OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION
WASHINGTON, D.C. 20460

June 24, 2024

MEMORANDUM

SUBJECT: Malathion (PC # 057701) Overview of Use and Usage, and Description of Pest Management Benefits, and Impacts of Potential Risk Mitigation in Alfalfa, Pine Seed Orchards, Pine Seedling Propagation, and Residential Homeowner Use Sites

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Product Review Panel Date: 05/08/2024

SUMMARY

Malathion is a broad-spectrum organophosphate insecticide classified by the Insecticide Resistance Action Committee (IRAC) as a Group 1B Mode of Action insecticide. This memorandum provides an overview of the use and usage of malathion to all registered sites and assesses the benefits of malathion in alfalfa, pine seed orchards, pine seedlings, and residential homeowner use sites.

Malathion is registered on a broad range of agricultural and non-agricultural use sites. Usage data indicates that malathion is regularly used in a variety of fruit and vegetable crops, wide-area mosquito control, and residential homeowner uses. Many other registered use sites exhibit low usage; this suggests that users either have other cost-effective tools available to control pests which malathion is effective against, or that the pests which malathion is effective against are not problematic in these use sites.

In alfalfa production, where reported malathion usage is low (<1% PCT), BEAD finds that malathion offers low to moderate benefits to users due to its broad-spectrum activity against pests, including the ability to simultaneously treat against two of alfalfa's key pests (alfalfa weevil and aphids). This, in addition to malathion's 0-day pre-harvest interval (PHI), provides users increased flexibility and saves them the need of performing additional insecticide applications or tank mixing products.

In slash pine seed orchards, malathion provides low to moderate benefits in managing slash pine flower thrips during occasional outbreaks, as it is among one of few chemical control options available. For use on pine seedlings, BEAD concludes that malathion likely has low benefits due to the availability of multiple alternatives with different modes of action as well as non-chemical control methods against target pests.

In residential homeowner use products for the treatment of ornamentals, lawns, and gardens, BEAD finds that malathion provides moderate benefits due to its broad-spectrum activity, versatility across various settings within such, and by being the only organophosphate with such attributes available as a homeowner product.

Measures under consideration to mitigate potential ecological risks include adding mandatory spray drift language for boomless ground applications, and a 96-hour water holding time before releasing floodwaters after the treatment of rice. BEAD expects minimal impacts to users resulting from the mitigation measures under consideration across alfalfa, pine seed orchards, pine seedlings, and residential homeowner use sites.

INTRODUCTION

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 3(g) mandates that the Environmental Protection Agency (EPA or the Agency) periodically review the registrations of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary in light of scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether adverse effects are unreasonable, FIFRA requires that the Agency consider the risks and benefits of any use of the pesticide.

Although substantial mitigation on malathion use has been recently enacted based on Biological Opinions from the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, the Agency has identified ecological risks to non-target species associated with the use of malathion. The Agency is considering various mitigations to reduce such risks which may include mandatory spray drift language to product labels, and the addition of a 96-hour water holding time before releasing floodwaters after the treatment of rice. No human health risks were identified.

This document presents an overview of the registered uses and reported usage of malathion for all registered use sites and describes malathion’s benefits and alternatives in alfalfa, pine seed orchards, pine seedlings, and residential homeowner use sites. This memo is one of four documents assessing the use, usage, benefits, and alternatives of malathion, as well as impacts of potential mitigation. Other related assessments by the Biological and Economic Analysis Division (BEAD) include 1) vegetable crops, 2) wide-area mosquito adulticides and other state and federal agricultural pest control programs 3) and commercial fruit production. These complementary memos are available in the malathion docket (EPA-HQ-OPP-2009-0317).

METHODOLOGY

BEAD defines the benefit of malathion as the extent to which it is important to users for the control of pests important to users in each use site. These benefits are based on various agronomic and biological factors, chemical characteristics of malathion, and alternative control strategies, which influence how a user chooses to manage pests and to what extent malathion is important. The unit of analysis is typically an acre of a crop that would normally be treated with malathion. Based on the available usage information and risks of concern, BEAD assesses benefits at this unit of analysis both because users make pest control decisions at the acre- or field-level, and because risks are usually measured at the same spatial levels (treated acres and treated fields).

BEAD first identifies how users apply malathion. BEAD provides information on the chemical characteristics of malathion in order to understand the physiological constraints on how the pesticide functions. BEAD then evaluates data on malathion usage to identify use patterns, including variations in regional usage. Next, BEAD determines use sites for which to conduct detailed benefits assessments through examination of available usage data, agronomic and economic information, and public comments from stakeholders on the uses of malathion.

