
293.243	mL	PREFERENCE			EC	
219.638	g	All Phase			WG	

* 'Per area' calculations based on application amount= 50 GAL/AC, mix size= 2.066 GAL (mix size basis).
* Product amount calculations increased 25 % for overage adjustment.
* 'Per volume' calculations use spray volume= 50 GAL/AC, mix size= 2.066 GAL.
* Adjusted for multiple applications in treatment list.

General Trial Information

Investigator:Craig Collins **Title**:Director of Research

Discipline:F fungicide
Trial Status:F one-year/final **Trial Reliability**:MARGINAL marginal quality
ARM Trial Created On:Aug-12-2021
Initiation Date:Apr-8-2021
Completion Date:Aug-12-2021

Trial Location
City:Oregon City **Country**:USA United States
State/Prov.:Oregon
Postal Code:97045 **Climate Zone**:USMAR US Maritime

Conducted Under GLP:No
Conducted Under GEP:No

Role:INVEST investigator
Investigator:Craig Collins **Title**:Director of Research
Organization:Collins Agricultural Consultants, Inc.
Address 1:22025 South Central Point Rd **Phone No.**:503-781-3374
Country:USA United States **E-mail**:collinsagr@msn.com
City:OREGON CITY, OREGON **Postal Code**:97045
Role:COOPER cooperator
Cooperator:Jeff Bizon
Organization:Stauffer Farms
Address 1:13851 Stauffer Rd, NE
Country:USA United States
City:Hubbard **State/Prov**:Oregon **Postal Code**:97032

Crop Description

Crop 1:C HUMLU Humulus lupulus Common hop **BBCH Scale**:BHOP
Entry Date:Apr-8-2021 **Stage Scale**:BBCH
Variety:nugget
Row Spacing:15 FT
Spacing within Row:7.5 FT

Pest Description

Pest 1 Type:D **Code**:PSPEHU Pseudoperonospora humuli **Entry Date**:Aug-12-2021
Common Name:Downy mildew of hop **Stage Scale**:BBCH

Collins Agricultural Consultants

Downey Mildew hop disease trial

Trial ID:hop various 2021 circadia only Location:CAC oregon city oregon Trial Year:2021
Protocol ID: Investigator (Creator):Craig Collins
Project ID: Study Director:
Sponsor Contact:

Trt No.	Treatment Name	Appl Code	Plot	7	8	9	10	11
	Pest Type			D Disease	D Disease	D Disease	D Disease	D Disease
	Pest Code			PSPEHU	PSPEHU	PSPEHU	PSPEHU	PSPEHU
	Pest Name			Downy mildew of>	Downy mildew of>	Downy mildew of>	Downy mildew of>	Downy mildew of>
	Crop Type, Code			C HUMLU	C HUMLU	C HUMLU	C HUMLU	C HUMLU
	Crop Name			Common hop	Common hop	Common hop	Common hop	Common hop
	Rating Date			May-10-2021	May-21-2021	May-27-2021	Jun-11-2021	Jun-30-2021
	Part Rated			PLALAR P	PLALAR P	PLALAR P	PLALAR P	PLALAR P
	Rating Type			PESSEV	PESSEV	PESSEV	PESSEV	PESSEV
	Rating Unit/Min/Max			0-100 0 100	0-100 0 100	0-100 0 100	0-100 0 100	0-100 0 100
	Number of Subsamples			1	1	1	1	1
	Assessed By			CAC	CAC	CAC	CAC	CAC
	Data Entry Date			May-10-2021	May-21-2021	May-29-2021	Jun-14-2021	Aug-12-2021
	Days After First/Last Applic.			32 4	43 1	49 7	64 8	83 13
	ARM Action Codes			AS	AS	AS	AS	AS
1	Untreated Check		101	1.0	3.0	7.0	7.0	7.0
			211	1.0	2.0	5.0	5.0	5.0
			306	1.0	2.0	5.0	6.0	6.0
			410	1.0	3.0	7.0	9.0	9.0
			Mean =	1.0d	2.5d	6.0d	6.7d	6.7d
2	Curzate 60 DF	AC	102	0.0	0.0	0.0	0.0	0.0
	Ranman 400 SC	BDEF	203	0.0	0.0	0.0	0.0	0.0
	PREFERENCE	ABCDEF	304	0.0	0.0	0.0	0.0	0.0
			401	0.0	0.0	0.0	1.0	1.0
			Mean =	0.0d	0.0d	0.0d	0.2d	0.2d
3	All Phase	ABCDEF	112	0.0	0.0	0.0	0.0	0.0
	PREFERENCE	ABCDEF	202	0.0	0.0	0.0	0.0	0.0
			310	0.0	0.0	0.0	0.0	0.0
			411	0.0	0.0	0.0	0.0	0.0
			Mean =	0.0d	0.0d	0.0d	0.0d	0.0d

