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

June 28, 2024

MEMORANDUM

SUBJECT: Mancozeb (PC Code # 014504) Registration Review: Assessment of Use, Usage, Benefits, and Impacts of Potential Mitigation in Various Vegetable Crops — Lettuce, Onions, Garlic, Broccoli, Cabbage, and Asparagus

FROM: LisaRenee English, Ph. D., Biologist
Biological Analysis Branch

Charmaine Hanson, Economist
Economic Analysis Branch

Rachel Fovargue, Biologist
Science Information and Analysis Branch
Biological and Economic Analysis Division (7503M)

THRU: Monisha Kaul, Chief
Biological Analysis Branch

T J Wyatt, Chief
Economic Analysis Branch

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

TO: Ben Tweed, Chemical Review Manager
Jordan Page, Senior Regulatory Advisor
Risk Management and Implementation Branch III
Pesticide Reevaluation Division (7508M)

BEAD PRODUCT REVIEW PANEL DATE: 04/10/2024

SUMMARY

Mancozeb is a broad-spectrum multisite fungicide registered for agricultural and non-agricultural uses. This memorandum describes the use, usage, benefits, alternatives, and impacts from potential mitigation for mancozeb in various vegetables including lettuce, broccoli, cauliflower, cabbage, onions, garlic, and asparagus. Mancozeb is used to prevent several diseases resulting from fungal, oomycetes, and bacterial infections. Specifically, downy mildew, purple blotch, Alternaria leaf spot, and Cercospora leaf spot are known to affect the vegetable crops of interest in this memo and can be controlled with mancozeb.

The benefits of mancozeb in lettuce, onion, and garlic production are high because of the limited number of multisite alternatives that could provide the same efficacy as mancozeb and the subsequent yield loss that is likely to occur if mancozeb were replaced. Also, the production cost per acre would increase if growers were to switch to many of the recommended single site fungicides in these crops. In broccoli and cabbage production, the benefits of mancozeb are considered low due to the availability of a more efficacious multisite fungicide for the same target pest. However, if growers were to replace mancozeb with the recommended single site fungicides, they would have to do so at an increased cost per acre due to the cost different between mancozeb and the single site fungicides. Finally, the benefits of mancozeb use in asparagus are determined to be low because there are multisite alternatives available and mancozeb is not commonly used.

However, chlorothalonil, the primary multi-site rotational partner to mancozeb in these crops, is currently undergoing registration review and there are proposed maximum annual rate reductions for all crops featured in this memo, except for lettuce. In circumstances where the proposed rate reduction may result in a reduced number of applications the importance and benefits of mancozeb may increase.

EPA has identified occupational human health risks of concern from use of mancozeb in vegetable crops. To reduce these risks, the Agency is considering risk mitigation measures such as increasing crop-specific restricted entry intervals (REI) to protect workers entering a treated field. For pesticide applicators, the Agency may require an Assigned Protection Factor 10 (APF10) respirator and use of double layer clothing for foliar applications of mancozeb. For workers mixing and loading pesticides, the requirement of a closed loading system is being considered when utilizing dry flowable and wettable powder formulations for use in aerial and chemigation applications. A closed loading system may entail the requirement that these formulations come in closed packaging that can be inserted into water in a pesticide delivery system and mixed with the container closed.

The impacts of these potential mitigations are described below.

- REIs of greater than five days in onion and garlic would likely have high impacts due to the need to scout every three to five days. This impediment would likely result in growers using a fungicide that is less efficacious (with possible resulting yield loss) that has less of an REI restriction.

- Similarly, a three- to four-day REI for mancozeb use in broccoli and cabbage would likely interfere with scouting but the benefits in these crops are considered low, thus the impacts of an increased REI may also be low. However, for those growers that do use mancozeb, they would likely switch to an alternative fungicide without this restriction, but yield loss would not be expected due to availability of more efficacious alternatives.
- The cost of an APF10 respirator and the associated fit test cost may have an economic impact on growers that do not already use this type of respirator. Wearing a respirator and double layer clothing could result in heat stress during times of high temperatures and/or humidity; applicators would need to take more frequent breaks which would prolong the time needed for applications.
- Requiring a closed loading system will increase packaging costs and may also require that applicators utilize equipment that can agitate/ mix while the system is closed. Costs of mancozeb use will therefore increase if this requirement were to apply. While growers could opt to switch to utilizing a liquid formulation, liquid formulations are more expensive.