BEAD then identifies why users apply malathion in sites selected for detailed assessment. BEAD reviews pesticide usage information and existing scientific and university extension publications to identify the important target pests and the attributes of malathion that make it useful in the pest control system. The way or ways that users currently use malathion is the baseline scenario. Having identified why and how users use malathion, BEAD identifies the likely alternative control strategies by reviewing extension recommendations, grower surveys, and considering economic factors.

BEAD then assesses the magnitude of the benefits by assessing the biological and economic impacts that users might experience should they need to employ alternative pest control strategies in the absence of malathion. Economic and biological impacts to a user in the absence of a pesticide can include monetary costs as well as other lost advantages of the pesticide, such as simplicity of use, flexibility, and utility in resistance management and/or integrated pest management programs. Users may also face costs with respect to commodity damage resulting in yield or quality reductions related to diminished pest control. Physical and/or managerial effort may also increase.

A similar approach is followed to assess the impacts of possible mitigations on the use of malathion to reduce risks. BEAD considers how the restrictions would affect the ability of users to control pests or affect the costs of using malathion.

For these analyses, data are sourced from university extension services, United States Department of Agriculture (USDA) (e.g., publicly available crop production, pesticide usage, and cost data as well as information submitted directly to EPA), publicly and commercially available grower survey data, public comments submitted to the Agency from various stakeholders, the open literature and BEAD's professional knowledge. The most heavily used sources of data from surveys of pesticide usage are purchased from Kynetec USA Inc, a private research firm which provides proprietary pesticide usage data on approximately 60 crops collected annually through grower surveys using a statistically valid approach, and from Kline and Co. which provides non-agricultural market research data.

CHEMICAL CHARACTERISTICS

Malathion is an organophosphate, classified by the Insecticide Resistance Action Committee (IRAC) as a Group 1B Mode of Action (MOA) insecticide and is registered for use in a wide range of agricultural and non-agricultural use sites. Like most organophosphates, malathion acts via contact on and ingestion by the target pest, disrupting the normal transmission of nerve impulses, specifically by inhibiting acetylcholinesterase (Chong et al., 2017).

Malathion was introduced into the market in 1950 and is one of the oldest organophosphates still in use (ATSDR, 2003). Malathion has a broad spectrum of activity against many insects and insect life stages and as a contact insecticide, it can provide quick reductions in pest populations in a variety of agricultural and non-agricultural settings.

USE AND USAGE OF MALATHION

Malathion Use

Malathion is registered for use on both agricultural and non-agricultural sites. Agricultural food and feed sites are a wide variety of fruit (apricot, avocado, blackberry, blueberry, boysenberry, cantaloupe, cherry [sweet and tart], currant, dewberry, figs, gooseberry, grapefruit, grapes, guava, kumquat, lemon, lime, loganberry, mango, nectarine, orange, papaya, passion fruit, peach, pear, pineapple, raspberry, strawberry, tangelo, and tangerine), vegetables (amaranth, arugula, asparagus, beans [dry and succulent], beets [garden] , broccoli, broccoli [chinese], broccoli raab [rapini], Brussels sprouts, cabbage, cabbage [Chinese] , carrot [roots], cauliflower, cavalo broccolo, celery, celtuce, chayote, chervil, chrysanthemum [edible] , collards, corn salad, cucumber, dandelion, dock [sorrel] , eggplant, endive, Florence fennel, garlic, horseradish, kale, kohlrabi, leek, lettuce, melon, mizuna, mustard [Chinese], mustard greens, mustard spinach, okra, onion [bulb and green], orach, parsley, parsnip, peas, peppers, potato, pumpkins, purslane, radish, rutabaga, salsify, shallot, spinach, squash, sweet potatoes, sweet corn, Swiss chard, tomato, tomatillo, turnip, watercress, watermelons, and yams), and other crops including nuts and grains (alfalfa, barley, birdsfoot trefoil, chestnut, clover, corn [field and pop], cotton, flax, grass [forage/hay], hops, lespedeza, lupine, macadamia nut, mint, mushroom, oats, pastureland, pecan, peppermint, rangeland, rice, rye, sorghum, spearmint, vetch, walnuts, wheat, and wild rice).

Malathion is registered for non-agricultural and non-food agricultural uses on the following sites: Christmas tree plantations, ornamental/residental turf (i.e. lawns; spot treatment only), ornamental plants (herbaceous, woody shrubs/vines, and trees), grain storage facilities (e.g. silos, grain elevators), home gardens (including fruits and vegetables for consumption), perimeter of buildings (outdoors; including residential dwellings), pine seed orchards (only on slash pine in the southeastern U.S.), uncultivated areas (such as fence rows, hedge rows and rights-of-way along roadways or electrical utilities), and wide-area mosquito control.
Some labelled use sites and rates are limited to application by federal and state pest control programs, such as the Boll Weevil Eradication Program, or the California Beet Curly Top Virus Control Program.