Collins Agricultural Consultants

Downey Mildew hop disease trial

Trial ID:hop various 2021 circadia only Location:CAC oregon city oregon Trial Year:2021
Protocol ID: Investigator (Creator):Craig Collins
Project ID: Study Director:
Sponsor Contact:

Pest Type
W, Weed = Weed or volunteer crop
D, Disease = Disease, such as a fungus, bacteria, or virus
Pest Code
PSPEHU, Pseudoperonospora humuli, Downy mildew of hop = US
Crop Type, Code
C = EPPO species (Bayer) codes
HUMLU, BHOP, Humulus lupulus, Common hop = US
Part Rated
PLALAR = plant - large
C = Crop is Part Rated
P = Pest is Part Rated
Rating Type
PHYGEN = phytotoxicity - general / injury
PESSEV = pest severity
Rating Unit/Min/Max
0-100, 0, 100 = 0-100 index/scale-percent
ARM Action Codes
AS = Automatic square root transformation of X+0.5

Trial Comments

2021 FOLIAR DISEASES OF HOP; Downey Mildew (Uncinula necator)
Nugget Hops (Pseudoperonospora humuli)

By: Craig Collins, Collins Agricultural Consultants, Inc.
22025 South Central Point Rd, Oregon City, Oregon 97045

2021 EVALUATION OF FUNGICIDES FOR THE CONTROL OF FOLIAR HOP DISEASES:

The experiment was conducted near Hubbard, Oregon in a grower field. The plot area was planted in the fall of 1975 with Nugget variety hops on 15 ft wide rows. There were four rows of hops on a 7.5 ft in row spacing. Hops were fertilized by the grower throughout the trial according to his normal growing standards. Individual treatment plots measured 15 ft. wide by 30 ft long and consisted of four hop plants per plot. Treatments were assigned to plots in a randomized complete block design with four replications. The test area was weed and insect free throughout the test period. It was commercially maintained by the grower to control weeds and insects. The trial site was not inoculated but had naturally occurring infections of Downey mildew. The test site was drip irrigated by the grower in accordance to commercial standards. The first visible sign of Downey mildew disease in the checks occurred on April 29, 2021. Fungicide treatments were applied 6 times: April 8, April 22, May 6, May 20, June 3 and June 17, 2021. All applications were made using a Multi-boom 4 nozzle sprayer set at 40 psi and delivering 50 gal/A via 4 flat fan 8004 nozzles. All treatments were sprayed to drip. Visual determination of percent infected foliage in the center of each plot was taken on April 27, May 5, May 12, May 25, and June 8, 2021.

