Organic Pesticide Use in Pistachio: 2015-2019

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Introduction

As of 2020, pistachios were the fourth-ranked agricultural commodity produced in California by value, with nearly $2.9 billion in cash receipts[1]. A majority of this production is located in the central and southern San Joaquin Valley. The primary arthropod pests of this crop include navel orangeworm (NOW; Pyralidae: *Amyelois transitella*), leaffooted plant bug (Coreidae: *Leptoglossus zonatus*), green stink bug (Pentatomidae: *Chinavia hilaris*), red-shouldered stink bug (Pentatomidae: *Thyanta custator accerra*), and Gill's mealybug (Pseudococcidae: *Ferrisia gilli*).

Control of NOW is particularly important due its association with *Aspergillus* fungi, which can lead to the production of aflatoxins. These are known human carcinogens that are heavily regulated in key markets. Most growers aim for <2% infestation by NOW, and as such a combination of chemical and cultural control strategies are frequently utilized. Infestations of leaffooted bug and stink bugs tend to be more sporadic, but where present can rapidly cause significant damage. Reports of crop damage from these pests have increased in recent years, possibly due to a shift towards the use of softer chemistries (e.g. chlorantraniliprole and methoxyfenozide) for control of NOW. Finally, Gill's mealybug was first reported in the early 2000s, and since then has steadily increased in importance as established populations have continued to spread throughout primary production regions. As efforts to transition away from the use of biologically disruptive pesticides continue, increased attention on lower-risk alternatives, including organic pesticides and non-chemical practices have increased. Here, we review recent trends in organic-allowed pesticide use in California pistachios and the pests targeted by these applications, before then discussing the availability of non-chemical practices.

[1] *Based on USDA Economic Research Service cash receipts, September 2021 release*

Methods and Data

This analysis is a review of all material applied to California pistachio over a 5-year period (2015-2019) that was approved for organic production by 1) the Organic Materials Review Institute (OMRI), 2) the Washington State Department of Agriculture (WSDA) Organic Program, or 3) the United States Department of Agriculture (USDA) National List of Allowed and Prohibited Substances. A total of 39 organic-allowed products were applied to pistachio during this time frame according to data from California's Pesticide Use Reporting (PUR) database. Within the dataset, fields were classified as 'organic' if only organic-allowed products were applied throughout the study period. Fields that included a mixture of allowed and prohibited products were classified as 'conventional'. After identifying organic and conventional fields based on spray history, total annual field acreage for each production type was then estimated from PUR data. Information on the target pests associated with the different pesticide use timings, as well as utilization of cultural and biological controls, were obtained from personal communications with growers, pest control professionals and UC Cooperative Extension personnel.

Pistachio Production Trends

According to estimates based on PUR data, organic pistachio acreage in California increased from 1,053 acres in 2015 to 1,933 acres in 2019 (84% increase), while conventional acreage increased from 325,201 to 440,402 acres (35%) during the same time period. These values include all land dedicated to pistachio production, including non-bearing fields, that receive pesticide treatment. Although organic production has experienced a greater rate of increase in recent years, it continues to make up less than one half of one percent of total pistachio production in the state. The San Joaquin Valley growing region accounts for approximately 98% of all organic and conventional pistachio production during this time period.

Use of Organic Products in Both Conventional and Organic Pistachio Orchards

When all organic and conventional sites were combined, three organic products (AF36, sulfur, and petroleum-based oils) accounted for 96% of total acres treated with organic-allowed materials, and just two products alone (AF36 and sulfur) accounted for nearly 90% of total organic product use. This is due to the fact that certain organic products are commonly used in conventional and organic pistachio production alike (AF36, sulfur, and petroleum-based oils) (Figure 1 and

Figure 2). Products used in both settings had similar use timings, suggesting they are being used for the same target organisms or outcome (Figure 3 and Figure 4).

Primary Products Used in Organic Pistachio

When data were compared between 'organic' and 'conventional' fields, unique use trends emerged for organic production. In organic orchards, the most commonly used products (as a proportion of total treated acreage) were sulfur, followed by pyrethrins, *Reynoutria sachalinensis*, *Bacillus thuringiensis* (*Bt*), AF36, spinosad, *Bacillus amyloliquefaciens* strain d747, and petroleum-based oils (Figure 2). There is notably no use of herbicides in organic orchards, since organic herbicides effectively do not exist. Capric and caprylic acid are exceptions; however, these materials were not applied in organic orchards during our study period. More details on each of these active ingredients can be found below in the Description and Use Trends for Specific Active Ingredients section.