Malathion-containing products are formulated as dust (for use on stored grain), emulsifiable concentrates, or ready-to-use concentrates (for ultra-low volume [ULV] applications).

Malathion products can be applied using ground, aerial, chemigation, and handheld equipment. Methods for both ULV and non-ULV applications are allowed on a subset of registered sites and maximum application rates vary across these methods.

Malathion Usage

<u>Agricultural Usage</u>

Usage values presented in this section are based on the most recent data available from each usage data source. The primary usage source is Kynetec USA, Inc., an agricultural market research firm. These data are supplemented with USDA NASS Chemical Use Survey data and, for crops where at least 80% of national acreage is in California, CDPR Pesticide Use Reporting data. Usage data are available for a number of crops, but many small-acreage and non-crop sites are not surveyed at a nationally representative level. Because not all crops are surveyed, the calculations presented below may slightly underestimate total national usage. The values presented in this document may differ from those presented in other BEAD documents, such as the Screening Level Usage Analysis (SLUA) or Summary Use and Usage Matrix (SUUM), because different timeframes of usage are represented.

Nationally, users reported applying over 400,000 pounds of malathion active ingredient (lbs AI) to at least 270,000 total acres treated (TAT) annually between 2017 and 2021 (Kynetec, 2022a; Kynetec, 2022b; USDA NASS, 2022; CDPR, 2023). Although malathion usage has seen a decline in national agriculture usage in recent years when compared to the previous decade (annual average of at least 850,000 lbs AI on 700,000 acres during the years 2007-2016), usage remains high among a variety of agricultural sites (Table 1, Kynetec 2022a).

Table 1. National average agricultural usage for all surveyed crops reporting notable usage of malathion, 2017-2021.

Crop	Percent Crop Treated (PCT)[a]	Annual Pounds AI Applied	Annual Total Acres Treated[b]	Single Application Rate (lbs AI/acre)	Annual Number of Applications
Fruits					
Raspberries	60	20,000	14,000[c]	1.38	1.5
Blueberries	34	57,000	53,000[c]	1.10	2.0
Blackberries	18	2,300	1,400[c]	1.68	1.2
Pears	16	15,000	11,000	1.39	1.4
Strawberries	16	26,000	14,000	1.92	2.0
Figs	11	1,300	800	1.72	1.1
Cherries	10	17,000	13,000	1.28	1.1
Oranges	8	53,000	45,000	1.18	1.0
Vegetables					
Onions	7	10,000	8,400	1.24	1.0
Asparagus	6	2,100	1,800	1.18	1.5
Pumpkins	3	2,000	2,700	0.74	1.2
Peppers	2	1,200	1,000	1.12	1.2
Tomatoes	2	18,000	12,000	1.50	2.6
Cucumbers	2	7,000	4,000	1.75	2.0
Sweet Corn	2	9,000	8,800	1.03	1.0
Brussels sprouts	NC	4,700	3,700	1.27	1.4
Field Crops					
Rice	1	31,000	25,000	1.25	1.0
Alfalfa	<1	85,000	74,000	1.16	1.1

Sources: Kynetec 2022a, Kynetec 2022b; Blueberry, blackberry, and raspberry data from USDA NASS, 2023; Brussels sprout and fig data from CDPR 2023
NC: PCT inestimable due to a known reporting error for the crop area planted for some counties within the California Department of Pesticide Regulation (CDPR) dataset
[a] Percent Crop Treated is defined as Base Acres Treated, the number of acres treated at least once, divided by the number of crop acres grown.
[b] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same physical acre.
[c] Total acres treated is not reported by USDA NASS; This value is calculated by dividing reported pounds of AI applied by the average single application rate.

Among crops that are surveyed for insecticide usage, malathion usage is not reported on a substantial percentage of national acreage of most crops for which it is registered (i.e., low PCT or no usage reported). Surveyed crops reporting little to no malathion usage (not listed in Table 1) include apricots, avocado, broccoli, cabbage, cantaloupes, carrots, cauliflower, celery, cotton, field corn, garlic, grapefruit, grapes (table and wine), lemons, lettuce, nectarines, peaches, pecans, potatoes, sorghum (milo), spinach, squash, walnuts, watermelons, wheat (spring and winter) (Kynetec, 2022a; Kynetec, 2022b; USDA NASS, 2022; CDPR, 2023). This suggests malathion is not used extensively in their production nationally. Additionally, honeydew melons and tangerines are surveyed for insecticide usage, but the data are withheld by USDA NASS to avoid disclosing information for individual operations. Therefore, BEAD is unable to estimate likely usage of malathion in the production of honeydew and tangerines.

