UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C., 20460

OFFICE OF
CHEMICAL SAFETY
AND POLLUTION
PREVENTION

November 9, 2020

MEMORANDUM

SUBJECT: Chlorpyrifos Usage and Benefits Assessment for Non-crop Uses

FROM: Nikhil Mallampalli, Entomologist
Biological Analysis Branch
Biological and Economic Analysis Division (7503P)

Claire Paisley-Jones, Biologist
Science Information and Analysis Branch
Biological and Economic Analysis Division (7503P)

THRU: Monisha Kaul, Chief
Biological Analysis Branch

Hope Johnson, Chief
Science Information and Analysis Branch
Biological and Economic Analysis Division (BEAD) (7503P)

TO: Patricia Biggio, Chemical Review Manager
Matthew Manupella, Acting Team Leader
Dana Friedman, Chief
Risk Management and Implementation Branch 1
Pesticide Reevaluation Division (7508P)

PRODUCT REVIEW PANEL DATE: August 12, 2020

SUMMARY

This memorandum reviews the non-crop uses and assesses the pest management benefits of chlorpyrifos, an organophosphate insecticide that is currently undergoing registration review. In

this document, BEAD summarizes available usage data, the pest management role of chlorpyrifos, and recommended effective alternatives to chlorpyrifos for key target pests in the various non-crop use sites (*e.g.* turfgrass in various settings, mosquito control, food processing facilities, etc) for which it is currently registered.

BEAD's review concluded that for most non-crop uses, chlorpyrifos is no longer recommended or heavily used for important insect pests. However, there a few exceptions to this overall conclusion. For pests of public health concern, such as mosquitoes and certain ticks, chlorpyrifos is one of a limited set of effective options available for wide area or broadcast use in specific use settings, such as government agency mosquito control districts (when suppressing adult mosquitoes), and golf courses (for ticks). For mosquitoes, chlorpyrifos also has value as one of a few insecticides that can be used against pyrethroid-resistant populations or to delay the onset of such resistance. While effective alternatives are available, due to the consequences to public health posed by the serious diseases transmitted by these pests, chlorpyrifos provides an important resistance management tool to sustain the effectiveness of non-organophosphate alternatives. Similarly, for the protection of certain types of cattle livestock from horn flies, chlorpyrifos confers a benefit to control fly populations that have developed tolerance to pyrethroids, a widely used class of insecticides. In addition, for horn fly populations that have not yet developed pyrethroid resistance, chlorpyrifos is an active ingredient that, when used in rotation with pyrethroids, could delay or even avoid insecticide resistance. Finally, for producers of outdoor-grown nursery plant stock, chlorpyrifos is one of a very limited set of insecticide options that qualify their products for pest-free certification in southeastern U.S. states that are currently under a USDA quarantine intended to prevent the spread of imported fire ants.

INTRODUCTION

The United States Environmental Protection Agency (EPA) is currently in the process of re-evaluating the risks posed to human health from the use of chlorpyrifos, a broad-spectrum organophosphate insecticide. Chlorpyrifos is currently registered for use in over 60 agricultural use sites, as well as for several non-crop settings, such as golf course turf, livestock premises, industrial structures, empty food storage premises, and adult mosquito control use.

In 2015, EPA issued risk assessments covering risks to human health posed by dietary exposure to chlorpyrifos. The Agency is now in the process of revising these risk assessments and is also evaluating the pest management benefits of chlorpyrifos in selected agricultural and non-crop use settings. This memorandum provides risk managers within the Agency an assessment of the usage, role and pest management benefits of chlorpyrifos in registered non-crop use settings. A separate memorandum assessing the economic benefits provided by chlorpyrifos to agricultural producers is also available in the chlorpyrifos regulatory docket (Berwald *et al.* 2020).

METHODOLOGY

BEAD first worked with the Registration Division (RD) to review all currently active non-crop and livestock label information, which accounts for 51 active product registrations. To help include all non-crop use sites and target pests on this large set of labels, RD provided an EPA registration number for each product, a descriptive summary of the use site, and target pests for each label. BEAD used the information summarized by RD to focus its literature research only on pests listed on chlorpyrifos labels for which extension or industry literature discusses this insecticide as a recommended or frequently used option. BEAD also used the information provided by RD to research the extension literature for information in regions that are reasonably likely to have significant problems with important target pests (*e.g.*, cockroaches in warm-climate states, livestock pests in states with significant cattle production, etc). For a few use settings (such as food processing facility premises), BEAD had to rely on the limited industry-oriented literature that discuss insect pest management. As mentioned above, in this research effort BEAD focused on the discussion in extension/industry sources that was relevant to pests for which chlorpyrifos was mentioned as an insecticide option, and also applied its best professional judgement to assess the pest management importance of chlorpyrifos in each category of use settings discussed below.

BEAD categorized use sites on the basis of either 1) the types of target pests involved (*e.g.*, arthropods of public health concern, such as mosquitoes) or 2) similarity (*e.g.*, turfgrass, pests of stored food or food processing establishments, *etc*.). BEAD's analysis is summarized below on the basis of these categories. BEAD then reviewed proprietary non-crop market survey data (Kline 2012, 2015, 2016, 2017) to identify usage information for as many non-agricultural use sites as possible. These usage data are presented in the section following immediately below. In addition, the current role of chlorpyrifos as a pest management tool and the availability of efficacious alternative insecticides or non-chemical management tactics was evaluated on the basis of extension and pest management industry literature developed by applied entomologists and pest management advisors. BEAD acknowledges that these sources may not capture all of the nuances involved in the specialized pest management settings being assessed in this memorandum, such as the local availability of effective chlorpyrifos alternatives in the pesticide marketplace or the feasibility of application methods required for some alternatives. Therefore, during the chlorpyrifos public comment period, BEAD requests information be submitted by non-crop pest management professionals and academic experts.

