OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

WASHINGTON, D.C. 20460

June 27, 2024

MEMORANDUM

SUBJECT: Mancozeb (PC# 014504) Registration Review: Assessment of Use, Usage, Benefits and Impacts of Potential Mitigation for Turf and Ornamental Plants

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PRODUCT REVIEW PANEL DATE: January 3, 2024

SUMMARY

Mancozeb is an ethylene bisdithiocarbamate multi-site protectant fungicide in the Fungicide Resistance Action Committee (FRAC) group M03. During the registration review process, the Environmental Protection Agency (EPA) identified human health (occupational handler and post-application) and ecological risks of concern associated with the use of mancozeb. To support the registration review decision, the Biological and Economic Analysis Division (BEAD) evaluates the benefits that mancozeb provides users in turf and ornamental use sites, presents potential alternatives to mancozeb, and discusses the impacts of potential mitigation measures to address potential risks of concern.

Mancozeb is used to control a broad spectrum of diseases in turf and ornamental plants. In turfgrass, particularly golf courses, mancozeb is important for disease management and fungicide resistance management in various diseases, including gray leaf spot, rapid blight, and leaf spot/melting out diseases. In ornamentals, including field-grown ornamentals such as Christmas trees, greenhouses, and landscapes, mancozeb is used to control fungal diseases on a variety of ornamental plants, including needle casts, leaf spots, and twig blights. These diseases can cause significant aesthetic damage to turf and ornamentals, including plant death, if not managed using fungicides such as mancozeb.

BEAD finds that mancozeb has moderate benefits in turfgrass and ornamental plant disease management. If unable to use mancozeb, the next best alternative would be other multisite fungicides, which are important for fungicide resistance management. In turf, the next best alternative would be chlorothalonil, and in ornamentals, the next best alternative could be chlorothalonil or captan, depending on what is registered for a specific use site and what is efficacious on mancozeb's target diseases. However, the Agency has proposed reductions to the annual rate for chlorothalonil, the market leading fungicide for golf course turf, sod, and ornamentals. If these reductions are implemented, it is unlikely that chlorothalonil could be used as a replacement for mancozeb, which would leave some use sites without an efficacious alternative multisite fungicide if mancozeb was unavailable. While single-site fungicides are recommended for mancozeb's target diseases, replacing a multi-site fungicide with a single-site fungicide would increase the risk of fungicide resistance development, which, if developed, would reduce the efficacy of single-site alternatives and worsen disease control. BEAD finds that mancozeb currently has moderate benefits in turfgrass and ornamentals, but its benefits could increase if chlorothalonil is restricted.

BEAD concludes that the potential mitigation measures will have impacts on users. The requirement of a respirator for mixers/loaders and mixer/loader/applicators will have moderate impacts on users from the cost of the respirator itself and the required annual fit test. Requiring an enclosed cab for applications in nurseries will have moderate impacts on applicators using mancozeb in nurseries from increased equipment or application costs. The cancellation of liquid and dry flowable formulations of mancozeb for applications via handgun and backpack sprayers in golf courses will have low to no impacts as applicators can switch to the wettable powder formulation of mancozeb. The cancellation of aerial applications in sod and the requirement of closed mixing/loading systems for the use of the liquid formulation in

chemigation in sod will have no impacts for most applicators as aerial and chemigation applications in sod are uncommon. Increases to the currently labeled REI of 24 hours could inhibit growers' ability to scout for insect and fungal pests in a reasonable amount of time as well as tagging and shearing/shaping trees during the growing season of the harvest year. The degree of impacts would correspond to the degree of REI increase, and a general REI beyond 7 days could make mancozeb applications infeasible for Christmas trees.

INTRODUCTION

The Federal Insecticide Fungicide and Rodenticide Act (FIFRA) Section 3(g) mandates that the Environmental Protection Agency (EPA or 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.

The Agency has identified occupational handler and post-application risks associated with the turf and ornamental uses of mancozeb. The occupational handler risks for mixer/loaders, applicators, and mixer/loader/applicators could potentially be mitigated by APF-10 respirators, prohibitions of certain formulations, additional engineering controls for certain application methods, or prohibitions of certain application methods. The post-application risks associated with the use of mancozeb on Christmas trees can be fully mitigated by increasing the restricted entry interval (REI) to 29 days.

Mancozeb is a multi-site fungicide that is registered for a variety of uses including use on turf and ornamental sites. In this document, the BEAD analyzes turf and ornamental uses of mancozeb, the benefits of mancozeb for those use sites, and impacts of potential mitigation. BEAD also assessed the usage and benefits of mancozeb on other agricultural and non-agricultural crops, including seed treatment uses, in separate memorandums. These memorandums are available in the mancozeb docket (EPA-HQ-OPP-2015-0291) at www.regulations.gov.

METHODOLOGY

This document assesses the benefits of the turf and ornamental uses of mancozeb and the impacts of potential mitigation measures to users in turf and ornamental use sites. The benefits of mancozeb are based on use site management practices, the chemical characteristics of mancozeb, and alternative control strategies, which influence how a user chooses to manage pests and to what extent mancozeb is important to the user.

BEAD reviews relevant information from product labels, including maximum allowable single application rate, limits to the number of applications per year, and restricted entry intervals. BEAD also evaluates available mancozeb usage data to identify use patterns, including pounds of active ingredient sold in market sectors covering registered use sites. BEAD reviews existing scientific publications to identify the important target pests and the attributes of mancozeb

that make it useful in the pest control system. Together, this information establishes where, when, and how applicators use mancozeb.

BEAD then evaluates the magnitude of benefits by assessing the biological and economic impacts that turf and ornamental producers might experience should they need to employ alternative pest control strategies in the absence of mancozeb. BEAD identifies the likely alternative control strategies by reviewing extension recommendations, stakeholder feedback, and considering economic factors. Impacts to a user using the next best alternative to mancozeb include monetary costs (e.g., from using more expensive chemicals) as well as loss of utility in resistance management, simplicity of use, flexibility, and/or integrated pest management (IPM) programs. There may also be impacts with respect to production loss, use site degradation, and/or quality reductions related to diminished pest control.