While low average annual PCT with malathion was observed in alfalfa (Table 1), this high acreage site accounted for about one third of malathion agricultural crop usage in terms of treated acres from 2017 to 2021 (Kynetec, 2022a). Blueberries and oranges were the next highest usage crops in terms of treated acres (Kynetec, 2022a).

Average number of applications of malathion per year varied by crop. Between 2017-2021, growers of field crops tended to use less frequent applications: for example, in alfalfa, cotton, field corn, rice, sorghum, sweet corn, and wheat (spring and winter), malathion was applied only 1 or 1.1 times per year (Kynetec, 2022b). Specialty crop growers tended to apply malathion more frequently: for example, in blueberries and strawberries, acres treated with malathion were treated on average two times per year (Kynetec, 2022b).

Surveys targeting the industrial vegetation management market (survey years: 2019, 2022) reported on insecticide usage in rangeland and pasture (Kline and Co., 2020b; Non-agricultural Market Research Data [NMRD], 2023). These surveys reported an annual average of 170,000 pounds of malathion applied to 340,000 acres in the rangeland and pasture sector (Kline and Co., 2020b; NMRD, 2023b). Malathion was the top insecticide in terms of acres treated in rangeland and pasture and represented about 20% of insecticide sales in terms of dollars in this market.

For post-harvest insecticide treatment of stored grain commodities, recent surveys (years 2017, 2020) indicate that approximately 920,000 pounds of malathion was sold annually in this market. Reported usage of malathion was entirely on-farm treatments of stored grains (Kline and Co., 2018b; NMRD, 2022d).

Federal and state agricultural pest control programs such as the Boll Weevil Eradication Program, California's Beet Curly Top Virus Control Program, United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) Rangeland Grasshopper and Mormon cricket suppression program, and USDA-APHIS Fruit Fly Exclusion and Detection Program report using malathion for the control of target pests. However, there are no publicly available data sources to estimate the extent of malathion usage by these government programs. The absence of such data should not be interpreted as lack of usage.

Non-Agricultural Usage

Usage information across non-agricultural and non-food/feed agricultural sites is limited but provides some broad indication of sites in which malathion is used.

Homeowner and residential malathion usage

Recent market surveys (years: 2019, 2022) of residential consumer use of insecticides report approximately 480,000 lbs of malathion sold in this market annually (Kline and Co., 2020a; Non-agricultural Market Research Data [NMRD], 2023a). Regionally, almost half of national outdoor insecticide sales in the residential consumer market occur in the U.S. South (spanning from Texas to the mid-Atlantic).

Pest management professionals use both chemical and non-chemical control methods to control pests within and around the exterior of commercial and residential establishments (NMRD, 2022b). A 2021 survey of this market sector reported approximately 180,000 pounds of malathion sold (NMRD, 2022b). All reports of malathion usage within this survey were indicated as mosquito control. Malathion represented less than 10% of the market in terms of dollars for products used by professional applicators for localized mosquito control in yards and around the exteriors of buildings (NMRD, 2022b).

Commercial malathion usage

While insecticide usage in ornamental plant production was surveyed in 2021, no usage of malathion was reported, suggesting low levels of usage of the active ingredient in the production of ornamentals (NMRD, 2022c).

Surveys targeting the industrial vegetation management market (survey years: 2019, 2022) reported pesticidal usage in forestry, and rights-of-way sectors (specifically railroad, roadsides, electrical utilities, and pipelines) (Kline and Co., 2020b; NMRD, 2023b). About 11,000 acres treated with malathion were reported across the roadway and electric utility sectors (less than 5% of the acres treated with insecticides in these sectors). No usage was reported in the railway or forestry sectors. Regionally, over 75% of national insecticide sales in the industrial vegetation management market occur in the U.S. South (spanning from Texas to the mid-Atlantic) (Kline and Co., 2020b; NMRD, 2023b).

Low levels of malathion were reported to be used in fly control for animal production (livestock) in a 2017 survey (Kline and Co., 2018a). A similar study in 2021 reported no malathion usage, further indicating low levels of malathion usage in this sector (NMRD, 2022a). No nationally representative usage data is available for pine seed orchards and Christmas tree production. A lack of data does not indicate a lack of usage. The U.S. Fish and wildlife service made an estimate of malathion usage on slash pine seed orchards in the 2022 Biological Opinion through expert elicitation and concluded that approximately 25 acres per year are treated (USFWS 2022).