USAGE DATA FOR CHLORPYRIFOS IN VARIOUS NON-CROP USE SETTINGS

Chlorpyrifos usage data for surveyed non-crop use sites are listed in Table 1, along with data source survey years. Kline and Company non-crop market research data are available for the following use settings: ornamentals; lawns and turf; wide area treatments for mosquitos, ant, and other miscellaneous insects; buildings/premises; rights of way/utilities; and trees. Available data indicate that the majority of non-crop chlorpyrifos usage in terms of pounds of active ingredient were applied to ornamental lawns and turf (Table 1). Within this market segment, turf farms account for the majority of usage, with 70,000 pounds active ingredient (AI) applied (Table 1). Nursery and greenhouse use on ornamentals are a close second, with 50,000 pounds AI applied (Table 1). This corresponds to chlorpyrifos' ranking in these sectors, where chlorpyrifos is the top insecticide applied by weight (lbs AI applied) in turf farms, and the second most used insecticide for ornamentals in nursery and greenhouses (Table 1).

Pounds of chlorpyrifos applied for wide area mosquito treatment are much lower than those applied to turf and ornamental, with only 10,000 pounds applied annually (Table 1). However, due to very low application rates typically used for mosquito adulticides, treatments for adult mosquitoes account for the vast majority of non-crop acres treated with chlorpyrifos, with over 1,000,000 acres reported to be treated for this purpose (Table 1). However, chlorpyrifos only accounts for 0.5% insecticides applied for this sector in terms of pounds applied (Table 1). As a group, the synthetic pyrethroids are far more highly used for mosquito control (Kline 2016). Chlorpyrifos is also registered for use on the following additional surveyed non-crop sites: wide area/ general outdoor treatment (for ants and other miscellaneous pests), buildings/premises, rights of way/utilities, and trees. However, while Kline and Company does survey these sites, the surveys did not report any usage for these sites, indicating that chlorpyrifos is not widely used in these sectors (Table 1). Chlorpyrifos is also registered for use on livestock areas and animals, but usage data on pounds applied are unavailable for these sites (Table 1).

California provides publicly available pesticide use data through its Pesticide Use Reporting (PUR) web portal and includes past usage data for chlorpyrifos. However, in 2019 the state began to implement a stop sale/stop use order for almost all uses of chlorpyrifos. Since future use of this insecticide will not be permitted in California, BEAD has not included data specific to the state in this document.

Table 1. National Chlorpyrifos Non-crop Usage by Crop. Data Averaged Over Reported Years.

Use Site/Geographic Area[a]	Years Surveyed	Annual Pounds AI Applied[b]	% of Market by Weight and Ranking of AI in Market[c]	Average Annual Total Acres Treated[d]
ALL Ornamentals, Lawns, and Turf (Sod Farms)	**2011[e]**	150,000	**6.5%** (6th in market on this use site)	--
Nursery/Greenhouse	**2011[e]**	50,000	**8.3%** (2nd in market on this use site)	70,000
Deep South	2011[e]	8,000	--	10,000
North Central	2011[e]	10,000	--	10,000
Northeast	2011[e]	9,000	--	20,000
South	2011[e]	20,000	--	10,000
West	2011[e]	2,000	--	2,000
Turf Farms	**2011[e]**	70,000	**58%** (1st in market on this use site)	60,000
Deep South	2011[e]	60,000	--	50,000
South	2011[e]	10,000	--	7,000
West	2011[e]	3,000	--	6,000

(Continued on next page)

Use Site/Geographic Area[a]	Years Surveyed	Annual Pounds AI Applied[b]	% of Market by Weight and Ranking of AI in Market[c]	Average Annual Total Acres Treated[d]
Golf Course Turf	**2011[e]**	20,000	**4.8%** (5th in market on this use site)	20,000
Deep South	2011[e]	6,000	--	4,000
North Central	2011[e]	3,000	--	3,000
Northeast	2011[e]	7,000	--	8,000
South	2011[e]	4,000	--	6,000
West	2011[e]	1,000	--	2,000
In Institutional Turf Facilities	**2011[e]**	<500	**0.2%**	600
West	2011[e]	<500	--	600
Applied to Turf by Landscape Contractors	**2011[e]**	<500	**0.05%**	<500
Northeast	2011[e]	<500	--	<500
Applied to Turf by Lawn Care Operators	**2011[e]**	3,000	**0.4%**	2,000
South	2011[e]	<500	--	<500
West	2011[e]	2,000	--	1,000
Wide Area Treatments	+	+	+	+
Mosquito Control; Household/ Domestic Dwellings Outdoor Premises; Recreational Areas	**2015[f]**	10,000	**0.50%**	1,100,000
North Central	2015[f]	500	--	90,000
South	2015[f]	9,000	--	900,000
West	2015[f]	1,000	--	100,000
Wide Area/ General Outdoor Treatment (for ants and other miscellaneous pests)	2016[g]	Surveyed but no usage reported		
Buildings/Premises				
Commercial/Institution-Al/ Industrial Premises/ Equip. (Indoor)	2016[g]	Surveyed but no usage reported		
Commercial/Institutional /Industrial Premises/Equip. (Outdoor)	2016[g]	Surveyed but no usage reported		
Nonagricultural Outdoor Buildings/Structures (non-residential)	2016[g]	Surveyed but no usage reported		
Household/ Domestic Dwellings Indoor Premises	2016[g,h]	Surveyed but no usage reported		
Wood Protection Treatment to Buildings/ Products Outdoor	2016[g]	Surveyed but no usage reported		
Food Processing Plant Premises (Nonfood Contact)	2014[i]	Surveyed but no usage reported		

(Continued on next page)

Use Site/Geographic Area[a]	Years Surveyed	Annual Pounds AI Applied[b]	% of Market by Weight and Ranking of AI in Market[c]	Average Annual Total Acres Treated[d]
Rights of Way/Utilities	+	+		
Rights of Way, Road Medians	2016[j]	Surveyed but no usage reported		
Utilities	2016[j]	Surveyed but no usage reported		
Sewer Manhole Covers and Walls	2016[j]	Surveyed but no usage reported		
Livestock Areas/Animals	+			
Agricultural Farm Premises (livestock housing and holding areas)	Not Surveyed for pounds applied			
Poultry Litter	Not Surveyed for pounds applied			
Beef/Dairy Cattle	Not Surveyed for pounds applied			
Trees	+	+		
Christmas Tree Plantations	2016[j]	Surveyed but no usage reported		
Hybrid Cottonwood/ Poplar Plantations	2016[j]	Surveyed but no usage reported		
Forest Plantings (Reforestation Programs) (Tree Farms, Tree Plantations, *etc*)	2016[j]	Surveyed but no usage reported		
Conifers and Deciduous Trees; Plantation, Nursery	2016[j]	Surveyed but no usage reported		
Forest Trees (Softwoods, Conifers)	2016[j]	Surveyed but no usage reported		