Additionally, EPA has identified bystander and ecological risks of concern from use of mancozeb in vegetable crops. To reduce these risks, the Agency may consider mitigation designed to lessen the likelihood of pesticide drift, this mitigation could include restrictions on windspeed, droplet size, applications during wet weather, application buffers, and groundboom height. Mitigation to reduce bystander exposure, as described above, is considered sufficient to address most ecological risks. However additional mitigation may be needed to further reduce ecological risks, including the addition of a buffer requirement to protect water bodies and mandatory use of Bulletins Live! Two to protect non-target species.

The impacts of these potential mitigations are described below.

- Restrictions that require a medium to courser droplet size, disallowance of applications during periods of rain, and a 3-foot groundboom height are seen as best production practices for these crop sites, so there should be little to no impact to growers that use mancozeb in vegetable production as described in this memo.
- A 10-mph wind speed maximum may prevent the timely application of mancozeb, potentially resulting in impacts to growers if alternative fungicides cannot be used to effectively manage diseases in these crops.
- A requirement for spray buffers may require that growers treat the buffer portion of the field with an alternative fungicide that does not have this requirement or leave the field untreated. In either scenario, growers are likely to have costs associated with a second application of an alternative fungicide or suffer yield losses in the untreated buffer area. The overall effect will vary depending on the size of the field affected.
- Requiring that growers obtain and follow additional mitigations in Bulletins Live! Two ahead of pesticide applications is a relatively new process. Therefore, users may face a learning curve when becoming acquainted with the system. Moreover, growers may be subject to additional and potentially more stringent mitigation measures than those described in this memo which can require significant planning and may be costly to implement and maintain, or even preclude the use of mancozeb.

Also, EPA may require mitigation to reduce run-off that requires growers to adopt one or more strategies from a list of EPA approved strategies.

- These strategies may have an economic impact, dependent on which strategy is adopted, as some measures can be quite costly. However, some growers may already be employing one or more strategy to reduce erosion and/or increase water retention.

INTRODUCTION

Mancozeb is a broad-spectrum protectant fungicide registered for use on agricultural and non-agricultural sites. The Federal Insecticide Fungicide and Rodenticide Act (FIFRA) mandates that the Environmental Protection Agency (EPA or the Agency) review the registrations of all pesticides periodically to ensure that their application does not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary to consider scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects of pesticide use are unreasonable, FIFRA requires that the Agency consider the risks and benefits associated with pesticide use, and possible methods of risk mitigations. The Federal Food, Drug, and Cosmetic Act also mandates that the Agency consider any potential risks from the consumption of pesticide residue in food products as part of the registration determination process.

Associated with use of mancozeb in vegetable crops, the Agency has identified human health risks due to occupational exposure (i.e., handler and post application) and ecological risks to several taxa (e.g., birds, mammals). To address human health risks, the Agency is considering crop specific increased reentry intervals and requiring the use of an APF10 respirator. To address ecological risks, the Agency is considering application restrictions on windspeed, droplet size, and boom height allowances. Mitigation to protect non-target organisms focus on reducing runoff, inclusive are restrictions that prevent applications within 48 hours of expected rain, application buffer requirements, and adoption of an EPA approved land modification strategy. Users of mancozeb will also be required to use the EPA database, Bulletins Live! Two, which identifies pesticide use limitation areas (PULAs) within six months of a mancozeb application.

The purpose of this memorandum is to analyze information on the use and usage of mancozeb, assess the benefits of its foliar use and the potential impacts of mitigation in the production of various vegetable crops including lettuce, onions, garlic, cabbage, broccoli, and asparagus production. A separate memorandum presents an assessment of mancozeb on seed treatment uses. BEAD also assessed the usage and benefits of mancozeb on other agricultural crops and non-agricultural sites in separate memorandums. These memorandums are available in the mancozeb docket (EPA-HQ-OPP-2015-0291) at www.regulations.gov.

METHODOLOGY

BEAD defines the benefit of the use of mancozeb as the extent to which it is important to agricultural end users, for example crop growers. The benefits of mancozeb are based on various agronomic factors, chemical characteristics, and alternative control strategies, all of which influence how a grower manages insect pests. The unit of analysis is an acre of an agricultural crop that would normally be treated with mancozeb. BEAD assesses benefits at this unit of analysis both because crop growers make pest control decisions at the acre- or field-level, and because risks are usually measured at the same spatial levels (treated acres and treated fields).