A similar approach is followed to assess the impacts of possible mitigations on the use of mancozeb to reduce risks. BEAD considers how the restrictions (e.g., increased restricted entry intervals [REIs]) would affect the ability of users to control pests or affect the costs of using mancozeb.

For this analysis, data are sourced from university extension services, the open literature, public comments on the mancozeb Draft Risk Assessment (DRA), public (USDA National Agricultural Statistics Service and California Department of Pesticide Regulation) and proprietary usage data (Kline and Co. and non-agricultural market research data), public comments submitted to the Agency from various stakeholders, and BEAD's professional knowledge. When available, robust pesticide usage data sources from the United States Department of Agriculture's National Agricultural Statistics Service (USDA NASS), California Department of Pesticide Regulation (CDPR), Kline and Company (Kline) and the Non-Agricultural Market Research Data (NMRD) form the foundation of BEAD's benefits analysis.

CHEMICAL CHARACTERISTICS

Mancozeb is an ethylene bisdithiocarbamate broad spectrum multisite protectant fungicide in the FRAC group M03 (FRAC, 2024). Mancozeb is a complex of two other dithiocarbamate fungicides, maneb and zineb, neither of which are registered outside of their combined molecule mancozeb. Mancozeb, as a multisite fungicide, works by deactivating multiple essential enzymes and amino acids in the cells of target pathogens. Due to these multiple pathways for inhibiting disease development, mancozeb, like other multisite fungicides, has a very low risk of resistance development (FRAC, 2010; FRAC, 2018). Multisite fungicides, including mancozeb, typically have a broad spectrum of activity, and mancozeb's broad spectrum of activity prevents diseases caused by bacteria, fungi, and oomycetes on seed and in the field.

USE/USAGE

Use

Mancozeb is registered for use on turf and ornamental plants. On turf sites, mancozeb is specifically registered for outdoor use on golf courses, sod farms, and non-residential lawns (this includes industrial and municipal lawns such as at office parks, schools, retail areas, and

recreational parks) (Table 1). Mancozeb is not registered for use on residential turf. For use on ornamental plants, mancozeb is broadly registered for use on both ornamentals used in outdoor landscaping (including residential ornamental landscaping) and ornamentals being produced in nurseries and greenhouses. Mancozeb is also registered for use on Christmas trees and Douglas fir trees. Mancozeb may be applied to registered turf, ornamental sites, and Christmas trees aerially, via chemigation (sprinkler/overhead irrigations), or by ground equipment. Mancozeb formulations for use on turf and ornamental use sites include dry flowables (water dispersible granules), flowable concentrates (liquid), and wettable powders.

Table 1. Maximum labeled use instructions for turf and ornamental uses of mancozeb.

Use Sites	Maximum Single Application Rate	Maximum Number of Annual Applications	Restricted Entry Interval (REI)
Turf	*See individual sites below*		
Non-residential lawns	17.4 lbs AI/A	4	NA
Golf course turf-cool season[1] greens, tees, and aprons	17.4 lbs AI/A	5	NA
Golf course turf-warm season[1] greens, tees, and aprons and cool season fairways	17.4 lbs AI/A	4	NA
Golf course turf-warm season[1] fairways	17.4 lbs AI/A	3	NA
Sod farms	17.4 lbs AI/A	4	24 hrs
Ornamentals	*See individual sites below*		
Douglas Fir and Christmas trees	3.2 lbs AI/A	*Not specified*	24 hrs
Commercial ornamental production	1.6 lbs AI/A	20	24 hrs
All other ornamental plants (landscaping, etc)	1.6 lbs AI/A	*Not specified*	NA

[1]Cool and warm season grasses are grass varieties categorized by characteristics of their growing and dormant seasons; warm season grasses are able to grow during warmer and drier conditions than cool season grasses.
NA: Not applicable; REI is not applicable to these use sites under the Agricultural Worker Protection Standard.

Usage

The Agency has limited usage information available for non-crop use sites. The Agency purchased 2021 turf and ornamental usage data, published by a non-agricultural market research firm, who surveyed various turf and ornamental sectors for usage information. In 2021, mancozeb was used throughout the US on golf courses, sod farms, within nurseries/greenhouses, by lawn care operators, and at institutional turf facilities (NMRD, 2022). Additionally, the USDA NASS and the CDPR publish publicly available horticultural usage information, both of which reported mancozeb usage, as outlined below.

Golf Courses

In a 2021 survey, approximately 260,000 lbs of mancozeb was reported to be used on golf courses (NMRD, 2022). In terms of pounds of mancozeb applied, golf courses were the highest usage market sector among surveyed turf and ornamental market sectors. However, in terms of acres treated, mancozeb was not a market leader among fungicides used on golf courses (NMRD, 2022). Information from the Mancozeb Task Force (MTF, 2021) indicates that golf course turf managers apply mancozeb by ground up to five times per year at 8.7 to 17.4 lbs AI/A.

Sod farms

Approximately 33,000 lbs of mancozeb was applied to turf sod farms in 2021 (NMRD, 2022). In terms of acres treated, mancozeb was not a market leader among fungicides used on sod farms (NMRD, 2022).

Lawns and Landscape Ornamentals

In 2021, mancozeb usage was reported by surveys targeting chemical use in the professional maintenance of lawns and landscaping (NMRD, 2022). Specifically, usage was reported on institutional turf (parks, cemeteries, schools, and colleges), by lawn care operators (defined as pesticide lawn and ornamental applicators for commercial, industrial, residential, and other non-residential properties), and by landscape contractors (management companies that generally design, plant, and care for flower beds and other landscaping). Approximately 175,000 pounds of mancozeb was reported across all of these surveyed market sectors (NMRD, 2022).

Production Ornamentals

From 2017 to 2022, floriculture and bedding crops, as well as nursery crops (both of which include ornamental plants) have increased their production of ornamental plants in acres grown in the open (USDA NASS, 2024). From 2017 to 2022, the production of floriculture and bedding crops have decreased under glass or other protection in terms of square feet grown, however, nursery crops have increased their area of production under protection (USDA NASS, 2024).