Notes	
a	Geographic regions based on U.S. Census Bureau regions. Northeast (ME, NH, VT, MA, CT, RI, NJ, NY, PA) North Central (ND, MN, WI, MI, OH, IN, IL, IA, ND, NE, SD, MO) West (WA, OR, CA, ID, NV, MT, WY, UT, CO, AZ, NM) South (OK, AR, TN, KY, WV, MD, DE, VA, NC) Deep South (TX, LA, MS, AL, GA, SC, FL)
b	The pounds AI displayed in this document may differ from those displayed in other BEAD documents because different calculation methods and underlying data used.
c	Chlorpyrifos' % of national market share by weight (% of chlorpyrifos pounds AI applied compared to the total pounds of all AIs used on the same site) is provided. Where available, chlorpyrifos' rank in the market, in terms of pounds applied compared to pounds of other AIs applied, is also provided in parentheses.
d	Total Acres Treated accounts for multiple applications to a single area. This may overestimate the base number of acres treated one or more times, as some acres are treated more than once.
e	Kline and Company. 2012.
f	Kline and Company. 2016.
g	NMRD. 2017.
h	Kline and Company. 2017b
i	Kline and Company. 2015.
j	Kline and Company. 2017a.

ASSESSMENT OF THE BENEFITS OF CHLORPYRIFOS IN NON-CROP USE SETTINGS

Chlorpyrifos as a public health insecticide

Mosquitoes

Chlorpyrifos is currently registered as a mosquito adulticide for use only by federal, state, tribal or local government officials responsible for public health or vector control. No larvicidal use is registered. Kline (2016) usage data (Table 1) indicate that chlorpyrifos is used in very small quantities compared to other registered adulticides. The most recent data available show that about 10,000 lb. a.i. of chlorpyrifos were sold for mosquito use in 2015 comprising about 0.5% of the total pesticides sold (Table 1). Other organophosphates, naled and malathion, comprise the largest share of adulticide usage, followed by the pyrethroid, permethrin (Kline 2016).

Alternative adulticides currently registered include pyrethroids (deltamethrin, etofenprox, pyrethrins, permethrin, prallethrin, and sumithrin), and other organophosphates (malathion and naled). While chlorpyrifos is not used often, it is worth noting that there are only two Modes of Action groups of chemicals - pyrethroids and organophosphates - available as mosquito adulticides. Although users would still have two other organophosphates to choose from to manage pyrethroid-resistant populations or to delay the onset of pyrethroid resistance, there may be operational and resistance management aspects of chlorpyrifos that confer importance to its pest management role where adult mosquitoes are concerned. In April 2015, the American Mosquito Control Association (AMCA) submitted a comment to the chlorpyrifos risk assessment docket and stated, “Although chlorpyrifos is not widely used as a mosquitocide, it remains a vital tool in resistance management schemes practiced by mosquito control districts” (AMCA 2015). A recent summary of the role of chlorpyrifos, from the University of Georgia’s extension service recommendations, highlights some of these aspects when it described chlorpyrifos as being non-corrosive, offering quick knockdown and a good option for resistance management purposes where mosquitoes show reduced susceptibility to permethrin or pyrethrins (Grey 2020).

Other insect pests of public health concern

Chlorpyrifos is also registered for use against ticks of various species in the following outdoor non-crop settings: golf courses, road medians, and industrial plant sites. Available usage data suggest that the outdoor non-crop use is concentrated in golf courses (Table 1). Some amount of that usage is probably directed at tick pests. Ticks listed on chlorpyrifos labels as being controlled include the deer tick (also called the blacklegged tick), American dog tick, cattle fever tick, Gulf Coast tick, and the lone star tick. All of these tick species are capable of transmitting several debilitating, sometimes lethal viral and bacterial diseases to humans and domesticated animals. The Gulf Coast tick is an aggressive biter of humans (Hertz and Kaufman 2014, CDC 2019), and the deer tick is a well-known vector of Lyme disease.

The Centers for Disease Control (CDC) recently published a review of tick management tactics that are effective against the Gulf Coast tick and others (Eisen and Stafford 2020). They highlighted the effectiveness of an integrated tick management program that incorporates broadcast spraying of synthetic or biologically derived acaricides, in combination with habitat management techniques such as mowing and clearing leaf litter and installing deer fencing to reduce tick populations. They also cited an earlier study that found that chlorpyrifos strongly suppressed host-seeking tick populations when used as part of such a program (Bloemer *et al.* 1990). However, Eisen and Stafford (2020) also cited other studies that showed that various pyrethroids also show good efficacy as components of an integrated program.

In addition, a recent survey of private commercial pest control firms in the three states with the highest incidence of Lyme disease (Pennsylvania, New Jersey, and New York) indicated that while several synthetic acaricides are used for tick management, chlorpyrifos is not mentioned (Jordan and Schulze 2019). Survey respondents listed several naturally derived acaricides (*e.g.*, cedar oil, thyme oil), as well as several synthetic acaricides. Except for carbaryl (a carbamate), all listed synthetic acaricides were pyrethroids.

Taken together, the information summarized above indicates that chlorpyrifos is probably not widely used as an acaricide to control ticks of medical importance. However, given the serious public health concern created by ticks, all currently registered control options, including chlorpyrifos, have some pest management benefit even if used in small quantities. In addition, if resistance to pyrethroids or carbaryl occurs in a particular location, the need for chlorpyrifos as a different chemistry (Mode of Action) for this use will obviously become more important. While cases of fully developed tick resistance in the United States appear to be rare, there are more frequent reports for ticks outside the country (Coles and Dryden 2014), which indicates that the potential for resistance developing here is a potential public health concern.