BEAD first examines how mancozeb is currently being used by growers by analyzing mancozeb usage data and reviewing extension recommendations to identify use patterns. Use patterns are defined by variations along spatial and temporal dimensions, average application rates, frequency of applications, method of applications, target pests, and any chemical characteristics of mancozeb that may be useful in the overall pest control strategy of a grower. Together, this information establishes where, when, and how agricultural crop growers use mancozeb.

Next, BEAD evaluates the extent of benefits of mancozeb by assessing the biological and economic impacts that growers 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 university extension recommendations, analyzing usage data from grower surveys, and considering economic factors. Impacts to a grower using the next best control alternative can include monetary costs (e.g., from using more expensive alternative insecticides), loss of utility in resistance management, simplicity of use, flexibility in formulation use, application timing, use of equipment types, and inclusion in integrated pest management programs. There may also be impacts with respect to crop yield loss and/or quality reductions related to diminished pest control.

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

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

CHEMICAL CHARACTERISITICS

Mancozeb is an ethylene bisdithiocarbamate broad spectrum multisite protectant fungicide in the FRAC group M03 (FRAC, 2024). Mancozeb is a complex of two 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.

AGRICULTURAL USE AND USAGE

Use

Mancozeb is a broad-spectrum contact fungicide registered for use across a variety of agricultural crops. This memorandum assesses the benefits of foliar use among registered vegetable crops (not including cucurbits and fruiting vegetables assessed in a separate memorandum). Mancozeb is specifically registered for use on the following vegetable crops: asparagus, broccoli, cabbage, fennel, lettuce, and onion (bulb) subgroup 3-07A. Mancozeb is also registered on Special Local Need (SLN) labels for use in Washington and Oregon state on the following vegetable crops grown for seed: alliums (leek, bunching and dry bulb onion), arugula, beets (garden and sugar), carrots, coriander, crucifers (*Brassica* spp. and *Raphanus* spp.), dill, endive, lettuce, parsley, parsnip, Swiss chard, and spinach. Carrots grown for seed is also registered on an SLN label in Idaho.

Mancozeb formulations for use on vegetable crops include dry flowables (water dispersible granules), flowable concentrates (liquid), and wettable powders. These products can be applied via broadcast or in-furrow using ground or aerial equipment. A dip treatment application is registered for asparagus crowns.

Usage

The usage values presented in this section are national annual averages and are based on the most recent data available from each usage data source. The values presented in this document may differ from those presented in other BEAD documents, such as the Screening Level Usage Analysis (SLUA) or the Summary Use and Usage Matrix (SUUM), because different timeframes are represented in those documents.

Nationally, surveyed growers of vegetable crops focused on in this memorandum (listed below in Table 1) reported applying approximately 680,000 pounds of mancozeb active ingredient (lbs AI) to 420,000 total acres treated (TAT) annually from 2017 to 2021 (Kynetec, 2022a; Kynetec, 2022b). Some smaller acreage crops, such as shallot and fennel, are not surveyed at a nationally representative level, and are not included in this estimate; therefore, these national usage values may slightly underestimate total national mancozeb usage on the vegetable crops of interest. Mancozeb usage on all relevant vegetable sites with nationally representative survey data are summarized in Table 1.

There are no recent, available, and nationally representative usage data for fennel, or crops in Crop Subgroup 3-07a beyond onion and garlic. There are also no usage data available for the regional use of mancozeb on crops grown for seed in Washington and Oregon. The absence of such data should not be interpreted as lack of usage.

Table 1. National Average Annual Mancozeb Usage in Surveyed Crops, 2017-2021

Crop	Average Percent of Crop Treated[1]	Average Total Acres Treated[2]	Average Pounds AI Applied	AI Avg. Single Application Rate (lbs AI/acre)	Number of Applications
Lettuce	56	220,000	320,000	1.5	1.4
Onions	52	140,000	240,000	1.7	2.4
Garlic	33	26,000	59,000	2.3	2.6
Cabbage	22	25,000	38,000	1.5	2.6
Asparagus	9	3,400	5,100	1.5	1.8
Broccoli	7	12,000	18,000	1.6	1.5

Sources: Kynetec 2022a, Kynetec 2022b

[1] Percent Crop Treated is defined as Base Acres Treated, the number of acres treated at least once, divided by the number of crop acres grown.