Public health usage - wide-area mosquito adulticide

Wide-area mosquito control is performed by mosquito control districts managed by the state. Recent national surveys (years: 2018, 2020, 2022) of mosquito adulticide usage reported an annual average of 750,000 lbs of malathion being applied to 19 million acres of land (Kline and Co., 2019; NMRD, 2021, 2023c). This accounted for over 20% of total acres treated for mosquito adult control, including multiple treatments to the same acre. Nationally, malathion usage has been increasing over the last 5 years, with over five times the usage reported in 2022 as compared to 2018 in both the pounds of malathion applied and the acres treated with malathion (Kline and Co., 2019; NMRD, 2021, 2023c). Malathion was most commonly applied through ground applications (Kline and Co., 2019; NMRD, 2021, 2023c). Although the Agency does not have regionally specific usage data available at this time, approximately 70% of all mosquito adulticides were sold in the South, particularly in states bordering the Gulf of Mexico (Kline and Co., 2019; NMRD, 2021, 2023c).

SCOPE OF THE ASSESSMENTS

BEAD determined use sites for which to conduct detailed benefits assessments through examination of available usage data, agronomic and economic information, and comments submitted by United States Department of Agriculture (USDA) Office of Pest Management Policy (USDA OPMP, 2023) identifying both ‘critically important’ and ‘important’ uses of malathion.

Based on usage patterns for malathion (shown in Table 1), the main agricultural use sites of malathion are fruit crops. For example, high usage sites include blueberries, strawberries, caneberries, cherries, figs, pears, and oranges. Information submitted by USDA-OPMP (USDA OPMP, 2023) support this observation by stating that malathion is of critical importance for production of blueberries, caneberries, strawberries, cherries, and figs. OPMP also stated that malathion is important in the production of citrus and tropical fruits. Therefore, BEAD assesses benefits of malathion in commercial fruit production in the following complementary memo: *Assessment of Usage and Benefits of Malathion (PC # 057701) in Fruit Crops.*

Usage data indicates that malathion may also be important in production of some vegetables, such as onion and asparagus. Additionally, the USDA-OPMP comment stated that malathion is important in production of cucurbits, and vegetables broadly (USDA OPMP, 2023). Therefore, BEAD assesses benefits of malathion in commercial vegetable production in the following complementary memo: *Assessment of Usage and Benefits of Malathion for Vegetable Crops (PC # 057701).*

Comment from USDA-OPMP also indicated that malathion is of critical use within several state and federal pest management programs: wide-area mosquito control, APHIS Mormon crickets and grasshoppers, cotton boll weevil eradication, management of invasive fruit flies, and California's Beet Curly Top Virus Control program. Usage data supports the assertion that malathion is a leading mosquito adulticide for wide-area applications. Usage data identifying malathion as a leading insecticide used on pasture may also support the claim of importance for use against Mormon crickets and grasshoppers. BEAD assesses the benefits of malathion among these state and national programs in the complementary memorandum: *Assessment of Usage and Benefits of Malathion as a Mosquito Adulticide and Federal and State Insect Pest Management Programs (PC # 057701).*

All related memoranda for the assessment of benefits of malathion can be found in the malathion registration review docket (EPA-HQ-OPP-2009-0317).

USDA-OPMP comments also indicate that malathion may be important in indoor mushroom production and usage data suggests that a major use for malathion is on the treatment of stored grain. However, BEAD does not assess either of these use sites because there are no identified risks of concern from indoor use of malathion.

In this memo, BEAD assesses the benefits of malathion in the following sites where malathion may be important:

- Alfalfa: USDA-OPMP comments state malathion is critical in alfalfa and hay forage. Additionally, alfalfa reported the highest number of acres treated with malathion among agricultural crops.
- Pine seed orchards: USDA-OPMP comments state that malathion is critically important for this use site.
- Pine seedlings: USDA-OPMP comments state that malathion is important for this use.
- Residential homeowner use products for treatment of ornamentals, lawns, and gardens: usage data indicates this as a major use of malathion nationally.

BEAD concludes that the benefits of malathion are low in other registered sites not already described in this section or assessed in accompanying memoranda, such as commercial ornamental production and field crops (e.g., rice, wheat, and field corn). Usage data for these sites, or similar sites, do not suggest that malathion is extensively utilized by growers or professional applicators in these sites—indicating that users either have other cost-effective tools available to control pests which malathion is effective against, or that the pests which malathion is effective against are not problematic in these use sites—and comments from USDA-OPMP do not indicate that malathion has important benefits in sites beyond those listed above.