For cockroaches, chlorpyrifos is available in the form of residential and non-residential bait stations and as granular and liquid formulations used as outdoor and indoor premise treatments for commercial establishments, such as warehouses, food processing establishments, *etc.* However, extension recommendations located by BEAD that are representative of warmer climates in the United States where these pests are likely to be more common, such as California and Georgia, do not mention chlorpyrifos-containing baits as an option for residential or commercial establishment cockroach control (Sutherland *et al.* 2019, Suiter 2020).

Although BEAD does not have usage data specific to this use (cockroach control), the absence of any extension recommendation to use chlorpyrifos likely means current usage is low. Several other insecticides, either in bait, gel, paste, granular, dust or spray formulations are recommended (Layton and Goddard 2019, Suiter 2020, Sutherland *et al.* 2019). These include (but are not limited to) insect growth regulators such as methoprene, pyriproxyfen, and fenoxycarb, narrow-spectrum chemicals such as boric acid, hydramethylnon, indoxacarb, and abamectin (which are also effective against ants), and broad-spectrum chemicals such as pyrethroids and carbaryl (a carbamate). These active ingredients are among those recommended for both homeowners and professional pest managers specializing in residential and commercial use settings (Suiter 2020, Suiter and Scharf 2020, UCIPM 2019, Layton and Goddard 2019). In addition to these insecticide options, extension experts recommend the use of non-chemical tactics such as regular sanitation and blocking access to interior premises by repairing cracks and holes.

Based on the literature summarized above, BEAD concludes that chlorpyrifos is probably not a critically necessary management option for cockroaches in residential or commercial settings now (as compared to its overall history of use in the U.S., as it has been a widely used insecticide in many non-agricultural settings), and is probably less important as a cockroach control option as compared to its utility in managing tick or adult mosquito populations. As with these other pests, however, there may be isolated areas where chlorpyrifos is useful in managing cockroach populations that are resistant to more than one of these MOAs. While cases of resistance to pyrethroids and hydramethylnon in cockroaches have been documented in the U.S., other alternatives such as abamectin or fipronil could also be used effectively in those situations (NCSU 2020, Suiter 2020, UCIPM 2019).

Chlorpyrifos as an option for livestock and poultry pest control

Chlorpyrifos is registered as a restricted use pesticide for use as a surface spray in various livestock housing and holding premises. Examples include empty poultry houses, hog barns, milk rooms, calf hutches, calving pens, and milking parlors. Target pests for this use include darkling beetles and flies. Chlorpyrifos is also registered as an active ingredient in ear tags (co-formulated with another organophosphate, diazinon) for use on certain types of cattle (beef cattle and non-lactating dairy cows). The chlorpyrifos ear tag label lists several blood-feeding (*e.g.*, horn flies, stable flies, and biting and sucking lice) and nuisance pests (*e.g.*, houseflies). The open wounds created by horn flies foster bacterial infections, and stable flies can transmit various serious cattle diseases, including Brucellosis and pinkeye (Coelho *et al.* 2015, Townsend 2000, Williams 2010). Face flies and houseflies can also mechanically transmit other diseases. High densities of any of the aforementioned fly species can irritate animals, resulting in reduced weight gain in both poultry and cattle and reductions in milk production in dairy cattle.

BEAD reviewed extension recommendations for livestock insect management from sources in Arkansas, Indiana, Louisiana, Nebraska, and North Carolina, all states with significant production of cattle, poultry, and hog livestock. Chlorpyrifos is mentioned as one of several insecticide recommendations only for cattle and poultry, and only for a small set of the many arthropod pests that can affect such animals (Boxler 2015, LSU 2020, NCSU 2020, UA 2020, Williams 2010).

For cattle, the chlorpyrifos ear tags are recommended for season-long control of horn flies and face flies. A chlorpyrifos premise spray is recommended for managing adult stable flies, houseflies and other filth flies. Ear tags do not provide sufficient protection from stable flies because these insects feed on animals' legs and are unaffected by insecticides placed near the head; houseflies and other filth flies have many other food sources besides the animals themselves (*e.g.*, manure) and also would not be adequately suppressed by ear tags alone (Williams 2010).

Recommended alternatives for the chlorpyrifos ear tag use include tags containing pyrethroids (cypermethrin, lambda-cyhalothrin, permethrin, and others), other organophosphates (TCVP, DDVP, coumaphos + diazinon, pirimiphos-methyl, diazinon as a stand-alone formulation), and abamectin. For the premise spray use, recommended alternatives to chlorpyrifos include pyrethroids (*e.g.*, bifenthrin, deltamethrin), organophosphates (DDVP), neonicotinoids (imidacloprid), spinosyns (spinosad), carbamates (methomyl), and cyromazine (Boxler 2015).

Some, such as cyromazine, are effective only against larvae in manure, *etc*., but others, such as pyrethroids and organophosphates, are effective against both adults and larvae (Boxler 2015, LSU 2020, NCSU 2020, UA 2020). Chlorpyrifos-impregnated ear tags only affect adult flies that contact the tags and have no direct activity against the larvae.

For poultry, chlorpyrifos premise sprays are recommended for empty housing to control adult houseflies, other filth flies, and stable flies by some but not all extension sources consulted by BEAD (LSU2020, NCSU 2020). Recommended alternatives to chlorpyrifos include several pyrethroids, TCVP and DDVP, as well as larvicides such as pyriproxyfen (LSU 2020, NCSU 2020, Tomberlin and Drees 2007, UA 2020).

According to Williams (2010), horn fly resistance to pyrethroids has developed in some areas of the Midwest, but organophosphate tags will control pyrethroid resistant horn flies. While this issue raises the importance of chlorpyrifos as an option for ear tag mediated control of these pests, there are other organophosphates also available in this form (*e.g.*, TCVP, DDVP).

Considering the observations summarized above, BEAD concludes that there is some benefit for chlorpyrifos use against horn flies in some types of cattle. For the other livestock uses of chlorpyrifos mentioned on labels, BEAD concludes that the pest management benefits of chlorpyrifos is low, given the presence of many other effective options representing several different Modes of Action as well as other organophosphate insecticides.