[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same physical acre.

All crops in Table 1 reported a notable percentage of total national crop acreage treated with mancozeb (*i.e*., percent crop treated [PCT]). As shown in Table 1, in terms of PCT, lettuce (56 PCT), onions (52 PCT), and garlic (33 PCT) reported the highest usage. Usage of mancozeb on each crop in Table 1 is discussed in further detail below.

<u>Lettuce</u>

Lettuce growers nationally reported that 56% of lettuce acres grown were treated with mancozeb (Kynetec 2022b). California and Arizona, together, account for almost 95% of the lettuce acreage grown nationally (USDA NASS, 2022). In California, the top state producer of lettuce, almost 70% of the lettuce acreage grown was treated with mancozeb with an average of 1.4 applications per acre (Kynetec, 2022b; USDA NASS, 2022). Growers in Arizona reported approximately 23% of lettuce acreage treated with mancozeb, with an average of 1.1 applications per year (Kynetec, 2022b).

<u>Onion</u>

Nationally, onion growers reported high usage of mancozeb with over half of the onion acres grown treated with the fungicide. Mancozeb usage was reported in every state surveyed for fungicide usage in onion (California, Georgia, Idaho, New York, Oregon, Texas, and Washington) (Kynetec, 2022b). This indicates that mancozeb was used by onion growers nation-wide. In terms of PCT, usage was highest in New York. Growers in New York reported that 98% of the onion acres in the state were treated with mancozeb, and mancozeb was applied, on average, four times per year in New York onion acreage (Kynetec, 2022b).

Garlic

Garlic is primarily produced in California, with over 80% of the national acreage being grown there (USDA NASS, 2022). California is subsequently the only state surveyed for garlic fungicide usage. Growers in California treated 34% of garlic acres with mancozeb and made 2.6 applications of mancozeb per year (Kynetec, 2022b).

Broccoli

Broccoli is primarily grown in California, representing over 80% of national acreage (USDA NASS, 2022). California is subsequently the only state surveyed for broccoli fungicide usage. Growers in California treated 7% of broccoli acres with mancozeb and made 1.5 applications of mancozeb per year (Kynetec, 2022b).

Cabbage

Nationally, cabbage growers reported mancozeb usage on 22% of the crop area grown; however, this estimate is strongly weighted by reporting from a single surveyed state. Although New York accounts for only 11% of national cabbage acreage, over 95% of nationally reported mancozeb usage, in terms of both pounds applied and acres treated, was reported in that state. (Kynetec, 2022a; USDA NASS, 2022). Growers in New York reported treating 92% of cabbage acres grown and using on average 2.6 applications of mancozeb per year (Kynetec, 2022b). Other states within the survey reported little to no mancozeb usage (California, Florida, Georgia, Michigan, North Carolina, and Wisconsin) (Kynetec, 2022b).

Asparagus

Asparagus growers nationally reported that 9% of asparagus acres were treated with mancozeb (Kynetec, 2022b). Although Michigan grows approximately half of the national asparagus acreage, mancozeb usage in the state was low (Kynetec, 2022b). Conversely, Washington and California, each producing 11% of the national asparagus acreage, reported much higher usage in terms of PCT (26 and 10 PCT, respectively) (Kynetec, 2022b).

SCOPE OF ASSESSMENT

High reported national or regional usage on registered vegetable crops as presented above (and in Table 1) suggests that mancozeb may be an important tool for growers in those production systems. To determine the potential magnitude of benefits in these crops, BEAD provides an assessment of mancozeb use in lettuce, garlic, onion, broccoli, cabbage, and asparagus in the next sections of this document.

Conclusions for the assessments of garlic and onion are extended to other crops in the onion (bulb) subgroup 3-07A as well as alliums grown for seed (including green onion) due to similar pest spectrums and production practices.

Conclusions for the assessments of broccoli and cabbage are extended to brassica crops grown for seed (*Brassica* spp.) due to similar pest spectrums and production practices.

All other vegetable crops registered for mancozeb use but not surveyed for usage data or otherwise identified as an important use site in public comments are not further assessed in this memorandum (*i.e*., fennel and regional crops grown for seed). BEAD does not extend conclusions from assessed crops to other vegetables since the target pests and available alternatives may differ significantly. BEAD concludes that mancozeb likely has at least moderate benefits in these production systems due to the continued renewal of the SLN registrations. However, this conclusion is uncertain due to lack of data and BEAD welcomes public comments (following publication of the preliminary interim decision) identifying critical uses of mancozeb in any field crops.