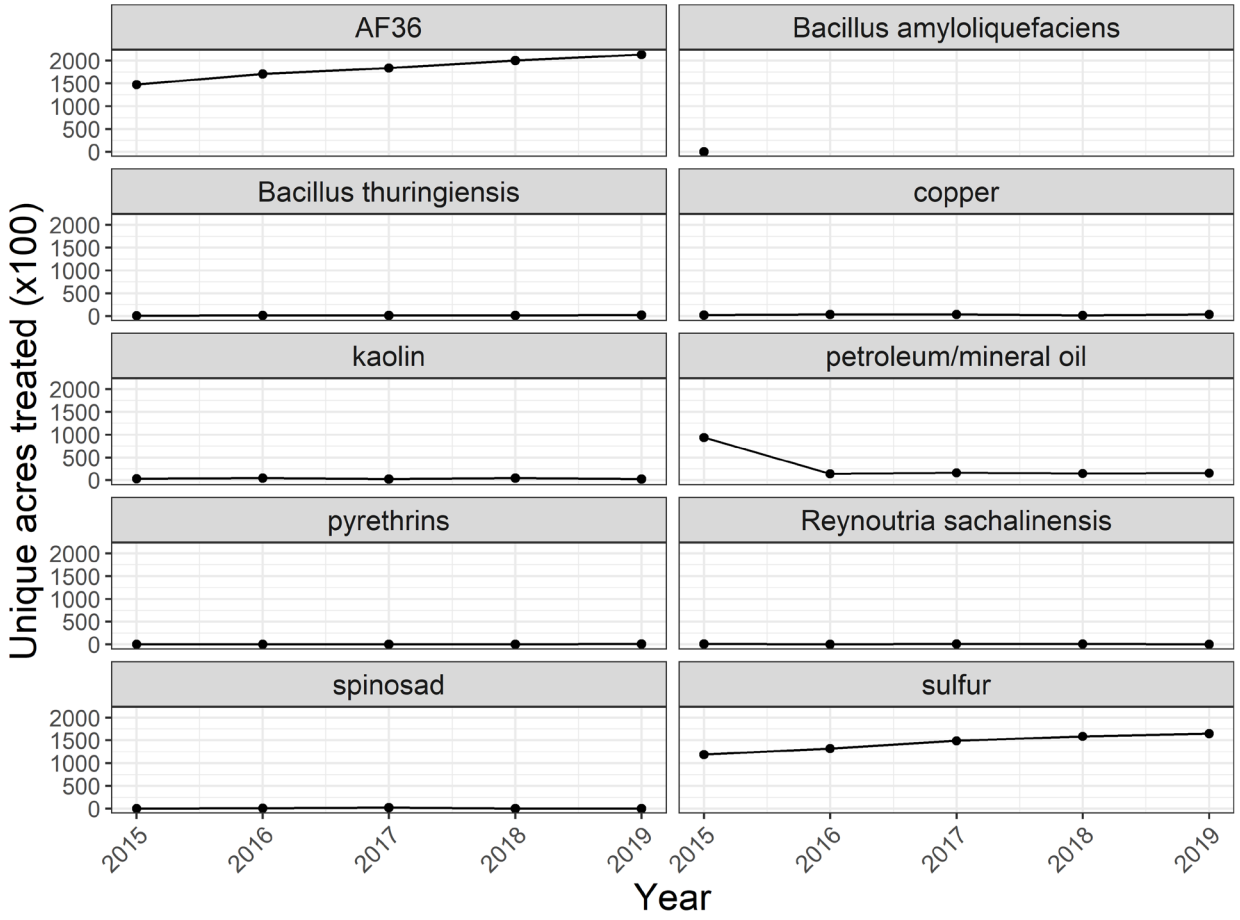

Figure 1. Unique conventional field acres treated per year with top organic active ingredients: pistachio, 2015-2019.