BENEFITS OF MALATHION

Alfalfa

Malathion has been used to treat a small fraction of alfalfa grown, with usage reported at less than 1 PCT (Table 1) (Kynetec, 2022b). Growers reported using malathion to target leafminers, though use was also reported against armyworm, aphids, lygus bug and other unspecified insect pests (Kynetec, 2022a).

Information submitted through public comment by the Arizona Pest Management Center (APMC) states that malathion is primarily used against aphids and the alfalfa weevil, where it is used as the standard application treatment for dual control of these pests when they occur at the same time in early spring (APMC, 2022). APMC also mentions that malathion's 0-day preharvest interval (PHI) in alfalfa is highly advantageous, as it can be necessary to treat insect pests prior to cutting or performing other field activities (APMC, 2022). Other secondary pests mentioned by APMC which are treated with malathion include armyworm and three-cornered alfalfa hoppers (APMC, 2022).

Alfalfa weevils[1] (*Hypera postica*) are reported as one of the primary defoliators in alfalfa, and heavy infestations can reduce tonnage and forage quality (ISU, 2023). Alfalfa weevil larvae and adults feed on leaves, causing defoliation and potentially delaying regrowth after the first cutting (KSU, 2013). Available and recommended chemical insecticides for alfalfa weevil control include indoxacarb, and spinosad (PUE, 2023; UCANR, 2017). Pyrethroids (e.g., lambda-cyhalothrin, beta-cyfluthrin, permethrin), which have been extensively used for alfalfa weevil control, may no longer represent an effective control option due to growing reports of resistance development (MSU, 2024; Rodbell et al., 2024).

There are four species of aphids considered to be economically important pests of alfalfa, the pea aphid (*Acyrthosiphon pisum*), cowpea aphid (*Aphis craccivora*), blue alfalfa aphid (*Acyrthosiphon kondoi*), and spotted alfalfa aphid (*Therioaphis maculata*) (CSU, 2011a; UA, 1998). The most damaging species are the blue and spotted alfalfa aphids, which can cause chlorosis and wilt, leading to eventual stunted growth and plant death (OSU, 2023). Available and recommended chemical insecticides for aphids include afidopyropen, dimethoate, chlorantraniliprole, flupyradifurone, flonicamid, methomyl, and pyrethroids (PUE, 2023; UCANR, 2023).

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[1] In certain states west of the Rocky Mountains such as California and Arizona, a second species called the Egyptian alfalfa weevil (*Hypera brunnipennis*) is morphologically indistinguishable from the alfalfa weevil and causes similar damage (CSU, 2011b; UCANR, 2017)

The alfalfa blotch leafminer (*Agromyza frontella*) is an introduced pest from Europe first detected in the US in 1968, whose larvae tunnel and feed within leaf tissue, and adults cause pinholes in alfalfa leaves (Peairs, 2018; Venette et al., 2009). Leafminer feeding results in potential reduced yields of 7-20% and a reduction in protein content by 10-20% (Peairs, 2018). Available and recommended alternatives for this pest include carbaryl, pyrethroids, chlorantraniliprole and methomyl (Peairs, 2018).

Lygus bugs (*Lygus* spp.) feed on the leaves, buds, and flowers of alfalfa plants, leading to stunted growth and reduced seed yields (UI, 2023; USU, 2007). Lygus bugs are considered the top arthropod pest in alfalfa seed production (O'Neal, 20217). The larval stages of armyworms (*Spodoptera* spp.) have been reported to cause defoliation, with large populations resulting in stand destruction (OSU, 2017; UNL, 2020). Available and recommended alternatives for these pests include pyrethroids, chlorantraniliprole, carbaryl, dimethoate, sulfoxaflor, flonicamid (early life stages), chlorpyrifos[2], and indoxacarb (PSU, 2023; O'Neal, 2017). Methoxyfenozide is also available against armyworm (KSU, 2024; PSU, 2023).

In the absence of malathion, users would be able to switch to one or more of several alternatives, depending on target pest pressure and crop end use (seed, hay, fodder), and be able to maintain adequate control against target pests. At most, users might lose some flexibility in managing some target pests throughout the growing season, leading to some operational and/or material cost increases.