BENEFITS OF MANCOZEB USE IN VEGETABLE CROPS

Mancozeb is typically used multiple times during a growing season; nationally, one to two applications of mancozeb were used per year in lettuce production and nearly three applications, on average, in garlic and onion (see Table 1). Mancozeb provides control of a broad spectrum of pathogens and will often be applied with a single-site fungicide, which is selected to target particularly prevalent disease. Mancozeb also helps manage resistance to the single-site fungicides by providing a different mode of action; single-site fungicides will also be rotated throughout the season. In the bulb and Brassica vegetables and in asparagus, chlorothalonil plays a similar role and is currently used with similar frequency (note: chlorothalonil is not registered in leafy vegetables). However, EPA recently proposed to reduce the allowable annual application rate for chlorothalonil, effectively constraining the number of applications that can be made over the season to current levels (Hansel *et al*., 2023). Thus, if mancozeb were not available for use, growers would not be able to increase the frequency with which they use chlorothalonil.

<u>Lettuce</u>

Lettuce is grown in all 50 states and the majority of mancozeb usage (>97%) in lettuce is applied to the crop to control downy mildew disease caused by an oomycete (*Bremia lactucae*) (Kynetec, 2022a). Downy mildew is a major disease that appears every year in lettuce production (Koike and Turini, 2017; Matheron, 2015; Scheufele, 2021). Downy mildew is favored by periods of cool and wet weather and as noted above, an average of 1.4 applications of mancozeb are applied annually to over half of the lettuce acreage grown nationally. Downy mildew in lettuce is primarily managed by growing downy mildew resistant cultivars (Koike and Turini, 2017; Matheron, 2015; Scheufele, 2021), but when fungal prevention is needed, mancozeb is the only effective multisite fungicide recommended (Koike and Turini, 2017).

Mancozeb, sulfur, and copper are registered multi-site fungicides. However, both sulfur and copper are used on less than 1% of the crop for control of downy mildew (Kynetec, 2022a). Koike and Turini (2017) notes that copper is only marginally effective and downy mildew is not a target pest listed on sulfur labels. Pressure from downy mildew may vary, but if needed, mancozeb alone or in combination with single site fungicides are recommended every seven to ten days (Koike and Turini, 2017; Matheron, 2015; Scheufele, 2021), but as noted earlier, the disease typically only requires one to two treatments of mancozeb per year (Table 1).

The recommended single site fungicides include cyazofamid, cymoxanil, or famoxadone + cymoxanil (Scheufele, 2021). Koike and Turini (2017) also include the single site fungicides phosphorus acid, mandipropamid, fluopicolide, acibenzolar-S-methyl, fenamidone, and dimethomorph. Though cymoxanil and cyazofamid are not among the most used fungicides (as shown in Table 2), they are recommended and may play an important role as tank-mix partners. Because copper reportedly has little efficacy against downy mildew, mancozeb is the only multisite fungicide available to lettuce producers that could be used as a tank-mix partner with these recommended single site fungicides, and without mancozeb, growers would be limited to single site fungicides only.

Table 2. National Total Acres Treated and Average Cost of Recommended Fungicides for Control of Downy Mildew in Lettuce, 2017-2021

Active Ingredient	FRAC Code and Resistance Risk[1]	Average Total Acres Treated (acres)[2]	AI Avg. Cost / Total Area ($/acre)
Mancozeb[3]	M03, low	210,000	$11
Mandipropamid	40, low to medium	160,000	$31
Fenamidone	11, high	100,000	$27
Dimethomorph	11, high	100,000	$18
Phosphoric acid	P07, low	94,000	$15
Acibenzolar	P01, not known	55,000	$41
Cymoxanil	27, low to medium	28,000	$13
Fluopicolide	43, medium	13,000	$45
Famoxadone	11, high	8,900	$11
Cyazofamid	21, unknown but thought to be medium to high	500	$19

Sources: Kynetec 2022a, FRAC 2024

[1] The likelihood that pathogens develop resistance against fungicides within the FRAC group with continued use, as denoted by FRAC, 2024

[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same field.