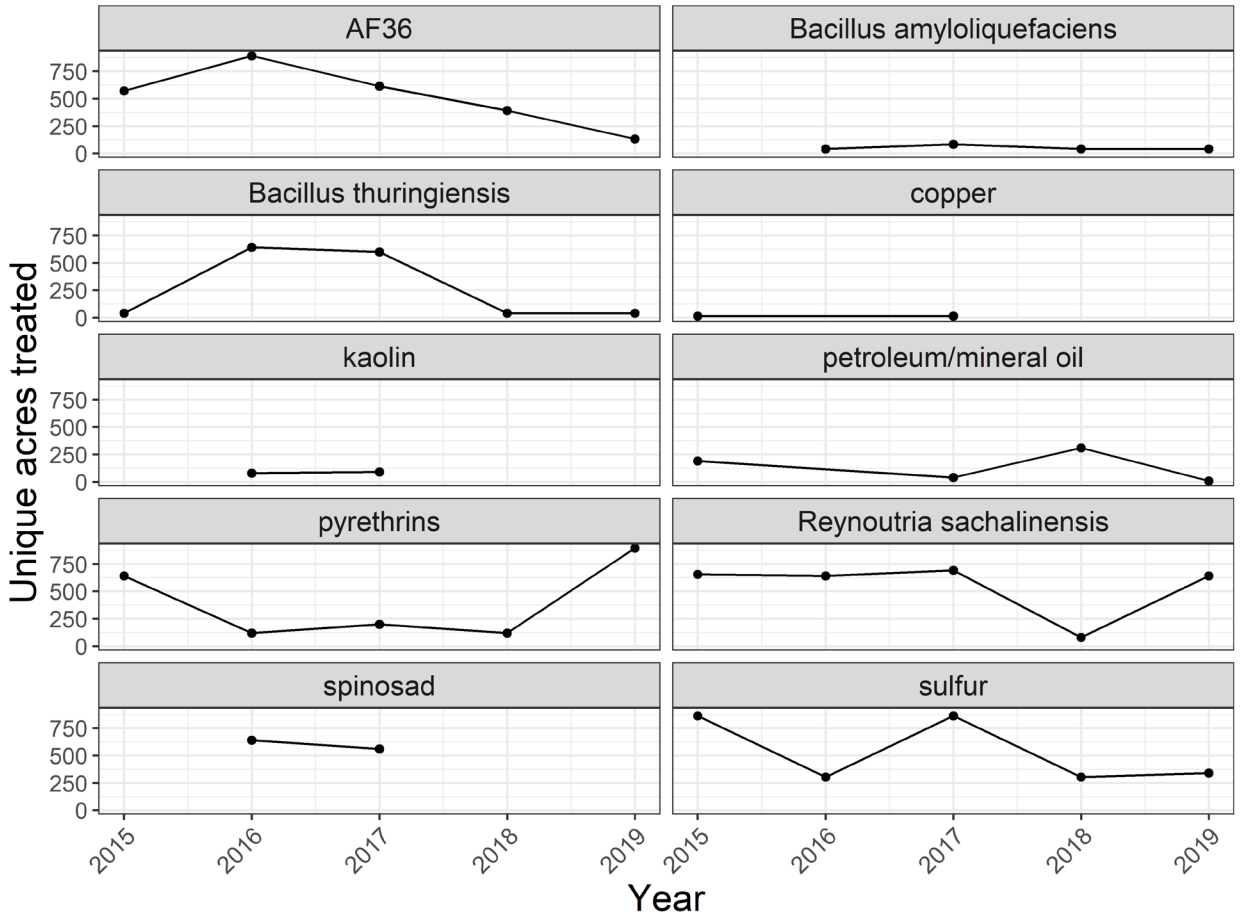

Figure 2. Unique organic field acres treated per year with top organic active ingredients: pistachio, 2015-2019.

Products with Minor or Sporadic Use

Use of 16 organic products was limited to relatively minor acreage, including azadirachtin, copper octanoate, copper oxide/oxychloride, and iron phosphate (200-400 acres/year); diatomaceous earth, copper sulfate (100-200 acres/year); and lime sulfur, capric/caprylic acid, hydrogen peroxide, peroxyacetic acid, canola oil, garlic, boric acid, potash soap, potassium silicate, abscisic acid, and gibberellins (<100 acres/year). These products were mostly (azairachtin) or exclusively (copper oxide/oxychloride, copper sulfate, copper octanoate, diatomaceous earth, iron phosphate, lime sulfur, hydrogen peroxide, peroxyacetic acid, canola oil, garlic, boric acid, potash soap, potassium silicate, abscisic acid, and gibberellins) used in conventional orchards.