Therefore, even though reported malathion alfalfa usage is low (<1% PCT), BEAD finds that malathion offers low to moderate benefits to users due to its broad-spectrum activity against important insect pests. Benefits also include the ability to simultaneously treat against the alfalfa weevil and aphid complex with a single active ingredient, saving growers the need to preform additional applications against each individual pest or to tank mix active ingredients, which could elevate operational and material costs. Malathion's 0-day PHI also provides users increased flexibility in managing their operations when compared to other available alternatives which may have more extensive PHIs[3].

Pine seed orchards

Pine seed orchards produce high-quality seed for downstream forestry operations. Malathion use on pine seed orchards is restricted to slash pine (*Pinus elliottii*) grown in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas. Slash pines grown for commercial production are generally sourced from genetically improved stock (Moore & Wilson 2006).

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[2] Chlorpyrifos is currently not allowed in crops grown and sold in California, Hawaii, Maryland, New York and Oregon.

[3] Several alternatives also have a 0-day PHI in alfalfa, but either do not control the same spectrum of target pests as malathion (e.g., afidopyropen), and/or can have extended PHIs depending on the crop end-use (seed, hay, fodder).

According to USDA-OPMP (2023), aerial applications of malathion is a critical need for the management of slash pine flower thrips (*Gnophothrips fuscus*, family Phlaeothripidae) in slash pine seed orchards, particularly during the January to February timing of flower opening in the southern U.S. However, the usage of malathion has declined in recent years, likely due to a decrease in thrips damage (USFWS 2022). Usage is estimated to be no more than 25 acres per year, based on a total of twenty-four counties across Alabama, Florida, and Georgia that were identified as the most likely to have slash pine seed orchards and malathion use (USFWS 2022). Pine seed orchards can range from hundreds to thousands of acres in size (Cloughesy, 2017; Fox et al., 2004; USFS, 2024ab), therefore estimated usage is low.
Slash pine flower thrips damages or kills females buds and flowers of only slash pines, leaving abrasions marked with beads of resin (Ebel et al. 1980). Buds can abort in cases of more severe damage, with historical reports of up to 45% flower mortality and more than 50% reductions in seed yield (Ebel et al, 1980). Malathion is the main insecticide registered for use against slash pine flower thrips (USFWS 2022), with applications typically timed in January through February for preventing thrips damage to flowers and conelets (DeBarr and Matthews 1971, Ebel et al. 1980, Fatzinger et al. 1992, Fatzinger & Dixon 1996). Acephate has historically been the main alternative to malathion for the management of slash pine flower thrips (Fatzinger et al. 1992, Fatzinger & Dixon 1996), but is restricted to use only in Florida, Georgia, North Carolina, and Virginia. While the usage of malathion is low, BEAD finds that malathion might provide low to moderate benefits in slash pine seed orchards, as it is among the few chemical control options available for managing slash pine flower thrips during occasional outbreaks.

Pine seedlings

USDA-OPMP (2023) also identified malathion as being of high importance for the control of pine sawflies in pine seedlings. Malathion is registered for use in Christmas tree plantations and in pine seed orchards and may be used to control sawflies on seedlings in these production systems.

In young pines (trees less than 15 feet tall), the redheaded pine sawfly (*Neodiprion lecontei,* family Diprionidae) is a pest that has the potential to completely defoliate trees in southern states where multiple generations occur annually (Wilson and Averill 1979, Mangini 2017). Severe outbreaks can result in the death or deformity of young pines (Salom and Day 2021), whereas sporadic outbreaks typically recede after a few years of heavy defoliation as populations are reduced by a wide range of natural enemies, including parasitoids, diseases, and mammals (Mangini 2017, Salom and Day 2021). Since newly emerged larvae feed on pine needles in large gregarious groups (DeBerry 2011), removal of sawfly infestations by hand is a non-chemical control option (Enebak et al. 2022). In general, sawflies are controlled during spraying for other pests in early spring and are considered secondary pests (Enebak et al. 2022).

Alternatives to malathion for sawfly control in young pine plantations (including Christmas trees) and pine tree nurseries include: carbaryl (Group 1A); bifenthrin, cyfluthrin, lambda-cyhalothrin, esfenvalerate, permethrin (Group 3A); spinosad (Group 5); and diflubenzuron (Group 15) (AFC, *undated*; Eneback et al., 2022; Mangini, 2017). BEAD concludes that malathion likely has low benefits for use on pine seedlings due to the availability of multiple alternatives with different modes of action as well as a non-chemical method of control.

Outdoor residential use

Malathion is registered for outdoor use in residential areas for applications to vegetable gardens, fruit trees, building perimeters, and as a spot treatment on ornamentals. Recent surveys of residential consumer pesticide usage reported approximately 480,000 lbs of malathion sold annually for outdoor use including use on gardens and to control nuisance insects around the outside of homes (Kline and Co., 2020a, NMRD, 2023a). This reported amount is greater than the total volume of malathion applied to outdoor agricultural sites annually (Kynetec, 2022a).