[3] Multi-site fungicide

Summary of Mancozeb Benefits in Lettuce Production

Mancozeb is important in lettuce production because it offers preventative disease management and serves as a multisite tank-mix partner with single site fungicides for resistance management. Mancozeb is also a cost-effective option for control of downy mildew. It is the least expensive of the top five most used fungicides, by TAT, for this pest, as shown in Table 2 above. Without mancozeb, growers would rely more heavily on single-site fungicides, resulting in higher costs of disease control, possible yield loss, and potentially increasing the risk that resistance develops to the single-site fungicides.

Thus, the benefits of mancozeb in lettuce production is considered high for downy mildew prevention.

Bulb Vegetables: Garlic and Onion

Mancozeb is registered nationally for use on all crops within the CFR defined crop subgroup 3-07A which includes dry bulb onions, garlic, and shallots. There is also a Special Local Needs (SLN) registration for growers in Washington and Oregon allowing use of mancozeb on additional bulb vegetable crops grown for seed including leeks and green onions. This analysis evaluates mancozeb importance in dry bulb onions and garlic, but the benefits, alternatives, and potential impacts from mitigation are expected to be comparable for other similar crops, such as leeks and shallots because the growth requirements, pest spectrum, and storage conditions are similar (Mahr, no date; Masabni and Lillard, 2009).

Mancozeb applications were reported on a substantial portion of garlic and onion acreage nationwide (garlic PCT 34; onion PCT 52 as shown in Table 1) (Kynetec, 2022b). Downy mildew and purple blotch were identified as the two diseases that required the greatest number of fungicidal treatments (based on total acres treated with all fungicides) in both crops (Kynetec, 2022a). Downy mildew is caused by the oomycete pathogen *Peronospora destructor*, while the fungus *Alternaria porri,* is responsible for causing purple blotch. Symptoms of both diseases are premature defoliation of the host plant which results in a smaller bulb size compared to healthy plants. These pathogens also make the host plant more susceptible to secondary bacterial and fungal infections that cause storage rot (Hausbeck, 2014). Purple blotch is often a secondary pathogen that attacks plants (Swett et al., 2019a) after damage occurs from downy mildew infection, but it can also infect healthy plants (Swett et al., 2019a).

California is the top producing state for both onions and garlic (USDA NASS, 2022) and California is the state with the greatest amount of mancozeb usage (per TAT) for downy mildew and purple blotch prevention. New York is the state with the greatest mancozeb percent crop treated for downy mildew control in onion (Kynetec, 2022a). Thus, this analysis draws on information about downy mildew control in New York onion production, and downy mildew and purple blotch control in California garlic and onion production.

Downy Mildew Control in New York and California

In New York onion production, mancozeb is the only multisite fungicide recommended for downy mildew control (Hoepting, 2023); however, phosphrous acid, a single site fungicide, is also recommended and has a rating of “low” for likelihood of resistance (FRAC, 2024). Hartman and Seebold (2005) report that phosphorous acid is especially effective on oomycete diseases, such as downy mildew. Phosphrous acid is also a recommended tank mix with several other single site fungicides including difenoconazole, azoxystrobin, tebuconazole, propiconazole, cyprodinil, fluxapyroxad, and pyraclostrobin (Hoepting et al, 2023).

Recommended multisite downy mildew controls in California garlic and onions include mancozeb and chlorothalonil (Swett et al., 2019a). Copper products are also registered for use in onions and garlic, but these chemistries are reportedly not very effective at preventing oomycete diseases (Swett et al., 2019a; Egel, 2021). Though sulfur is registered for use in onions and garlic, sulfur is not recommended for either of these target diseases. In addition to the multisite fungicides, several single site fungicides as well as tank mixes of multiple single sites and single site plus multisite fungicide are recommended for downy mildew control in garlic and onions. These include fenamidone, fluazinam, dimethomorph, ametoctradin + dimethomorph, oxathiapiprolin + mandipropamid, mefenoxam + mancozeb, and mefenoxam + chlorothalonil (Table 3) (Swett et al., 2019a).

Mancozeb is used on slightly more onion/garlic acreage than is chlorothalonil, even though mancozeb costs $2 more per acre. This may indicate that mancozeb offers some benefit that chlorothalonil cannot match, since growers are willing to pay the extra cost. Mancozeb, is $1 to $31 dollars less expensive than most of the recommended single site fungicides used for downy mildew control.