Nationally, low amounts of mancozeb in terms of pounds applied was reported to be used in the production of ornamentals within nurseries and greenhouses in 2021 (NMRD, 2022). This indicates a large decline in usage in the sector when compared to an analogous report from 2013 (Kline, 2014). Usage data from California, which represents approximately 12% of national horticultural acreage (second highest among states), corroborate a decline in usage (USDA NASS, 2019; CDPR, 2022a,b). In California, the annual average area treated between 2017-2021 represents almost a 40% decrease in pounds of mancozeb applied in nurseries and greenhouses compared to the previous five-year period (2012-2016) (CDPR, 2022a,b).

The majority of ornamental production in the US has been increasing in production area from 2017 to 2022 (USDA NASS, 2024). The increase in production area simultaneously corresponding with the decrease of mancozeb usage across data sources indicates that mancozeb is not widely utilized as a fungicide tool in ornamental production.

Christmas Trees

The Agency does not have usage information on mancozeb use in Christmas tree production. The absence of such data should not be interpreted as lack of usage.

Benefits of Mancozeb

Turfgrass

Mancozeb is registered for disease control in golf courses, sod farms, and non-residential lawns. Turf diseases cause aesthetic damage to turf and in golf courses and athletic fields can damage the quality of the playing surface, thereby reducing recreational value. There is a broad spectrum of common and damaging turfgrass diseases; consequently, broad spectrum fungicides such as mancozeb are important to control multiple diseases at once to preserve aesthetic quality of turf.

Information from the Mancozeb Task Force (MTF, 2021) indicates that mancozeb is applied both alone and with other fungicides as part of a tank mix. MTF states that mancozeb is applied by ground to golf course turf from one up to the maximum of five times per season.

Currently, chlorothalonil is the market leading fungicide, in terms of pounds of active ingredient applied (NMRD, 2022). Santiago et al. (2023) report that golf course managers apply chlorothalonil up to eight times per year at or near the maximum rate: i.e., some managers are already using the maximum annual rate for chlorothalonil. However, the Agency has proposed substantial reductions in the maximum allowable annual application rate for chlorothalonil use in turf, which would limit the number of applications annually to two to four applications at the maximum rate depending on the area to be treated (e.g., golf course greens, fairways, etc.). Santiago et al. (2023) find that, if this proposal is implemented, turf managers would likely increase the frequency of mancozeb applications to replace the lost chlorothalonil applications.

Target Pests

University extension guidelines for turfgrass disease management recommend mancozeb for a number of important fungal turfgrass diseases, including brown patch (*Rhizoctonia solani*), gray leaf spot (*Pyricularia grisea*), leaf spot/melting out (*Bipolaris* spp.; *Dreschlera* spp.), and rusts (*Puccinia* spp.) (Clarke et al., 2020; NCSU, 2019). Additionally, mancozeb is recommended for the emerging disease rapid blight (*Labyrinthula terrestris*) (APMC, 2021; GCSAA, 2021; Penn State, 2023).

Brown patch (*Rhizoctonia solani*) causes roughly circular yellow to brown patches on turf that range from a few inches to several feet in diameter (NCSU, 2019). Turf is most susceptible to brown patch infections during extended periods of hot, humid weather (NCSU, 2019; Clarke et al., 2020). All species and growth stages of turf are susceptible to brown patch, although resistant cultivars are available (NCSU, 2019; Clarke et al., 2020). The most important recommendation for management of brown patch is to avoid prolonged periods of leaf wetness. NCSU (2019) recommends irrigating less frequently during high disease pressure conditions, irrigating early in the morning (before sunrise) to speed drying of foliage after

sunrise, and aerating soil to improve drainage. Fungicides, including mancozeb, are recommended for the prevention and management of brown patch starting when night temperatures consistently exceed 60 degrees (NCSU, 2019; Clarke et al., 2020). Mancozeb is rated as good or moderate for brown patch control by Clarke et al. (2020) and NCSU (2019), respectively[1].

Gray leaf spot (*Pyricularia grisea*) causes foliar blighting that first occurs in patches from four to 12 inches in diameter that quickly coalesce to produce large, irregular areas of damaged turf (NCSU, 2019). Rapid blight is most severe during hot, humid summer months in newly established turf stands, particularly perennial ryegrass stands, but becomes less damaging as turf matures (Clarke et al., 2020; NCSU, 2019). Management options include planting resistant turf varieties, delaying seeding until temperatures are cool, moisture management, and fungicides. Turf managers are advised to mix highly effective fungicides with moderately effective contact fungicides like mancozeb or chlorothalonil and to rotate fungicide MOAs after every application, especially when applying high resistance risk fungicides (Clarke et al., 2020; NCSU, 2019). Mancozeb is rated as moderate or good for gray leaf spot control by Clarke et al. (2020) and NCSU (2019), respectively.

Leaf spot and melting out diseases, caused by *Bipolaris* and *Dreschlera* spp., are common turf diseases. Bluegrasses are most susceptible to these diseases during periods of warm and humid weather. Conversely, in bermudagrasses and ryegrasses, most damage occurs during cool and wet periods during the fall and spring (NCSU, 2019). These diseases initially cause leaf spots, which appear as small brown to black flecks on turf leaves and sheaths. As the disease progresses, lesions expand and the pathogen can rot the turf by colonizing the basal portions of the plant; this stage of the disease is referred to as melting out (NCSU, 2019). NCSU (2019) and Clarke et al. (2020) recommend planting resistant cultivars when available, with NCSU calling it one of the most effective and economical ways to manage leaf spot and melting out. These guidelines also recommend reducing turf stress to prevent these diseases, as they are most severe on turf that is growing slowly due to poor weather or poor management. NCSU (2019) and Clarke et al. (2020) recommend a number of fungicides, including mancozeb, for management of these diseases in susceptible turf on a preventive basis or early during the leaf spot phase of the disease. Mancozeb is rated as excellent for leaf spot and melting out control (Clarke et al., 2020; NCSU, 2019).