Three organic products were sporadically used (i.e. applications concentrated in 1-2 years only) mostly in conventional fields; this included copper hydroxide (a micronutrient), *burkholderia* and *chromobacterium* (microbial insecticides). See below for more information on these and all other products.

Description and Use Trends for Specific Active Ingredients

Arthropod Pest Management

Sulfur

Consistent applications of sulfur are seen May - August, primarily for control of citrus flat mite (Acari: Tenuipalpidae: *Brevipalpus lewisi*). Annual use is similar in organic and conventional orchards, with approximately 40% of acreage receiving at least one sulfur application per year. Total acres treated with sulfur is consistent at around 200,000 acres/year. A similar monthly use pattern is seen in both conventional and organic orchards.

Bacillus thuringiensis ssp. Kurstaki (Bt)

Bt is an ingestion product primarily used for control of NOW. The application window is July-September (Figure 3 and Figure 4), with most applications going on in September (50%) during the third flight of NOW, which is the critical treatment period for this pest in pistachio due to declining hull integrity. The remaining applications are evenly split between July and August, which reflects a slightly earlier flight timing (August sprays) or potentially an application during the earlier second flight due to increased incidence of early-split pistachios (July sprays). Use of *Bt* is almost exclusively restricted to organic production, with 20% of organic acreage receiving at least one application per year. Organic growers tend to apply *Bt* multiple times (2-3x) per year, resulting in a total of about 1,600 treated acres annually.