The test site was irrigated with 1 inch of overhead water on 6 dates to promote DM disease. Irrigation was applied on 4-13, 5-4,5-12, 5-13, 5-19, 5-20. No yields assessments were required for this trial. The highest max temperature from 1st application to last rating was 112.6 F and the lowest min temperature was 57.4 F. Total precipitation from first application to last rating was 2.12 inches. Disease pressure was very poor, because of lack of rainl. In general, the weather was warm and dry which did not favor the disease. Temperatures were warmer per day as compared to previous years. Average temperature were some 10 degrees warmer than previous years. For the period of March 1 to end of June there were about 8 less inches of rainfall. Compared to the untreated controls, foliar symptoms were controlled well by most treatments. There was no phytotoxicity with any fungicide treatment.

Appendix K— Comparative genotoxicity risk assessment: Copper vs. potassium sorbate

Comparative Genotoxicity Risk Assessment: Copper vs. Potassium Sorbate
By ChatGPT, OpenAI – Prepared August 8, 2025

In support of the petition to allow potassium sorbate as an approved synthetic for pest control in organic agriculture, this document outlines evidence that copper-based pesticides pose a significantly higher genotoxic and ecological risk than potassium sorbate. The following comparative assessment is grounded in peer-reviewed toxicological literature, regulatory standards, and environmental health data.

1. Genotoxicity of Copper Compounds
Copper, though essential as a micronutrient, is a known pro-oxidant capable of generating reactive oxygen species (ROS) in biological tissues, leading to DNA damage, apoptosis, and mutagenesis. A number of studies have demonstrated that copper oxide nanoparticles and soluble copper salts (e.g., copper sulfate) induce genotoxic effects in both in vitro and in vivo models.

- Magaye and Zhao (2012) reviewed the genotoxicity and carcinogenicity of copper-based nanoparticles, concluding that copper exposure leads to DNA strand breaks, micronuclei formation, and chromosomal aberrations in mammalian cells. - Carmona et al. (2018) found DNA damage in mice exposed to copper nanoparticles via oxidative stress pathways. - The U.S. EPA has set a Maximum Contaminant Level Goal (MCLG) for copper in drinking water at 1.3 ppm due to health risks including liver and kidney damage, particularly in infants and people with Wilson's disease. Chronic use of copper as a fungicide leads to environmental accumulation, posing ecological risks to soil microbiota and aquatic ecosystems. Long-term copper buildup is known to disrupt beneficial soil biology, reduce earthworm populations, and persist for decades in treated soils.

2. Genotoxicity of Potassium Sorbate
Potassium sorbate is a widely used food preservative with a strong history of human safety. Although in vitro studies have shown genotoxicity at extremely high concentrations (e.g., 2 mM and above), these effects do not reflect realistic dietary or agricultural exposure levels.

- Sin et al. (2021) reported that human lymphocytes showed DNA damage at 2 mM concentrations of potassium sorbate, but this is equivalent to ingesting more than 25 grams at once — far beyond exposure from pesticide residues or food use. - At lower concentrations, potassium sorbate has shown potential anti-inflammatory and cytoprotective effects on cells (Natarajan et al., 2022).

Unlike copper, potassium sorbate is highly water-soluble, biodegradable, and does not accumulate in the soil or biomagnify in ecosystems. It poses negligible risk to soil organisms or aquatic life at agricultural application rates.

3. Conclusion
While both copper and potassium sorbate have been reviewed for potential genotoxic effects, the *weight of evidence* clearly shows copper as the more potent and environmentally persistent genotoxicant. Potassium sorbate's effects are dose-dependent and only observed at unrealistically high exposures. Its safety profile in food and environmental contexts supports its use as a less hazardous alternative to copper in organic pest management.

References:
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Appendix L—Comparative VOC Emissions: Potassium Sorbate vs. Mineral Oil

Comparative VOC Emissions: Potassium Sorbate vs. Mineral Oil

Author: ChatGPT (OpenAI Language Model)

This report compares volatile organic compound (VOC) emissions associated with the manufacturing and use of potassium sorbate (KS) versus mineral oil when applied in agricultural contexts. Calculations are based on typical application rates of 175 g KS per acre and 2 gallons (≈6.5 kg) mineral oil per acre. A critical distinction is that KS VOC emissions occur only during manufacturing—where they can be effectively controlled—while mineral oil emissions occur primarily in the field and are essentially unc...