Rapid blight, caused by the protist *Labyrinthula terrestris,* is a relatively new turf disease that was first discovered in California in 1995 and has since spread to at least 11 states (Kerrigan et al., 2012; Penn State, 2023). Rapid blight affects cool-season grasses, such as bluegrasses, most ryegrasses, and wheatgrasses (Kerrigan et al., 2012; Penn State, 2023). Until *L. terrestris* was identified as a pathogen on turfgrass, *Labyrinthula* spp. had only been known to be associated with marine environments (Kerrigan et al., 2012). Rapid blight is most damaging in drought-prone areas with high soil salinity and is most prevalent in the Western part of the U.S. where golf courses are typically irrigated with reclaimed high-salt water (GCSAA, 2021; Kerrigan et al.,

[1] Clarke et al. (2020) and NCSU (2019) rate fungicide efficacy on a four-point scale. In this assessment, four out of four is referred to as “excellent” control, three out of four as “good” control, two out of four as “moderate” control, and one out of four as “poor” control.

2012). Recommended control measures include reducing irrigation water salinity, planting resistant varieties and using effective fungicides, such as mancozeb (Kerrigan et al., 2012; Penn State, 2023). Clarke et al. (2020) and NCSU (2019) do not make fungicide recommendations for rapid blight, but a comparative efficacy study done by the University of California-Riverside (UCR, 2012) finds that mancozeb applied alone "provided among the best rapid blight suppression when applications were made on a routine basis."

Rust (*Puccinia* spp.) causes yellow to orange pustules on turf that rupture and release orange clouds of spores when turf is disturbed (NCSU, 2019). Like for leaf spot and melting out diseases, extension guidelines note that rust is most severe in turf that is growing slowly from poor management or poor weather (NCSU, 2019; Clarke et al., 2020). In addition to improving turf management, guidelines recommend planting resistant turf varieties and, when necessary, fungicides such as mancozeb. Mancozeb is rated as good or moderate for rust by Clarke et al. (2020) and NCSU (2019), respectively.

Potential Alternatives

When evaluating alternatives to mancozeb, BEAD considers comparative efficacy, spectrum of disease control, and risk of pathogens to develop resistance to alternatives. The ideal alternative to mancozeb would effectively control all of mancozeb's target diseases with a low risk of fungicide resistance development.

Chlorothalonil is a multi-site fungicide, like mancozeb, that is recommended for all of mancozeb's target diseases and more, with comparable or superior efficacy to mancozeb (Clarke et al., 2020; NCSU, 2019). As explained above however, chlorothalonil may not be a viable alternative because growers cannot make additional applications and may, in fact, have to reduce the number of applications under the recent EPA mitigation proposal.

For brown patch and leaf spot/melting out diseases, there are numerous alternative fungicides with various modes of action providing equivalent or superior control compared to mancozeb, including the low-resistance risk fungicides fludioxonil (FRAC group 12) and fluazinam (FRAC group 29) (Table 2). FRAC (2019) makes qualitative rankings on the likelihood for a pathogen to develop resistance based on biological factors, experience, and resistance claims over the past 50 years. FRAC (2019) rates *Rhizoctonia solani*, the causal agent of brown patch, as having a low risk of resistance development, and does not rate leaf spot/melting out pathogens for resistance, indicating that these diseases are not of resistance concern. If unable to use mancozeb, turf managers could use recommended single-site fungicides, including effective low-risk fungicides, for control of these diseases with few or no impacts on disease management or resistance management.

Table 2: Fungal diseases for which mancozeb is recommended and alternative single-site fungicide MOAs.

Disease	Mancozeb (M03) Efficacy	MOAs offering comparable or superior efficacy							
		1	2	3	7	11	12	19	29
Brown Patch	3; ++		X	X	X	X	X	X	X
Leaf spot/melting out	3.5; ++++		X			X	X		X
Rust	3; ++			X		X			
Gray leaf spot	2; +++	X		X		X			

Efficacy ratings from Clarke et al. (2020) and NCSU (2019). Ratings are from 1 to 4 or + to ++++.

For rust, there are fewer recommended single site alternatives than in leaf spot/melting out and brown patch (Table 2). Demethylation inhibitors (DMIs; FRAC group 3, medium risk of resistance), including tebuconazole and propiconazole, and quinone outside inhibitors (QoIs; FRAC group 11, high risk of resistance), including azoxystrobin and pyraclostrobin, are comparably efficacious to mancozeb. While FRAC (2019) rates *Puccinia* spp., the causal agent of turfgrass rust, as having a low risk of resistance, the use of DMIs or QoIs as alternatives to mancozeb for rust control may spur fungicide resistance development in economically important diseases that can co-occur with rust. Fungicide resistance has been confirmed to DMIs in dollar spot and to QoIs in anthracnose, gray leaf spot, and Pythium blight. Additionally, tebuconazole, a DMI fungicide, is already a market leading fungicide in turf (NMRD, 2022); therefore, additional applications to replace mancozeb may not be allowed per the label or recommended per fungicide resistance management guidelines. If unable to use mancozeb for rust, turf managers could replace it with single-site fungicides with little impact on rust control; however, making more applications of medium and high resistance risk fungicides could lead to resistance development and consequent reductions or complications in disease control for other diseases.

Gray leaf spot (*Pyricularia grisea*) has a high risk of fungicide resistance development with a limited number of effective controls (Table 2; FRAC, 2019). Single-site fungicides that control gray leaf spot comparable to mancozeb are the DMIs, the QoIs, and thiophanate-methyl (FRAC group 1, high risk of resistance) (Table 2). The most effective fungicides for gray leaf spot, thiophanate-methyl (FRAC group 1) and QoIs, are also at the highest risk of resistance development (Clarke et al., 2020; KSU, 2023). Resistance to QoIs, in addition to various fungicides not registered for turf, have been documented in gray leaf spot populations (Clarke et al., 2020; FRAC, 2020). KSU (2023) claims that azoxystrobin (QoI) resistance has been documented in gray leaf spot populations in many states; in these areas, QoIs would not be viable alternatives to mancozeb for gray leaf spot control. Thiophanate-methyl resistance has been found in many diseases in many use sites; in turf, this includes anthracnose and dollar spot (Clarke et al., 2023). While thiophanate-methyl resistance has not yet been detected in gray leaf spot populations, it is considered a high-risk fungicide and resistance management measures are necessary (FRAC, 2020; KSU, 2023). If turf managers could not use mancozeb, they would need to replace it with single-site fungicides to control gray leaf spot. This would increase the risk of fungicide resistance both in gray leaf spot and in other diseases, which, if developed, would impede control of these diseases and further limit the available effective control options.