Malathion is available in homeowner products as a broad-spectrum insecticide, used to effectively target a variety of insect pests including beetles, flies, true bugs, aphids, wasps, and caterpillars (UAEX, 2021). It is also an effective knock-down insecticide against the invasive spotted lanternfly (*Lycorma delicatula*) (PSE, 2021).

Malathion is also labeled on residential homeowner products to control nuisance mosquitoes and adult flies, largely as a residual surface spot spray (Buckner *et al.,* 2019). Application areas include spot treatments on vegetation, lower parts of house foundations and fences, and around garbage cans to target mosquitoes and/or flies that land on the treated surfaces (US EPA, 2023a).

Effective control of a wide variety of pests across multiple residential settings, such as gardens, turf, ornamentals, and fruit trees, among others, benefits people in terms of enhanced recreation, well-being, and aesthetics.

Alternatives to control malathion target pests include products that contain carbaryl, spinosad, various pyrethroids, insecticidal soaps, horticultural oils, azadirachtin (neem oil) and trichlorfon (turf pests only) (Foster and Obermeyer, 2017; UF, 2021). However, malathion is the only organophosphate (IRAC group 1B) with registered products still available for homeowner use targeting a wide array of pests across various settings (e.g., gardens, ornamentals, fruit trees), and as such, might be providing benefits in the form of effective and flexible management of multiple target pests.

Therefore, BEAD finds it likely that malathion provides moderate benefits in residential use sites, due to its broad-spectrum activity, and being the only organophosphate available as a homeowner product with versatility across various settings.

IMPACTS OF POTENTIAL MITIGATION

Regarding potential mitigations to reduce risks to non-target organisms, substantial mitigation from the 2022 Biological Opinions has already been implemented on labels to provide protection for species federally listed as threatened or endangered. Mitigation to further reduce potential ecological risks to listed and non-listed species may include adding mandatory spray drift language for boomless ground applications, and a 96-hour water holding time before releasing floodwaters after the treatment of rice. The mandatory spray drift language for boomless sprayers is expected to have minimal impacts on the use sites discussed in this document, as boomless sprayers are not typically used within the use sites assessed in this document. Likewise, BEAD expects little impact to rice growers from the water holding requirement because malathion has low benefits for rice production and only about one percent of the rice acreage is treated with malathion (Table 1).

CONCLUSION

Malathion is a broad-spectrum organophosphate insecticide classified by the Insecticide Resistance Action Committee (IRAC) as a Group 1B Mode of Action insecticide. Malathion is registered on a broad range of agricultural and non-agricultural use sites. Usage data indicates that malathion is regularly used in a variety of fruit and vegetable crops, wide-area mosquito control, and residential homeowner uses.

Many registered use sites, such as rice and commercial ornamental production, exhibit low usage and therefore suggest that users either have other cost-effective tools available to control pests which malathion is effective against, or that the pests which malathion is effective against are not problematic in these use sites. BEAD concludes low benefits in many of these low usage sites.

Based on usage data and stakeholder comments, BEAD evaluated the benefits of malathion in alfalfa, pine seed orchards, pine seedlings, and residential homeowner uses.

In alfalfa production, where reported malathion usage is low (<1% PCT), BEAD finds that malathion offers low to moderate benefits to users due to its broad-spectrum activity against pests, including the ability to simultaneously treat against two of alfalfa's key pests (alfalfa weevil-aphid complex). This, in addition to malathion's 0-day PHI restrictions, provide users increased flexibility in managing their operations and saves them the need of performing additional applications or tank mixing.

In pine seed orchards, malathion provides low to moderate benefits in managing slash pine flower thrips during occasional outbreaks, as it is among one of few chemical control options available for their control. On pine seedlings, where malathion is mainly used for the control of redheaded pin sawfly, malathion seems to provide low benefits due to the availability of multiple alternatives with different modes of action, as well as the availability of non-chemical control options.

In residential homeowner use products for the treatment of ornamentals, lawns, and gardens, BEAD finds that malathion provides moderate benefits due to its broad-spectrum activity, versatility across various settings withing such, and by being the only organophosphate with such attributes available as a homeowner product.

Mitigation measures under consideration to reduce potential ecological risks include adding mandatory spray drift language for boomless ground applications, and a 96-hour water holding time before releasing floodwaters after the treatment of rice. BEAD expects minimal impacts to users resulting from proposed mitigation measures across all evaluated use sites.

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