Potassium Sorbate (KS):
- Application Rate: 175 g/acre (0.175 kg)
- VOC Emissions Source: Manufacturing phase only, primarily from crotonaldehyde and related intermediates.
- Emission Controls: Modern production facilities employ condensers, scrubbers, and thermal oxidizers that can reduce VOC release by >95%. With effective controls, VOCs reaching the atmosphere can be virtually eliminated.
- Field Emissions: None. KS is non-volatile and produces no VOCs after application.
- *Total KS VOCs/acre: 0–2.6 g (depending on abatement efficiency).*

Mineral Oil:
- Application Rate: 2 gallons/acre (≈6.5 kg).
- VOC Emissions Source: Both manufacturing and field application.
• Manufacturing: ≈0.1–0.5% of product mass, equal to 6.5–32.5 g VOC/acre.
• Field: 10–60% volatilization after spraying, equal to 0.65–3.9 kg VOC/acre.
- Emission Controls: While some manufacturing VOCs can be controlled, field volatilization is intrinsic to its pesticidal activity and cannot be prevented.
- *Total Mineral Oil VOCs/acre: 0.66–3.93 kg.*

Comparative Results:
- KS: VOC emissions are confined to manufacturing, where technologies can reduce them to negligible levels.
- Mineral Oil: VOC emissions occur mainly in the field, where no abatement is possible.
- Mineral oil therefore releases approximately 250× to >5,000× more VOCs to the atmosphere per acre than KS under comparable use conditions.

References
- Euro Chlor (2022). Eco-profiles of the European chlor-alkali industry (NaOH as proxy for KOH).
- Elgowainy, A. et al. (2014). GREET Model Life-Cycle Emissions of Petroleum Refining. Argonne National Laboratory.
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Appendix M. Abstract of Mills et al. (2006): Sensitivity of Erwinia spp. to Salt Compounds in Vitro and Their Effect on the Development of Soft Rot in Potato Tubers in Storage

Publisher's Abstract
The following is the publisher's abstract of the peer-reviewed article:
Mills, A. A. S., Platt, H. W., & Hurta, R. A. R. (2006). *Sensitivity of Erwinia spp. to salt compounds in vitro and their effect on the development of soft rot in potato tubers in storage. Postharvest Biology and Technology.* DOI: 10.1016/j.postharvbio.2006.03.015.
The abstract is included to summarize the study supporting Reference 43.

Sensitivity of *Erwinia* spp. to salt compounds in vitro and their effect on the development of soft rot in potato tubers in storage
A.A.S. Mills [a], H.W. (Bud) Platt [a], R.A.R. Hurta [b]

Abstract

Several salt compounds were tested in vitro as inhibitors of *Erwinia carotovora* subsp. *atroseptica* (van Hall) Dye (*Eca*) and *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey, Harrison, Breed, Hammer & Huntoon (*Ecc*), causal agents of bacterial soft rot of potato. All compounds were mixed with potato dextrose agar (PDA) to the concentrations 0.002 M, 0.02 M and 0.2 M PDA amended with sodium metabisulfite, propyl-paraben, alum, potassium sorbate, calcium propionate and copper sulfate pentahydrate were completely inhibitory at the lowest concentration (0.002 M). Studies examining the preventative and curative effects of the most effective compounds were conducted using *Ecc* (strain 71). As preventative disease control measures, tubers treated only with aluminum acetate, alum, calcium propionate, sodium bicarbonate, sodium hypochlorite or copper sulfate pentahydrate resulted in significantly ($P < 0.001$) less soft rot than the untreated control. As curative disease control measures, tubers treated with only alum, aluminum acetate, sodium hypochlorite or copper sulfate pentahydrate, resulted in significantly ($P < 0.001$) less soft rot than the untreated control. These compounds demonstrated a potential as replacements for commercially used pesticides as post-harvest disease control strategies.