For rapid blight (*Labyrinthula terrestris*), Kerrigan et al. (2012), Penn State (2023) and UCR (2012) report that the most effective chemical control is pyraclostrobin (FRAC 11) mixed or alternated with mancozeb. A 2012 comparative efficacy trial done by UCR found that mancozeb applied alone and with other fungicides provided among the best rapid blight suppression when applications were made on a routine basis" compared to single-site fungicides in the FRAC groups 3, 7, 11, 29, and chlorothalonil. However, subsequent efficacy trials find that mancozeb alone may not provide sufficient control, especially under high disease pressure. UCR (2014) finds that mancozeb tank-mixed with single-site fungicides is effective for rapid blight but notes that mancozeb alone was not effective. UCR (2019) finds that mancozeb and many single-site fungicides in the FRAC groups 3, 7, and 11 do not provide significantly different control from the untreated control, instead finding that only potassium phosphite (FRAC P07) and mixtures containing potassium phosphite significantly reduce disease cover and turfgrass cover loss from rapid blight better than the untreated control. Potassium phosphite was not tested in previous efficacy trials (UCR, 2012; UCR, 2014). Potassium phosphite has a low risk of fungicide resistance development (FRAC, 2024). While it is not currently labeled for rapid blight, potassium phosphite could be a good alternative to mancozeb for effective rapid blight control. *Labyrinthula terrestris* is a protist, so broad spectrum fungicides like mancozeb and pesticides such as potassium phosphite, which are recommended for other protist diseases (e.g., *Phytophthora*, downy mildew) are more effective than fungicides, such as DMIs, which are effective only on true fungi. On the other hand, potassium phosphite alone is not generally recommended for fungal diseases and would only be a one-to-one replacement for mancozeb for rapid blight with little to no control of mancozeb's other target diseases.

Benefits of mancozeb in turf

If unable to use mancozeb, the next best alternative would be chlorothalonil for most diseases and potassium phosphite for rapid blight. Chlorothalonil, however, while highly effective on most of mancozeb's target diseases with no documented fungicide resistance, may not be a viable alternative to mancozeb. If the annual rate reductions proposed by the Agency are implemented, or if turf managers are already applying the maximum amount of chlorothalonil, then chlorothalonil would not be a viable alternative to mancozeb.

If chlorothalonil was restricted and turf managers could not use mancozeb, they would need to mix and alternate different single-site fungicides as recommended by FRAC (2010) and extension guidelines (Clarke et al., 2020) to minimize the risk of fungicide resistance. If recommended single-site fungicide alternatives have a medium or high risk of resistance, this could increase the likelihood of resistance development both in mancozeb's target diseases and in co-occurring diseases compared to having effective multisite and low resistance risk fungicides for disease management.

Mancozeb is a broad-spectrum fungicide recommended for a variety of turf diseases. In addition to its efficacy in managing its target diseases, mancozeb is important for resistance management, especially gray leaf spot, for which there are few alternative MOAs and documented resistance issues. While current mancozeb usage is relatively low, the proposed restrictions to chlorothalonil, if implemented, may cause mancozeb's usage to increase as it has been identified as a likely alternative to chlorothalonil for several diseases (Santiago et al.,

2023). BEAD finds that mancozeb currently has moderate benefits in turf, but if chlorothalonil is restricted, the benefits of mancozeb would be high.

Ornamentals

Mancozeb is recommended for a number of diseases in ornamentals used in outdoor landscaping, ornamentals produced in nurseries and greenhouses, field-grown ornamentals, conifers, and Christmas trees. Just as there is a broad variety of ornamental plants, there is a broad spectrum of common and damaging ornamental diseases; consequently, broad spectrum fungicides such as mancozeb are important to control multiple diseases at once to preserve the aesthetic quality and value of ornamental plants.

Target Pests and Potential Alternatives

In the Southeastern U.S. Pest Control Guide for Nursery Crops and Landscape Plantings (SNIPM, 2017), which presents the efficacy of different fungicides for ornamental plants and trees in greenhouses, nurseries and landscapes, recommends mancozeb for many fungal diseases including Botrytis blight, cedar rusts, fungal stem cankers, fungal leaf spots, and Passalora needle blight. These recommendations are consistent with other ornamental disease management recommendations, including UMass (2014) and MSU (2023), which make recommendations specific to woody ornamentals and conifers, respectively. These extension publications recommend mancozeb, among other fungicides, for a large number of fungal diseases of trees, including needle blights, needlecasts, rusts, and cankers.

Mancozeb is not typically recommended for non-fungal diseases in ornamental production. SNIPM (2017) rates mancozeb as “fair” on downy mildew and rates the registered oomycete-specific fungicides, of which there are many, as “good”. UMass (2014) and MSU (2023) do not make recommendations for downy mildew diseases and do not recommend mancozeb for *Phytophthora* spp., the predominant oomycete pests on woody plants. SNIPM (2017) rates mancozeb as “fair to good” on bacterial leaf spots and blights but does not recommend it alone for these diseases nor for the bacterial disease fire blight, only premixed with copper. MSU (2023) does not make bacterial disease recommendations, but UMass (2014) recommends mancozeb, alongside copper, phosphorus fungicides, fosetyl-Al, and streptomycin sulfate for fire blight and Pseudomonas blight.