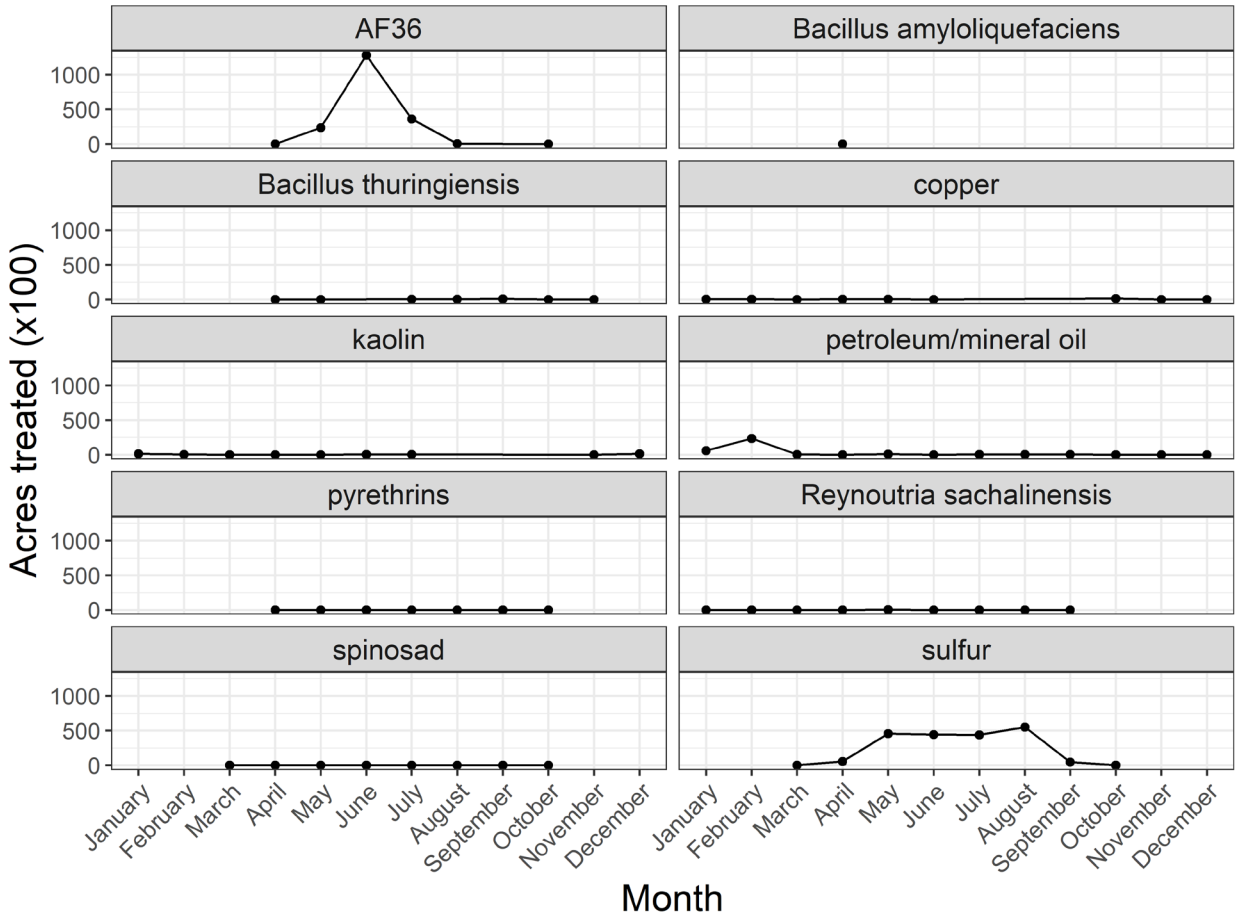

Figure 3. Average monthly acres treated in conventional fields with selected organic AIs. Values were calculated by dividing monthly totals (2015-2019) for each AI by the number of years in our study period (five). Standard errors were not calculated due to some AIs only being applied in a single year.