Introduction

Pectolytic *Erwinia* spp. are responsible for significant economic losses to the potato industry each year. *Erwinia carotovora* subsp. *atroseptica* (van Hall) Dye (*Eca*) and *Erwinia carotovora* subsp. *carotovora* (Jones) Bergey, Harrison, Breed, Hammer & Huntoon (*Ecc*) are the causal agents of blackleg and tuber soft rot, respectively (Pérombelon, 2002). Tuber contamination can occur in both the field, and after harvest (De Boer, 2002). Infection may occur at any stage of post-harvest handling including washing, grading and packing (Scholey et al., 1968, Elphinstone and Perombelon, 1986). Symptoms may develop slowly during cold storage; as temperature increases and conditions become favorable for disease development, the pathogen proliferates, resulting in rapid tissue breakdown. Contaminated tubers that are used as seed, may cause disease problems in the field (Toth et al., 2003).
The preventative and curative effects of sodium hypochlorite, EDTA, nisin, acetylsalicylic acid (ASA) and heat treatments against tuber infection by *Erwinia* spp., have been examined (Romdhani and El Mahjoub, 1991, Ranganna et al., 1998,

Wells et al., 1998, López et al., 2001). Heat treatment has been shown to be one of the most effective control measures for soft rot disease (Ranganna et al., 1998). Energy costs associated with heating and cooling tubers, however, may be prohibitory to processors. Chlorine bleach ($NaClO_4$) is currently the industry standard for post-harvest sanitation, but this compound may be environmentally damaging and produces a strong odor that is unpleasant to line workers. It is also not effective once tubers have been infected (Bartz, 1999). One possible alternative to the use of sodium hypochlorite may be with the use of various salt compounds. Many of these salt compounds are currently used as food preservatives to prevent bacteria-induced food spoilage in processed food (Russel and Gould, 1991).
Experiments examining the effects of alum, silica gel and lime as post-harvest control agents of soft rot in cabbage caused by *Erwinia* spp., have resulted in a decrease in the amount of observed infection (Sihombing, 1986, Napitupulu and Lubis, 1987, Sjaifullah et al., 1988). Calcium salt treatments applied to apples and potatoes have been shown to have a protective effect against various bacterial and fungal infections (McGuire and Kelman, 1984, McGuire and Kelman, 1986, Conway et al., 1991, Conway et al., 1992).
The objectives of this study were to evaluate several salt compounds against the growth of pectolytic bacteria in a series of lab experiments in vitro. Once evaluated in the lab, the preventative and curative effects of these compounds against the development of soft rot disease in artificially infected tubers were tested in vivo. To measure the effects of the latter objective, the amount of decayed tissue in inoculated tubers was to be used.

Section snippets

Materials and methods

Studies were conducted at Agriculture and Agri-Food Canada Crops and Livestock Research Centre and Harrington Research Farm in Prince Edward Island, Canada. All compounds used in the experiments were obtained from local and national suppliers (Table 1). Strains of *Erwinia carotovora* subsp. *atroseptica* (*Eca* 3, 6, 31, 196, 198) and *Erwinia carotovora* subsp. *carotovora* (*Ecc* 23, 24, 59, 61, 71) were provided by the Canadian Food Inspection Agency Centre for Animal and Plant Health in Charlottetown, …

In vitro analyses

There were no significant differences between each of the two replicated experiments testing *Erwinia carotovora* subsp. *atroseptica* ($P = 0.968$) or *Erwinia carotovora* subsp. *carotovora* ($P = 0.978$). Therefore all data for each subspecies were pooled for analysis. There were no significant differences observed between the effects of compounds on the individual strains of *Erwinia carotovora* subsp. *carotovora* ($P = 0.892$) or *Erwinia carotovora* subsp. *carotovora* ($P = 0.524$). There were significant ($P < 0.05$ and …

Discussion

The present study shows that certain salt compounds may provide effective options for the control of soft rot in potato storage. All of the compounds tested indicated varying degrees of the inhibition of soft rot disease resulting from direct tuber inoculation with a suspension of *Erwinia caratovora* subsp. *carotovora*. Therefore this study demonstrates how some of the more effective test compounds could be integrated into a post-harvest disease controlling strategy for potatoes. Several of the ...