If unable to use mancozeb, the ideal alternative would be another multisite fungicide. Multisite fungicides in ornamentals include chlorothalonil, captan, and coppers; however, these fungicides may not be registered for all ornamental plants or be effective on mancozeb’s target disease(s). In MSU (2023), diseases for which mancozeb is the only recommended multisite fungicide include Diplodia shoot blight and canker, gall rust, and Phomopsis twig blight and canker. NCSU (2017) recommends mancozeb as the only multisite fungicide for Phomopsis tip blight. Conversely, UMass (2014) recommends coppers and chlorothalonil for Diplodia and Phomopsis diseases in addition to mancozeb. Mancozeb is the only multisite recommended by UMass (2014) for Sirococcus dieback, Fusarium canker, various anthracnose diseases of trees, and Guignardia leaf spot. While most diseases also have recommended single-site fungicide controls, mancozeb is the only recommended fungicide for isthmiella needlecast (MSU, 2023), peach leaf curl, and Marssonina leaf spot (UMass, 2014). While recommendations may differ

from one another, these differences could be based on host plants or geographic region, which influence pest spectra and pressure.

Benefits of Mancozeb in Ornamentals

If unable to use mancozeb, ornamental producers and landscape managers who currently use mancozeb would need to switch to an alternative fungicide if one is available for the target disease(s). As in turf, the best general replacement fungicides would be other broad spectrum multisite fungicides efficacious on mancozeb's target diseases; in ornamentals, these would be copper, chlorothalonil, or captan. These alternatives may be inviable as alternatives due to limited applications, use site limitations, or efficacy. As in turf, chlorothalonil, one of the best potential alternatives, may not be a viable alternative in the absence of mancozeb in field-grown ornamentals as the Agency has proposed substantial annual rate reductions for chlorothalonil applications, which would limit the number of applications annually.

If unable to use mancozeb and alternate multi-site fungicides, such as copper, chlorothalonil, or captan, could not be used as alternatives, landscape managers and ornamental producers would need to mix and alternate different single-site fungicides as recommended by FRAC (2010) and extension guidelines. If recommended single-site fungicides have a medium or high risk of resistance, this could increase the likelihood of resistance compared to having effective multisite and low resistance risk fungicides for disease management; however, this strategy would best facilitate continued effective disease management. If unable to control disease with available alternatives, ornamentals would suffer aesthetic damage and potential losses from uncontrolled disease, which could reduce marketability and yield in ornamental production. While mancozeb's usage in ornamentals is declining, there could be scenarios where mancozeb is still critically important, such as in the diseases listed above where alternative options are limited. As in turf, BEAD finds that mancozeb currently has moderate benefits in ornamentals, but benefits could increase if chlorothalonil is restricted.

IMPACTS OF POTENTIAL MITIGATION

The Agency has completed the preliminary human health and ecological risk assessments for mancozeb and identified potential occupational handler risks of concern associated with mancozeb use in turf and ornamental sites. To reduce occupational handler risks from the use of mancozeb, the Agency uses a hierarchy of mitigation measures with increasing amounts of exposure reduction. Depending on the magnitude of the exposure, risks may be fully mitigated with personal protective equipment (e.g., respirators, gloves). If personal protective equipment does not fully mitigate the exposure risk, then engineering controls (e.g., closed systems, closed cabs) are necessary. If risks cannot be fully mitigated with engineering controls, then a prohibition of the formulation and/or application method is necessary.

Mancozeb may be applied to registered turf, ornamental sites, and Christmas trees aerially, via chemigation (sprinkler/overhead irrigations), or by ground equipment. Mancozeb formulations for use on turf and ornamental use sites include dry flowables, liquids, and wettable powders. Not all combinations of formulation and application equipment require additional mitigation.

EPA identified the following occupational handler risks of concern associated with turf and ornamental uses of mancozeb:

1. Occupational handler risks for mixer/loaders using dry flowable formulations via chemigation or groundboom or aerial applications and for mixer/loader/applicators using any formulation via mechanically pressurized handguns.
2. Occupational handler risks for mixer/loaders using the liquid formulation via chemigation in sod.
3. Occupational handler risks for applicators associated with airblast applications of all formulations in nurseries.
4. Occupational handler risks for applicators associated with liquid and dry flowable formulations in handgun or backpack sprayer applications in golf courses.
5. Occupational handler risks associated with aerial applications to sod.
6. Post-application risks associated with handset irrigation and hand harvesting Christmas Trees after mancozeb applications.

To mitigate these risks, EPA is considering the following:

1. Requiring APF-10 respirators for mixer/loaders using dry flowable formulations and for mixer/loader/applicators using any formulation via mechanically pressurized handguns.
2. Requiring closed mixing/loading systems for liquid formulation of mancozeb applied via chemigation in sod.
3. Requiring enclosed cabs for airblast applications in nurseries.
4. Cancellation of dry flowable and liquid formulations for handgun or backpack sprayers in golf courses.
5. Cancellation of aerial applications to sod.
6. Increase in restricted entry intervals for Christmas Trees.

Require an APF-10 Respirator.
To reduce risks to mixers, loaders, and applicators, the Agency is considering requiring an APF-10 respirator for mixer/loaders using dry flowable formulations and for mixer/loader/applicators using any formulation via mechanically pressurized handguns.

The Agency anticipates moderate negative impacts to mancozeb users by requiring an APF-10 respirator for mixers, loaders, and applicators. Respirator costs are extremely variable depending upon the protection level desired, disposability, comfort, and the kinds of vapors and particulates being filtered. Assigned Protection Factor 10 (APF-10) respirators include N95 masks which are readily available. Under the Worker Protection Standard, users of respirators are also required to have a fit test done annually; in 2024, EPA estimated the procedure to cost about $350 (Smearman and Berwald 2024). In addition to potential monetary costs of respirators, the use of a respirator can reduce productivity of workers wearing a respirator, which could increase the time required to mix and load tanks and apply mancozeb, which could increase costs. Alternatively, pesticide users could hire a commercial applicator at an additional cost. For application methods other than mechanically pressurized handguns, users can switch to an alternative formulation of mancozeb that does not require the use of an APF-10 respirator.