Chlorpyrifos as an option in the imported fire ant and other USDA quarantine and exclusion programs

Chlorpyrifos is among the insecticides that allow containerized or balled and burlapped nursery stock to qualify for USDA's pest-free certification for insect pests that are either already present in the U.S. or must be prevented from entering the country on contaminating produce or shipping materials (USDA 2016). BEAD reviewed current publications from USDA's Animal and Plant Health Inspection Service (APHIS) which describe treatment options considered acceptable for pest-free certification of various commodities and transportation and storage structures (USDA 2016, 2019). These sources indicate that chlorpyrifos is among the accepted treatments for eradicating (i) miscellaneous 'insects such as crickets, beetles, and Africanized honeybees from empty containers and industrial premises used for processing and shipping commodities, (ii) wood-damaging insects such as carpenter ants, carpenter bees, and certain beetles and wasps in wood products including containers, and (iii) imported fire ants (IFA) from nursery stock (i.e., containers and in-field produced balled-and-burlapped plants) grown within the IFA quarantine region (USDA 2016).

For the first two sets of these quarantine uses – eradicating miscellaneous insect pests and wood-damaging pests – the USDA also accepts several alternatives to chlorpyrifos representing different MOAs or treatment approaches. For miscellaneous pests, several pyrethroids (*e.g.*, cyfluthrin, deltamethrin, lambda-cyhalothrin) or malathion can be used. For wood-damaging insects, cyfluthrin is the only other accepted liquid spray treatment. However, in addition to these spray treatments, for both these types of pests, broad-spectrum fumigation with methyl bromide or sulfuryl fluoride is also acceptable (USDA 2016). Given the availability of these effective options across different chemistries, which include insecticides besides pyrethroids and organophosphates, it is unlikely that chlorpyrifos itself plays an essential role in pest-free certification by the USDA-APHIS for these pests, although fumigation is probably much more expensive than spray treatments.

Currently, the fire ant quarantine area covers most of the southeastern U.S. (USDA 2018). The fire ant species of concern are the red imported fire ant (*Solenopsis invicta*) and the black imported fire ant (*S. richteri*). BEAD's review of the USDA-APHIS treatment recommendations indicates that for IFA, chlorpyrifos is one of two options for immersion and drench liquid formulation treatments available to growers for containerized and balled/burlapped nursery stock plants of many types prior to shipment out of the quarantine area (USDA 2016). The USDA currently approves only bifenthrin (a synthetic pyrethroid) and chlorpyrifos for these treatments. (USDA 2019). Given that only two Modes of Action are available for such treatments, BEAD concludes that chlorpyrifos plays an important role in the nursery stock component of the USDA-APHIS IFA quarantine program. Currently, the fire ant quarantine area covers the southeastern U.S., and stretches west to parts of Texas (USDA 2019).

Chlorpyrifos as an option for insect pests of turfgrass

Chlorpyrifos labels list several pests of turfgrass that are either controlled or suppressed. These labels are for use on "commercial" turf, which includes only turf grown on golf courses, road medians, and "industrial sites." The exact types of industrial sites are not clearly specified. Some of the arthropod pests on these labels include various caterpillars, weevils and white grubs, true bugs, various ants (including IFA), fly larvae, mole crickets, mites, millipedes, and sowbugs. In addition, chlorpyrifos can be used against IFA as either a mound drench or broadcast treatment on golf courses and sod farms only (regardless of whether or not they are under IFA quarantine).

BEAD's review of relevant extension literature indicates that chlorpyrifos is recommended for a small subset of the turf pests listed above. However, chlorpyrifos is one of several recommended insecticides for some beetles, particularly billbugs (weevils) and the annual bluegrass weevil, cranefly adults and larvae, mole crickets, caterpillars (*e.g.*, armyworms and sod webworms), and nuisance ants (*e.g.*, pavement ants, big-headed ants) (LSU 2020, McCarty 2020, UA 2020). Many of these pests are considered severely injurious to turf. Recommended alternatives to chlorpyrifos for these target pests include (but are not limited to): several pyrethroids and neonicotinoids, carbaryl, acephate, and other more target-specific chemistries such as hydramethylnon (for ants), chlorantraniliprole (for billbugs and caterpillars), trichlorfon (for mole crickets), and others (LSU 2020, McCarty 2020, UA 2020). While there is some reported usage of chlorpyrifos in these turfgrass settings (Table 1), exactly how much is being used for specific target pests is not part of the information available. Regardless, given the large number of recommended alternatives available, BEAD concludes that in these use settings, for the target pests listed earlier in this section, chlorpyrifos is not a pest management option that is critically needed or irreplaceable. While there may be isolated cases where localized resistance to alternative insecticides creates an increased need for chlorpyrifos, this issue was not raised by extension literature reviewed by BEAD. In addition, insecticides representing several MOAs as well as organophosphates besides chlorpyrifos (*e.g.*, acephate) are available for many of the pests discussed in this section; all of these can assist in resistance management efforts.

Regarding the use of chlorpyrifos for IFA management in "professionally managed" turf (i.e., golf courses and sod farms), there are several recommended and effective alternatives. These chemicals represent several different Modes of Action and at least one (acephate) is also an organophosphate insecticide. Recommended alternatives include: pyrethroids (*e.g.*, bifenthrin, deltamethrin, lambda-cyhalothrin), neonicotinoids (imidacloprid), carbamates (carbaryl), spinosyns (spinosad), and fipronil (Hudson and Shimat 2020, LSU 2020, McCarty 2020). Some are recommended as both mound drench and broadcast treatments, while others are recommended only for one or other of these treatment methods (Hudson and Shimat 2020, LSU 2020, McCarty 2020). A subset of pyrethroids, acephate, and baits containing other chemistries such as hydramethylnon and methoprene are also registered for the general public to use against IFA in other turfgrass settings such as home lawns, recreational turf, *etc*. (LSU 2020, Vail and Chandler 2020, Drees *et al.* 2013).

Given the availability of several effective options, IFA management in any of the aforementioned types of turfgrass use sites probably routinely incorporates several different insecticides, including chlorpyrifos. However, as available usage data (Table 1) indicate, chlorpyrifos is an insecticide that is used on several thousand acres of golf course turf and turf farms, with the highest use in the Deep South (Table 1), where IFA is a common problem. The popularity of chlorpyrifos is probably due to factors other than efficacy, such as lower product cost or ease of treatment, since there are several alternatives that are at least as effective against the target pest. BEAD has no reliable data on which to base an examination of the importance of these factors. BEAD concludes that turf farm and golf course managers could adapt alternatives to replace chlorpyrifos in terms of continuing to use effective insecticides against the IFA. However, it should also be noted that IFA management costs could increase and/or management regimens could become more complicated in the absence of chlorpyrifos.