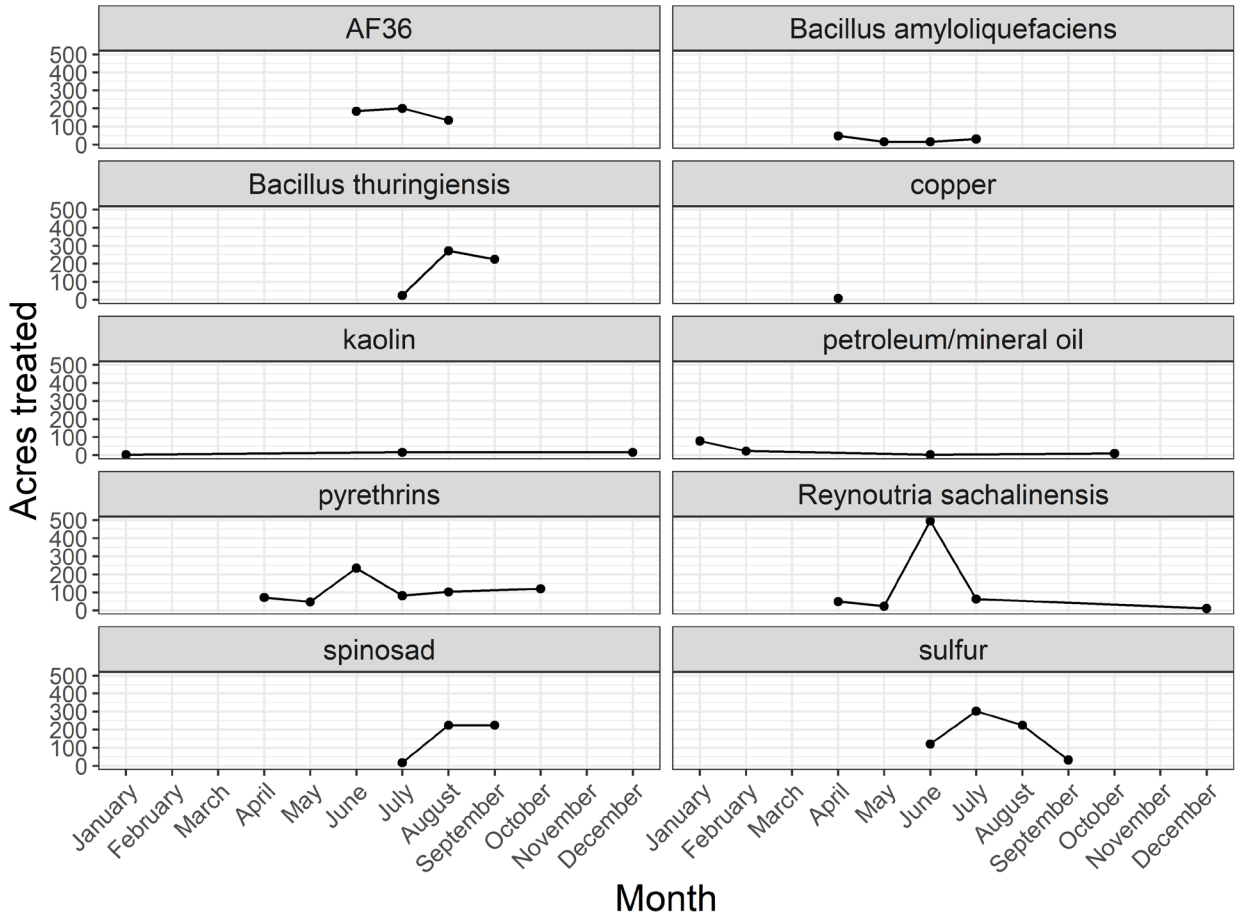

Figure 4. Average monthly acres treated in organic fields with selected organic AIs. Values were calculated by dividing monthly totals (2015-2019) for each AI by the number of years in our study period (five). Standard errors were not calculated due to some AIs only being applied in a single year.

Pyrethrins

Pyrethrins are contact products primarily used for control of plant bugs, stink bugs and/or NOW. With so many potential targets, the application window is wide, from April – August, with most use occurring May – July and a peak in June (Figure 3 and Figure 4). Many organic growers frequently apply this AI at least 2-3x/year, and in some cases up to 6x/year. Total annual use is consistent at around 1,500 acres treated per year. This AI is almost exclusively used in organic orchards.

Spinosad

Spinosad is a contact and ingestion product primarily used for control of NOW. The application window is May – September, with peaks in May, July and September (Figure 3 and Figure 4). Use of this AI fluctuates a lot between years, with an average application on about 1,200 acres/year, but closer to 2,000 acres/year in high use years (2016-2017), possibly due to high NOW populations

reported in those years. This product is disproportionately applied in organic orchards, with about 19% of organic acreage receiving at least one application versus less than 0.2% of conventional acreage per year. Multiple applications (2x/year) are common in organic orchards. Spinosad use is similar, though slightly less frequent, than *Bt* suggesting it is used as an alternative for NOW control.

Azadirachtin

Azadirachtin is a broad-spectrum contact product derived from neem oil. The application window is May-June, which approximately coincides with timing for targeting crawlers of Gill's mealybug (Hemiptera: Pseudococcidae: *Ferrisia gilli*), as well as plant/stink bugs and NOW. Applications are rare in both organic and conventional orchards (<1% of acreage), though it is disproportionately used in organic production.

Microbials - Burkholderia and Chromobacterium

These are key AIs in products sold by Marrone BioInnovations. The use of both was sporadic year-to-year. Nearly all *Burkholderia* applications were in July, with most use concentrated in a single year (2019). *Chromobacterium* applications primarily occured in June/July, and nearly all of it occurred in a single year (2018). All (*Burkholderia*) or most (*Chromobacterium*) applications were made in conventional orchards.

Mating Disruption

Mating disruption has been developed for NOW and there are multiple commercially available products on the market from four manufacturers (Suterra; Pacific Biocontrol; Semios; Trece), one of which was OMRI certified ('Cidetrak', Trece) during the period under review. While use of conventional mating disruption products was extensive in conventional orchards, there was no reported use in organic orchards, possibly due to the unique labor requirements of the OMRI-listed 'Cidetrak' product. Unlike the other three products, which utilize aerosol emitters placed at 1-2 emitters/acre, the 'Cidetrak' technology relies upon polymeric emitters that need to be hung from the tree canopy at a rate of approximately 20 emitters/acre. This requirement may have reduced adoption due to the increased labor requirements for installation and end-of-season removal. It is also possible that 'Cidetrak' technology is being used in organic orchards but is not being correctly reported to DPR.

Disease Control

Aspergillus flavus strain af36 (AF36)

This product is used for control of *Aspergillus* spp. fungal pathogens that lead to the production of aflatoxins, which are known human carcinogens that are heavily regulated in key markets. Control of NOW is also important for

management of *Aspergillus*, since this fungus is associated with NOW infestations. The application window for AF36 is April – August with a peak in June. AF36 is applied annually to 48% of conventional and 40% of organic acreage for a total of approximately 185,000 acres/year. Use in conventional orchards has been steadily trending upward over the past 5 years; however, the number of organic acres treated with this material has declined sharply since 2016 (Figure 1 and Figure 2). There is a similar monthly use pattern in conventional and organic production.