Require Closed Loading for Liquid Formulations via Chemigation in Sod.
EPA is considering the requirement of a closed loading system for applications using the liquid formulation of mancozeb via chemigation equipment in sod. Chemigation is not a typical application method for fungicide applications in sod (TPI, 2021). Additionally, producers could instead use the liquid formulation of mancozeb with an APF-10 respirator or the wettable powder formulation of mancozeb with no additional mitigation measures.

Require an Enclosed Cab for Airblast Applications in Nurseries.
EPA is considering the requirement of an enclosed cab for airblast applications of mancozeb in nurseries. Applicators who do not already have the appropriate equipment would either have to purchase the equipment, retrofit their current machinery, hire a commercial firm with the equipment to make mancozeb applications, or use an alternative fungicide. All of these options increase the cost of using mancozeb except for use of an alternative fungicide.

Cancellation of Liquid and Dry Flowable Formulations for Handgun and Backpack Sprayers.
To reduce risks to applicators, the Agency is considering cancellation of liquid and dry flowable formulations of mancozeb for applications via handgun and backpack sprayers in golf courses. To continue using handgun or backpack sprayers, applicators will need to switch to the wettable powder formulation of mancozeb. Based on stakeholder outreach, some users are already using the wettable powder formulation for this application method (NALP, 2022). Since a formulation of mancozeb is still available for use with this application method, the Agency anticipates few impacts from this mitigation.

Cancellation of Aerial Applications in Sod.
To reduce risks to applicators, the Agency is considering cancellation of all formulations of mancozeb for applications via aerial equipment in sod. Stakeholder outreach has indicated that aerial applications to sod are uncommon, so this mitigation measure should have no impact for most users (TPI, 2021), but applicators currently using aerial application methods will need to switch to an alternative fungicide that can be applied aerially since aerial applications are generally made when use of ground equipment is impractical. Increased use of alternative fungicides may increase the risk of resistance, especially if use of chlorothalonil is constrained by the proposed annual rate reductions.

Increase in Restricted Entry Intervals for Christmas Trees.
To reduce post-application risks to workers, the Agency is considering an increase in the restricted entry intervals (REIs) for Christmas trees. Fungicide application timing may vary depending on the target disease. In Christmas trees, MSU (2023) recommends that producers apply fungicides, including mancozeb, for brown spot needle blight and Swiss needlecast from spring to early summer to coincide with needle elongation. MSU (2023) recommends treating for lophodermium needle cast, another common disease for which mancozeb is recommended, from the end of July through late September to coincide with spore release. MSU (2023) advises that fungicide applications around August 1 and again September 1 are usually sufficient for most plantations for control of important Christmas tree diseases (MSU, 2023). Increasing the REI for all activities occurring in Christmas tree production would have high impacts. Increases to the currently labeled REI of 24 hours could inhibit growers' ability to scout for insect and fungal pests in a reasonable amount of time as well as tagging and

shearing/shaping trees during the growing season of the harvest year. The degree of impacts would correspond to the degree of REI increase, and a general REI beyond seven days could make mancozeb applications infeasible for Christmas trees.

CONCLUSION

BEAD finds that mancozeb has moderate benefits in turfgrass and ornamental plant disease management. Mancozeb is used to control a broad spectrum of diseases in turf and ornamental plants. In turfgrass, particularly golf courses, mancozeb is important for disease management and fungicide resistance management in various diseases, including gray leaf spot, rapid blight, and leaf spot/melting out diseases. In ornamentals, including field-grown ornamentals such as Christmas trees, greenhouses, and landscapes, mancozeb is used to control fungal diseases on a variety of ornamental plants, including needle casts, leaf spots, and twig blights.

If unable to use mancozeb, the next best alternative would be other multisite fungicides, which are important for fungicide resistance management. In turf, the next best alternative would be chlorothalonil, and in ornamentals, the next best alternative could be chlorothalonil or captan, depending on what is registered for a specific use site and what is efficacious on mancozeb's target diseases. However, the Agency has proposed reductions to the annual rate for chlorothalonil, the market leading fungicide for golf course turf, sod, and ornamentals. If these reductions are implemented, it is unlikely that chlorothalonil could be used as a replacement for mancozeb, which would leave some use sites without an efficacious alternative multisite fungicide if mancozeb was unavailable. While single-site fungicides are recommended for mancozeb's target diseases, replacing a multi-site fungicide with a single-site fungicide would increase the risk of fungicide resistance development, which would reduce the efficacy of single-site alternatives and worsen disease control. BEAD finds that mancozeb currently has moderate benefits in turfgrass and ornamentals, but its benefits could increase if chlorothalonil is restricted.

BEAD concludes that the potential mitigation measures will have impacts on users. The requirement of a respirator for mixers/loaders and mixer/loader/applicators will have moderate impacts on users from the cost of the respirator itself and the required annual fit test. Requiring an enclosed cab for applications in nurseries will have moderate impacts on applicators using mancozeb in nurseries from increased equipment or application costs. The cancellation of liquid and dry flowable formulations of mancozeb for applications via handgun and backpack sprayers in golf courses will have low to no impacts as applicators can switch to the wettable powder formulation of mancozeb. The cancellation of aerial applications in sod and the requirement of closed mixing/loading systems for the use of the liquid formulation in chemigation in sod will have no impacts for most applicators as aerial and chemigation applications in sod are uncommon. Increases to the currently labeled REI of 24 hours could inhibit growers' ability to scout for insect and fungal pests in a reasonable amount of time as well as tagging and shearing/shaping trees during the growing season of the harvest year. The degree of impacts would correspond to the degree of REI increase, and a general REI beyond 7 days could make mancozeb applications infeasible for Christmas trees.

REFERENCES

APMC. 2021. Comment submitted by Arizona Pest Management Center at University of Arizona (UA) regarding the Mancozeb human health risk assessment and the draft ecological risk assessment. Available online: https://www.regulations.gov/comment/EPA-HQ-OPP-2015-0291-0071

California Department of Pesticide Regulation (CDPR). 2022a. California Pesticide Information Portal (CalPIP). Database Subset: 2017-2021. Available at: https://www.cdpr.ca.gov/index.htm [Accessed November 2023].