Table 3. National Total Acres Treated and Average Cost of a Recommended List of Fungicides Used to Control Downy Mildew in Garlic and Onions, 2017-21

Active Ingredient	FRAC Number and Resistance Risk[1]	Average Total Acres Treated (acres)[2]	AI Avg. Cost / Total Area ($/acre)
Mancozeb[3]	M03; low	55,000	$11
Chlorothalonil[3]	M05; low	42,000	$9
Fenamidone	11; high	14,000	$19
Ametoctradin + Dimethomorph[4]	45/40; medium to high/low to medium	5,300	$40
Oxathiapiprolin	49; medium to high	3,400	$15
Fluazinam	29; low	2,600	$42
Dimethomorph	11; high	1,800	$20
Oxathiapiprolin + Mandipropamid[4]	49/40; medium to high/low to medium	2,300	$42
Mefenoxam + Mancozeb[3,4]	4/M03; high/low	4,900	$36
Mefenoxam + Chlorothalonil[3,4]	4/M05; high/low	38,000	$34
Phosphorous Acid	P07; low	1,200	$18
Cyprodinil	D1; medium	5,100	$23
Fluxapyroxad	C2; medium to high	2,800	$39
Pyraclostrobin	C3; high	9,600	$12
Difenoconazole	G1; medium	5,100	$10
Azoxystrobin	C3; high	3,800	$15
Tebuconazole	G1; medium	<500	$3
Propiconazole	G1; medium	<500	$5

Sources: Kynetec 2022a, FRAC 2024

[1] The likelihood that pathogens develop resistance against fungicides within the FRAC group with continued use, as denoted by FRAC, 2024

[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same field.
[3] Multi-site fungicide
[4] Active Ingredient + Active Ingredient. These fungicide active ingredients are available together as part of a premix product, and the usage data presented in this table is from this product. Some of these fungicides are also available as an individual fungicide product or as a premix product with a different fungicide. To prevent "double counting" of treated acreage for a given individual fungicide in the table, the usage data for individual fungicide products (e.g., mancozeb) and premix fungicide products (e.g., mefenoxam + mancozeb) were listed as separate lines in the table.

Purple Blotch Control in California

For purple blotch control, Swett et al. (2019b) recommends mancozeb, chlorothalonil, boscalid, penthiopyrad, pyraclostrobin, pyrimethanil + fluopyram, azoxystrobin + difenoconazole, difenoconazole + cyprodinil, pyraclostrobin + fluxapyroxad, and boscalid + pyraclostrobin. The recommended fungicides with usage and cost data for control of purple blotch are included in Table 4 below. Though both mancozeb and chlorothalonil are recommended multisite fungicides, mancozeb is used on more acreage (per TAT) than chlorothalonil and at a higher cost per acre. This indicates that mancozeb may provide a benefit that chlorothalonil cannot match. If mancozeb were not available and growers had to substitute single site fungicides, they would have to do so at an increased cost of $17 to $39 per acre (Table 4).

Table 4. National Total Acres Treated and Average Cost of a Recommended List of Fungicides Used to Control Purple Blotch in Garlic and Onions, 2017-21

Active Ingredient	FRAC Number and Resistance Risk[1]	Average Total Acres Treated (acres)[2]	AI Avg. Cost / Total Area ($/acre)
Mancozeb[3]	M03; low	42,000	$11
Chlorothalonil[3]	M05; low	26,000	$9
Boscalid	7; medium to high	2,400	$37
Penthiopyrad	7; medium to high	2,800	$33
Pyrimethanil + Fluopyram[4]	9/7; medium /medium to high	1,400	$38
Azoxystrobin + Difenoconazole[4]	11/3; high/medium	1,300	$28
Difenoconazole + Cyprodinil[4]	3/9; medium/medium	6,800	$33
Pyraclostrobin + Fluxapyroxad[4]	11/7; high/medium to high	3,500	$50
Boscalid + Pyraclostrobin[4]	7/11; medium to high /high	6,900	$49

Sources: Kynetec 2022a, FRAC 2024
[1] The likelihood that pathogens develop resistance against fungicides within the FRAC group with continued use, as denoted by FRAC, 2024
[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same field.