Reynoutria sachalinensis

Reynoutria sachalinensis is the active ingredient in a fungicide used primarily for control of *Botryosphaeria* spp., and most applications are in June (Figure 4). This product is almost exclusively used in organic orchards, with 42% of annual organic acreage receiving at least one application verses less than 0.2% of conventional acreage. Some organic growers make multiple applications (2x/year), resulting in just over 1,200 acres per year. Monthly use patterns in conventional and organic orchards are similar.

Bacillus amyloliquefaciens strain D747

Bacillus amyloliquefaciens is a biological fungicide with relatively minor use. The application window is April – July, with most applications going on in April and July (Figure 4). This product is likely being used for control of *Botryosphaeria* spp. (April applications), as well as *Alternaria* spp. (July applications).

Horticultural products

Mineral oil and petroleum oils

Dormant applications of mineral and petroleum oils are primarily to advance bud break, but can also possibly contribute to control of overwintering insects (e.g. *Phytocoris* spp. and immature soft scale). Use is fairly consistent with about 33,000 acres treated/year. Mineral oil is applied annually to about 7% of conventional and organic acreage alike, whereas petroleum oil is used on less than 1% of acreage. A similar monthly use pattern is observed in both conventional and organic orchards.

Kaolin clay

There are two distinct use periods for this product, December/January and July. The winter application is to advance bud break by increasing chill hours (the clay lowers radiative warming of buds), and the summer application is used to reduce sun burn. At least one application of kaolin clay per year was made to approximately 3% of organic acreage and just under 1% of conventional for a total of about 3,300 unique field acres per year. Given the two use periods per year for this material, multiple applications to the same field were sometimes

made, bringing the total number of acres treated per year to just over 4,000. Similar monthly use patterns were observed in conventional and organic orchards.

Herbicides

Capric/Caprylic Acid

This is a fatty-acid product recommend for organic weed control. The application period is April – August with a peak in June. This product is likely being used for control of weedy vegetation within the tree rows. Use of these materials during the study period was very rare (never exceeded 121 unique acres per year) and occurred in conventional orchards only.

Micronutrients

The following are all micronutrients primarily applied in conventional orchards. Copper hydroxide and copper octanoate both had a distinct peak in October, with additional lower but consistent use of copper hydroxide in the January – May period. Copper oxide/oxychloride (mostly March – April), iron phosphate (May – July), and copper sulfate (April) were all minor use over the year.

Other

Six products had such minor use that their purpose was not clearly discernible, this included diatomaceous earth (use unclear), lime sulfur (possible insect control), hydrogen peroxide and peroxyacetic acid (used to clean irrigation lines), canola oil and garlic (likely insect control).

Practices Not Included in PUR

Biological controls

While some potentially useful natural enemies are available through commercial insectaries, such as the generalist predator green lacewings (Neurooptera: Chrysopidae: *Chrysoperla* spp.), the NOW parasitoid *Goniozus legneri* (Hymenoptera: Bethylidae), predatory mites (Mesostigmata: Phytoseiidae: *Neoeiulus californicus*) and sixspotted thrips (Thysanoptera: Thripidae: *Scolothrips sexmaculatus*), augmentation of natural enemies to increase biological control of key pests is not widely utilized in organic pistachio production.

Cultural controls

The most common cultural practice for pest management in organic pistachio is winter sanitation of remnant "mummy" nuts for control of NOW. NOW overwinter as larvae or pupae in the unharvested remnant nuts that reside in the tree canopy and on the orchard floor over the winter period. As such, the removal and destruction of these overwintering hosts is a fundamental component of management for this pest, not just pistachio but in almonds and walnuts as well.

Not only do these remnant nuts serve as overwintering sites for NOW, but first flight adult moths in the spring will also utilize them as a reproductive substrate. Unfortunately, winter sanitation is especially challenging in pistachios due to the small size and durability of nuts, which makes them more difficult to gather and destroy with traditional equipment. Specialized equipment has recently been developed that is able to more effectively crush remnant pistachios, but it is still in an early stage of adoption.