Chlorpyrifos as an option for the control of structural insect pests

Chlorpyrifos is registered for use against termites that can damage pre-construction foundations (except in Florida), wooden fence posts, utility poles, railroad ties, landscape timbers, logs, poles, and posts. Carpenter ants and carpenter bees are also listed as target pests for wooden structures such as fences and poles.

BEAD's review of recent extension literature that discusses management of these insects did not show any recommendation to use chlorpyrifos against any of these pests. Several other insecticides are recommended as effective options for one or more of these insects, however. For termites these include (but are not limited to) pyrethroids (*e.g.*, bifenthrin, lambda-cyhalothrin), and other chemistries such as fipronil, chlorfenapyr, and noviflumiron (Miller, 2010, NDACS 2020, NCSU 2020, LSU 2020, Suiter 2020). For wood-damaging ants and bees, the recommended insecticides include carbaryl, pyrethroids, chlorfenapyr, and other ant-specific options such as boric acid and indoxacarb (MacGown *et al.* 2007, NCSU 2020, Suiter 2020, UCIPM 2009). For all these pests, while other organophosphates are not mentioned, there are at least three or more Modes of Action represented, suggesting that the absence of chlorpyrifos as a treatment option would not create additional resistance management problems.

Chlorpyrifos as an option for other commercial and industrial settings

Chlorpyrifos is registered for use as a commercial indoor treatment in the following use settings: food and non-food areas of manufacturing and industrial plants; ship holds; railroad boxcars; and outdoor commercial perimeter applications for food-processing plants and warehouses. Target pests listed on labels for these use settings include grain mites, stored-product beetle pests such as dermestid (carpet) beetles, granary weevil and saw-toothed grain beetle, and stored product moth pests, such as the Indian meal moth and the Angoumois grain moth. In food handling establishments, flies are also target pests, but no particular species is listed. However, it is reasonable to assume that the house fly would be a typical target, given its world-wide ubiquity.

BEAD found very few publicly available technical descriptions of insecticide and other control options for commercial and industrial settings . However, proprietary market surveys indicate that pyrethroids are the most widely used class of insecticides in these use settings (NMRD 2017). Food handling establishments, including processing facilities, warehouses, restaurants, and other food preparation facilities, used around 200,000 lbs a.i. of pyrethroids in 2014 (Kline 2015). Professional pest management companies used over 3 million lbs a.i. of pyrethroids for control of various nuisance and public health pests both in and around residential and commercial buildings (NMRD 2017). Industrial vegetation management professionals used around 56,000 lbs a.i. of pyrethroids in use settings such as roadways and rangeland, (Kline 2017a). The prevalence of pyrethroids in these markets is probably a major reason why the much lower chlorpyrifos usage does not register significantly in these studies. As pyrethroids are the clear market leader in these use settings, it is likely that chlorpyrifos usage has largely been replaced by this class of insecticides.

For the food industry use settings, two relatively recent articles from industry-produced and oriented technical magazines provided some useful descriptions of pest management. According to one of these sources (Corrigan 2002), the food industry overall has been transitioning to integrated pest management (IPM) programs that provide adequate pest management through frequent monitoring and non-chemical tactics such as exclusion, sanitation, *etc*. Another industry source (Kammerling 2019) used his professional role as a pest management company operator to estimate that pesticide usage has been reduced “by more than 95% in many food plants and warehouses”, and asserted that chlorpyrifos is now not an optimal choice for these use settings, given the human health risks it poses. When insecticides must be used, Corrigan (2002) categorized treatments in food industry sites into two broadly defined categories: residual treatments and non-residual applications. He defined non-residual treatments as those whose “killing effect” only lasts during the actual time of treatment with no pest-killing residual activity left over. Examples of “non-residual” applications provided by Corrigan (2002) were tactics such as the use of pyrethrums to flush out insects hiding in a piece of manufacturing equipment or the use of ultra-low dose treatments (ULD) with insecticides. Both types of treatments were described as important components of food plant IPM programs (Corrigan 2002).

Examples of residual interior and exterior premise treatments include sprays and baits containing various active ingredients; a pyrethroid (cyfluthrin) and abamectin were specifically mentioned (Corrigan 2002). Chlorpyrifos was once in heavy use as a premise spray with some residual activity in food plants and warehouses (Kammerling 2019), however use has probably declined greatly, considering it is not discussed in these relatively recent industry sources of technical pest management information as an important pest control tool; BEAD did not locate other technical sources discussing chlorpyrifos use (even in a historical sense) for these use settings. Other interior contact treatments often used recently in food industry settings include ultra-low volume fogging and insecticide injections into areas such as pipes that can serve as harborage for pests (Corrigan 2002, Kammerling 2019).

While the industry sources located by BEAD did not often mention or explicitly compare chlorpyrifos and its registered insecticide alternatives, BEAD's review of active registrations labeled for food industry use sites indicated that several pyrethroids (such as pyrethrins and bifenthrin) are available as sprays and fogging options. Various other chemistries such as fipronil, abamectin and boric acid, as well as the organophosphate DDVP are registered as baits and/or sprays (NPIRS 2020).

BEAD could not find any similar discussions of the technical details of insect pest management for sites such as ship holds and railroad boxcars in either extension or industry sources that are publicly accessible. However, BEAD compiled lists of insecticides currently registered for these specific use sites (NPIRS 2020) for multiple pests that are likely targets of insecticides (*e.g.*, cockroaches and stored-product infesting moths and beetles). For ship holds, in addition to chlorpyrifos, the organophosphate malathion is available, as well as a small set of pyrethroids (allethrin, bifenthrin, esfenvalerate, and pyrethrins), and depending on the target pest, the insect growth regulators novaluron and pyriproxyfen (NPIRS 2020).