California Department of Pesticide Regulation (CDPR). 2022b. California Pesticide Information Portal (CalPIP). Database Subset: 2012-2016. Available at: https://www.cdpr.ca.gov/index.htm [Accessed November 2023].

Clarke BB, Vincelli P, Koch P, Munshaw G. 2020. Chemical Control for Turfgrass Diseases 2020. Available at: http://www2.ca.uky.edu/agcomm/pubs/PPA/PPA1/PPA1.pdf.

FRAC (Fungicide Resistance Action Committee). 2010. FRAC recommendations for fungicide mixtures designed to delay resistance evolution. Accessed at https://www.frac.info/docs/default-source/publications/frac-recommendations-for-fungicide-mixtures/frac-recommendations-for-fungicide-mixtures---january-2010.pdf

FRAC. 2018. Importance of multisite fungicides in managing pathogen resistance. https://www.frac.info/docs/default-source/publications/statement-on-multisite-fungicides/frac-statement-on-multisite-fungicides-2018.pdf

FRAC. 2019. Pathogen Risk List. https://www.frac.info/docs/default-source/publications/pathogen-risk/frac-pathogen-list-2019.pdf

FRAC. 2020. List of first confirmed cases of plant pathogenic organisms resistant to disease control agents. https://www.frac.info/docs/default-source/publications/list-of-resistant-plant-pathogens/list-of-first-confirmed-cases-of-plant-pathogenic-organisms-resistant-to-disease-control-agents_05_2020.pdf

FRAC. 2024. Fungicide Resistance Action Committee (FRAC)–- FRAC Code List 2024. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2024.pdf

GCSAA. 2021. Comment submitted by Golf Course Superintendents Association of America (GCSAA) regarding the Mancozeb human health risk assessment and the draft ecological risk assessment. https://www.regulations.gov/comment/EPA-HQ-OPP-2015-0291-0078.

Kline and Company. 2014. Professional Turf and Ornamental Markets for Pesticides and Fertilizers 2013: U.S. Market Analysis and Opportunities. [Accessed December 2023].

Kerrigan, J.L., Olsen, M.W., Martin, S.B. 2012. Rapid Blight of Turfgrass. The Plant Health Instructor. https://www.apsnet.org/edcenter/disandpath/fungalorg/pdlessons/Pages/RapidBlight.aspx

KSU (Kansas State University). 2023. Gray leaf spot – Pyricularia grisea. https://hnr.k-state.edu/extension/horticulture-resource-center/common-pest-problems/documents/Gray%20Leaf%20Spot%20on%20Perennial%20Ryegrass.pdf

MSU. 2023. Michigan Christmas Tree Pest Management Guide. Michigan State University (MSU). Accessed at: https://www.canr.msu.edu/christmas_trees/uploads/files/Michigan%20Christmas%20Tree%20Pest%20Management%20Guide%202023.pdf

NCSU (North Carolina State University). 2019. NC State Extension Publications: TurfFiles – Diseases. Butler, L., Kerns, J. Accessed at: https://www.turffiles.ncsu.edu/diseases-in-turf/

National Association of Landscape Professionals (NALP). 2022. Mancozeb – Landscape Uses Survey Responses.

Nonagricultural Market Research Data (NMRD). 2022. Study of turf and ornamental usage in 2021. [Accessed May 2023].

MTF (Mancozeb Task Force). 2021. Mancozeb Task Force responses to EPA Questions regarding Turf Golf Courses Potato Seed Treatment and Rice Seed Treatment. Available in the mancozeb docket.

Penn State (Pennsylvania State University). 2023. Rapid Blight. Penn State Turf Pest Diagnostic Laboratory. https://turfpestlab.psu.edu/pest-profiles/rapid-blight/

Santiago S, Hendrick L, Post J. 2023. Chlorothalonil (PC Code 081901) Usage, Pest Management Benefits, and Impacts of Potential Mitigation for Turfgrass and Ornamentals. September 14, 2023. https://www.regulations.gov/document/EPA-HQ-OPP-2011-0840-0147.

Smearman, S. and D. Berwald. 2024. Cost Estimates for Requiring Respirators. Biological and Economic and Analysis Division, Office of Pesticide Programs, Environmental Protection Agency. January 24, 9 pp. Available upon request.

Southeastern U.S. Pest Control Guide for Nursery Crops and Landscape Plantings. Southern Nursery IPM Working Group (SNIPM). 2017. Accessed at https://content.ces.ncsu.edu/southeastern-us-pest-control-guide-for-nursery-crops-and-landscape-plantings/

Turfgrass Producers International (TPI). 2021. Responses to EPA's Inquiry for Turfgrass Producers International Regarding Mancozeb Usage, Application Methods, and Alternatives

for Sod. Provided from Casey Reynolds, Executive Director, TPI to Murphey Coy on October 1, 2021.

University of California Riverside (UCR). 2012. Management of Rapid Blight Disease on Putting Greens in Southern California. https://turfgrass.ucr.edu/sites/default/files/2023-08/rapid-blight-2012-ucr-2.pdf

UCR. 2014. Evaluation of Fungicides for Control of Rapid Blight Disease on Putting Greens. https://gcsanc.com/wp-content/uploads/2016/12/Rapid_Blight_2014_revised.pdf

UCR. 2019. Management of Salinity and Rapid Blight Disease on Annual Bluegrass Putting Greens 2019 Report. UCR Turfgrass Science. Petelewicz, P., Glegola, S., Gomez, B., Baird, J. https://turfgrass.ucr.edu/sites/default/files/2023-04/2019_salinity_final.pdf

University of Massachusetts (UMass). 2014. UMass Extension's Professional Management Guide for Diseases of Trees and Shrubs. Brazee, N.J. UMass Extension Landscape, Nursery and Urban Forestry Program. https://ag.umass.edu/landscape/publications-resources/diseaseguide

United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). 2019 Census of Horticultural Specialties. Complete data available at https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Census_of_Horticultural_Specialties/index.php

USDA National Agricultural Statistics Service (USDA NASS). 2024. 2022 Census of Agriculture. Available at: www.nass.usda.gov/AgCensus. Accessed June 2024.