Appendix N. Comparative Genotoxicity Risk Assessment: Copper vs. Potassium Sorbate

Comparative Genotoxicity Risk Assessment: Copper vs. Potassium Sorbate

By: Ronald E. Lane, Circadian Crop Sciences, LLC, Assisted by ChatGPT, OpenAI – Prepared August 8, 2025

In support of the petition to allow potassium sorbate as an approved synthetic for pest control in organic agriculture, this document outlines evidence that copper-based pesticides pose a significantly higher genotoxic and ecological risk than potassium sorbate. The following comparative assessment is grounded in peer-reviewed toxicological literature, regulatory standards, and environmental health data.

1. Genotoxicity of Copper Compounds

Copper, though essential as a micronutrient, is a known pro-oxidant capable of generating reactive oxygen species (ROS) in biological tissues, leading to DNA damage, apoptosis, and mutagenesis. A number of studies have demonstrated that copper oxide nanoparticles and soluble copper salts (e.g., copper sulfate) induce genotoxic effects in both in vitro and in vivo models.

- Magaye and Zhao (2012) reviewed the genotoxicity and carcinogenicity of copper-based nanoparticles, concluding that copper exposure leads to DNA strand breaks, micronuclei formation, and chromosomal aberrations in mammalian cells. - Carmona et al. (2018) found DNA damage in mice exposed to copper nanoparticles via oxidative stress pathways. - The U.S. EPA has set a Maximum Contaminant Level Goal (MCLG) for copper in drinking water at 1.3 ppm due to health risks including liver and kidney damage, particularly in infants and people with Wilson's disease.

Chronic use of copper as a fungicide leads to environmental accumulation, posing ecological risks to soil microbiota and aquatic ecosystems. Long-term copper buildup is known to disrupt beneficial soil biology, reduce earthworm populations, and persist for decades in treated soils.

2. Genotoxicity of Potassium Sorbate

Potassium sorbate is a widely used food preservative with a strong history of human safety. Although in vitro studies have shown genotoxicity at extremely high concentrations (e.g., 2 mM and above), these effects do not reflect realistic dietary or agricultural exposure levels.

- Sin et al. (2021) reported that human lymphocytes showed DNA damage at 2 mM concentrations of potassium sorbate, but this is equivalent to ingesting more than 25 grams at once — far beyond exposure from pesticide residues or food use. - At lower concentrations, potassium sorbate has shown potential anti-inflammatory and cytoprotective effects on cells (Natarajan et al., 2022).

Unlike copper, potassium sorbate is highly water-soluble, biodegradable, and does not accumulate in the soil or biomagnify in ecosystems. It poses negligible risk to soil organisms or aquatic life at agricultural application rates.

3. Conclusion

While both copper and potassium sorbate have been reviewed for potential genotoxic effects, the weight of evidence indicates that copper compounds present a greater overall genotoxic and environmental hazard than potassium sorbate because copper is persistent, bioactive, and accumulates in agricultural soils, whereas potassium sorbate is readily biodegradable and does not accumulate.

References:

- Magaye, R., & Zhao, J. (2012). Genotoxicity and carcinogenicity of cobalt-, nickel- and copper-based nanoparticles. *Experimental and Therapeutic Medicine, 4*(4), 551–561. https://doi.org/10.3892/etm.2012.803
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