For railroad boxcars, a larger set of pyrethroids (including lambda-cyhalothrin and cypermethrin), DDVP, propoxur (a carbamate), pyriproxyfen, and fipronil are registered (NPIRS 2020). Their availability suggests that chlorpyrifos does not occupy a critically important role for controlling insects in railroad boxcars or ship holds in the U.S.

Although the information sources discussed above are limited, given the availability of broad-spectrum insecticide alternatives (at least two of which are also organophosphates) and non-chemical management tactics, BEAD concludes that chlorpyrifos is probably a minor component of modern insect pest management programs for the miscellaneous industrial use sites that are discussed in this section.

CONCLUSIONS

Chlorpyrifos appears to have important pest management benefits for the following non-crop uses: (i) where mosquitoes and ticks must be controlled and other options are unavailable due to supply issues or where pyrethroid resistance in local mosquito or tick populations is a problem; (ii) USDA/APHIS quarantine requirements for IFA-free certification of nursery stock of landscape ornamental plants and fruit and nut crops that will be transported outside quarantine areas, and (iii) protection of certain types of cattle from horn flies with insecticide-impregnated ear tags.

For mosquitoes and ticks, chlorpyrifos is not used as often as many alternatives. However, given the severity of the diseases that mosquitoes and ticks can transmit, the loss of any effective option from the already limited set of insecticides raises public health concerns, as it would place a extra burden on the remaining insecticide options, possibly accelerating the development of insecticide resistance.

For the IFA quarantine uses, the USDA accepts a very limited set of treatments for a pest-free certification. Only chlorpyrifos and one pyrethroid are approved for liquid treatments of containerized and balled/burlapped nursery stock. Given this low diversity in insecticide Modes of Action, the loss of chlorpyrifos could not only create feasibility problems for some producers who attempt to obtain IFA-free certification but also increases the risk of pyrethroid resistance developing in IFA populations in affected production areas.

For protection of cattle from horn flies, BEAD concludes that in areas where pyrethroid resistance is established, chlorpyrifos is one of a few organophosphate alternatives that offer benefits as effective pest management tools. In the other non-crop settings discussed in this document, such as insect protection of livestock premises, food processing establishments, and structural pest control, BEAD cannot find evidence that chlorpyrifos is currently critically important for pest management. There appear to be several other pest control options that are recommended and/or in use.

BEAD is aware that these conclusions are based on selected publicly available extension information, industry-produced publications, and limited usage information. These sources may not capture all of the nuances involved in the specialized pest management settings being assessed in this memorandum, such as the local availability of effective chlorpyrifos alternatives in the pesticide marketplace or the feasibility of application methods required for some alternatives. Therefore, during the chlorpyrifos public comment period BEAD requests information be submitted by non-crop pest management professionals and academic experts.

REFERENCES

AMCA. 2015. Comment Submitted to the Regulatory Docket for the Registration Review of Chlorpyrifos, Docket ID: EPA-HQ-OPP-2008-0850. Available on the web at www.regulations.gov.

Boxler, D. 2015. Nebraska Management Guide for Insect Pests of Livestock and Horses. Publication No. EC14-1550 of the University of Nebraska Institute of Agriculture and Natural Resources Extension. Available on the web at https://entomology.unl.edu/livestock/livestockpestcontrol.pdf.

Corrigan, B. 2002. Focus on IPM: Food Safety IPM Guide. Pest Control Technology (PCT) magazine July 12, 2002. Available on the web at https://www.pctonline.com/article/focus-on-ipm--food-safety-ipm-guide/.

CDC. 2019. Tickborne Diseases of the United States. Online factsheet from the Centers for Disease Control and Prevention. Available on the web at https://www.cdc.gov/ticks/tickbornediseases/tickID.html.

Coelho, A.C., J. G. Díez, and A.M. Coelho. 2015. Risk Factors for Brucella spp.

in Domestic and Wild Animals. Ch. 1 In: Updates on Brucellosis, M. M. Baddour (ed.). Intechopen publishers. Available at http://dx.doi.org/10.5772/61325.

Coles, T. and M. Dryden. 2014. Insecticide/acaricide resistance in fleas and ticks infesting dogs and cats. Parasites & Vectors 7: 8-18.

Drees, B.M., P. Nester, Brown, M. Keck, and K. Flanders. 2013. Fire Ant Control: The Two-Step Method and Other Approaches. Publication ENTO-434 of the Texas A&M AgriLife Extension Service. Available on the web at https://www.agrilifebookstore.org/v/vspfiles/downloadables/ENTO-034.pdf.

Eisen, L. and K. C. Stafford. 2020. Barriers to effective tick management and tick-bite prevention in the United States (Acari: Ixodidae). J. Medical Entomol. XX(X), 2020, pp 1–13. doi: 10.1093/jme/tjaa079.

Gray, E.W. 2020. Mosquito Control: Options for Commercial and Government Entities. An IPM publication from the University of Georgia Extension Service. Available on the web at https://extension.uga.edu/programs-services/integrated-pest-management/publications/handbooks.html.

Hertz, J. C., and P. E. Kaufman. 2014. Featured Creatures: The Gulf Coast Tick. Available on the web at http://entnemdept.ufl.edu/creatures/URBAN/MEDICAL/Gulf_coast_tick.htm.

Hudson, W. and J. Shimat. 2020. Turf: Insect Control in Commercial Turf. Part of the University of Georgia Pest Management Handbook, University of Georgia Extension Special Bulletin 28. Available on the web at https://extension.uga.edu/content/dam/extension/programs-and-services/integrated-pest-management/documents/handbooks/2020-pmh-chapters/Turfgrass.pdf.

Kammerling, R. 2019. Pest Management in the Food Industry: How Far Have We Come?. Pest Management magazine, June/July. Available on the web at https://www.foodsafetymagazine.com/magazine-archive1/junejuly-2019/pest-management-in-the-food-industry-how-far-have-we-come/.

Kline and Company. 2013. Professional Turf and Ornamental Markets for Pesticides and Fertilizers 2012. [Accessed June 2020.]

Kline and Company. 2015. Pest Control in Food-Handling Establishments 2014: U.S. Market Analysis and Opportunities. [Accessed April 2020.]

Kline and Company. 2016. Mosquito Control Markets 2015: U.S. Market Analysis and Opportunities. [Accessed April 2020.]

Kline and Company. 2017a. Industrial Vegetation Management of Pesticides and Fertilizers 2016: United States Market Analysis and Opportunities. [Accessed April 2020.]

Kline and Company. 2017b. Consumer Markets for Pesticides and Fertilizers 2016: U.S. Market Analysis and Opportunities. [Accessed April 2020.]

Layton, B. and J. Goddard. 2019. Control Cockroaches in and Around Your Home. Publication 3346 of Mississippi State University Extension. Available on the web at https://extension.msstate.edu/sites/default/files/publications/publications/P3346_web.pdf.

LSU. 2020. 2020 Louisiana Insect Pest Management Guide. An extension service publication from the Louisiana State University AgCenter. Available on the web at https://www.lsuagcenter.com/portals/communications/publications/management_guides/insect_guide/2016%20insect%20pest%20management%20guide%20%20complete%20book.

MacGown, J.A., R.L. Brown, J.G. Hill, and B. Layton. 2007. Carpenter Ants of Mississippi. Bulletin 1158 of the Mississippi Agricultural and Forestry Experiment Station, Mississippi State University. Available on the web at https://mississippientomologicalmuseum.org.msstate.edu/Researchtaxapages/Formicidaepages/ant.publications/Carpenter.Ant.Bulletin%20.pdf.

McCarty, B. (ed). 2020. 2020 Clemson University Pest Control Guidelines for Professional Turfgrass Managers. Available on the web at https://www.clemson.edu/extension/publications/index.html.

Miller, D.M. 2010. Subterranean Termite Treatment Options. Publication 444-500 of the Virginia Cooperative Extension Service. Available on the web at https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/444/444-500/444-500_pdf.pdf.

NCSU. 2020. 2020 North Carolina Agricultural Chemicals Manual, Chapter V: Insect Control. A publication of the College of Agriculture and Life Sciences of North Carolina State University. Available on the web at https://content.ces.ncsu.edu/north-carolina-agricultural-chemicals-manual.

NCDACS. 2020. North Carolina Department of Agriculture and Consumer Services Structural Pest Control Section: Termiticides Approved for Use in North Carolina. http://www.ncagr.gov/SPCAP/structural/Termiticide_List.html.

NMRD (Non-Agricultural Market Research Data). 2017. Proprietary studies conducted and sold by a consulting and research firm. Report on consumer pesticide usage. [Accessed April 2020.]
NPIRS. 2020. National Pesticide Information Retrieval System. A collaborative service provided by the EPA and Purdue University. Available on the web at http://npirs.ceris.purdue.edu/doc/fmenu.html.

Suiter, D. R. 2020. Household and Stored Products: Household and Structural Insect Control. Part of the University of Georgia Pest Management Handbook, University of Georgia Extension Special Bulletin 28. Available on the web at https://extension.uga.edu/content/dam/extension/programs-and-services/integrated-pest-management/documents/handbooks/2020-pmh-home-chapters/Household,%20Structural,%20and%20Stored%20Products.pdf.

Suiter, D.R. and M.E. Scharf. 2020. Insecticide Basics for the Pest Management Professional. University of Georgia Extension Publication Bulletin 1352. Available on the web at https://secure.caes.uga.edu/extension/publications/files/pdf/B%201352_3.PDF.

Sutherland A.M., Choe, D-H, Rust, M.K. 2019. UC IPM Pest Notes: Cockroaches. UC ANR Publication 7467. Oakland, CA. Available at www.ipm.ucanr.edu .

Tomberlin, J.K. and B. Drees. 2007. Poultry Pest Management. Publication E-445 of the Texas A&M University AgriLife Extension System. Available on the web at http://posc.tamu.edu/wp-content/uploads/sites/20/2012/08/b-10881.pdf.

Townsend, L. 2000. Face Flies and Pinkeye. Factsheet Ent-510 of the Cooperative Extension Service of the University of Kentucky. Available at https://entomology.ca.uky.edu/ef510#:~:text=In%20addition%20to%20being%20very,cornea%20and%20conjunctiva%20of%20cattle.

Townsend, L. 1996. Insecticide-Impregnated Cattle Ear Tags. Publication ENTFACT-505 of the University of Kentucky Cooperative Extension Service. Available on the web at https://entomology.ca.uky.edu/ef505.

UA. 2020. Insecticide Recommendations for Arkansas. Publication MP144 of the University of Arkansas System, Division of Agriculture Research and Extension. Available on the web at https://www.uaex.edu/publications/mp-144.aspx.

UCIPM. 2009. Integrated Pest Management In and Around the Home: Carpenter Ants. Pest Notes Publication 7416 of the University of California Statewide Integrated Pest Management Program Agriculture and Natural Resources. Available on the web at http://ipm.ucanr.edu/PDF/PESTNOTES/pncarpenterants.pdf.

UCIPM. 2019. Integrated Pest Management for Home Gardeners and Landscape Professionals: Cockroaches. Pest Notes Publication 7467 of the University of California Statewide Integrated Pest Management Program Agriculture and Natural Resources. Available on the web at Available on the web at http://ipm.ucanr.edu/PDF/PESTNOTES/pncockroaches.pdf.

USDA. 2016. United States Department of Agriculture Treatment Manual, second edition. Available on the web at https://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf.

USDA. 2018. United States Department of Agriculture. Map of Imported Fire Ant Federal Quarantine Area as of 17 April 2018. Accessed August 2020.

USDA. 2019. Imported Fire Ant Program Manual. Available on the web at https://www.aphis.usda.gov/import_export/plants/manuals/domestic/downloads/fire_ant.pdf.

Vail, K.M. and J. Chandler. 2020. 2020 Fire Ant Products for the General Public Sorted by Formulation, Product Name and Use Site. Publication W652 of the University of Tennessee

Agricultural Extension Service. Available on the web at https://extension.tennessee.edu/publications/Documents/W652.pdf.

Williams, R.E. 2010. Livestock and Poultry: Control of Cattle Pests. Purdue University Cooperative Extension Service Publication E-12-W. Available on the web at https://extension.entm.purdue.edu/publications/E-12.pdf.