[3] Multi-site fungicide
[4] Active Ingredient + Active Ingredient. These fungicide active ingredients are available together as part of a premix product, and the usage data presented in this table is from this product. Some of these fungicides are also available as an individual fungicide product or as a premix product with a different fungicide. To prevent "double counting" of treated acreage for a given individual fungicide in the table, the usage data for individual fungicide products (e.g., boscalid) and premix fungicide products (e.g., boscalid + pyraclostrobin) were listed as separate lines in the table.

Mancozeb Benefits in Bulb Vegetable Production

For downy mildew and purple blotch prevention in California, garlic and onion producers are often using the multisite fungicides, mancozeb and chlorothalonil. Mancozeb is used on more acres treated than chlorothalonil even though mancozeb costs more. Chlorothalonil labels report that chlorothalonil only suppresses downy mildew and Hoepting (2023) reports that chlorothalonil has limited activity over downy mildew. Even though chlorothalonil is reportedly less efficacious than mancozeb, if mancozeb were not available, growers would most likely increase their use of chlorothalonil, however yield losses may be realized due to reduced efficacy.

Though switching to chlorothalonil could be a current option, chlorothalonil is going through the EPA registration review process with proposed mitigation to reduce the maximum annual application rate in garlic and onion by more than half. Thus, growers may not be able to increase use of chlorothalonil and would have to replace mancozeb with single site fungicides, at a much higher cost (see Tables 3 and 4) and at a greater increase in the potential of fungicide resistance for single site fungicides.

Considering current disease prevention in garlic and onions, mancozeb has high benefits nationally, but especially in New York where 98% of all onion acres were treated with mancozeb. In the absence of mancozeb, growers may be able to use chlorothalonil but at a reduced efficacy and possible yield loss, in addition to paying a higher cost for recommended and multiple single site fungicides (as shown in Tables 3 and 4).

Brassica Vegetables: Broccoli and Cabbage

Among brassica head and stem vegetables, mancozeb is registered nationally for use in broccoli and cabbage. Through a Special Local Needs (SLN) registration, growers in the states of Washington and Oregon are allowed to use mancozeb on any Brassica spp. crops grown for seed (*e.g*. cauliflower, bok choy, etc.). This analysis focuses on head and stem broccoli and cabbage, but the benefits and alternatives are expected to be similar for other brassica crops (*i.e*., grown for seed), considering they have the same target pests (Reeves et al., 2021; Bradford et al., 2023; University of Massachusetts, 2024; Ocamb, 2024a; Ocamb, 2024b).

Growers surveyed by Kynetec (2022a) identified Alternaria leaf spot caused by the fungus *Alternaria brassicicola* and downy mildew caused by the oomycete *Hyaloperonospora brassicae,* as the diseases using the greatest amount of mancozeb in both cabbages grown in New York and broccoli grown in California. Extension literature from New York and California confirm that these two diseases are important in brassica production, and that serious yield

losses result with inadequate control (Koike and Subbarao, 2007a, 2007b; Boucher, 2012; New England Vegetable Management Guide, 2023; Rutgers, 2024;). Alternaria leaf spot typically presents itself during warm and humid weather (Hoidal, 2023), while downy mildew is more prevalent during times of cool and humid weather (Reeves et al., 2021).
Though mancozeb is reportedly used to control Alternaria leaf spot and downy mildew in broccoli and cabbage (Table 5; Kynetec, 2022a), mancozeb is not a recommended protectant for either disease (Koike and Subbarao, 2008; Hoepting, 2020; Reeves *et al*., 2021; Smart and Sudermann, 2024). However, Boucher (2012) reports that there are few fungicides that can control major brassica diseases, but mancozeb will suppress Alternaria leaf spot. Recommended controls of *Alternaria* species include the multisite fungicide chlorothalonil, and a few single site fungicides with an efficacy rating of excellent, including cyprodinil + fludioxonil, boscalid, fluopyram + tebuconazole, and fluopyram + trifloxystrobin. Copper is also a recommendation (Hoepting, 2020). Though sulfur products are registered for use in brassica crops, sulfur is not recommended for either of these pests and is therefore not considered an alternative to mancozeb.

Recommended downy mildew controls in California brassica include chlorothalonil, copper, fosetyl-aluminum, and mefenoxam + chlorothalonil (Koike and Subbarao, 2008).

Usage and cost data for mancozeb and the recommended fungicides for control of Alternaria leaf spot and downy mildew are included in Table 5 below.

Table 5. National Total Acres Treated and Average Cost of a Selected List of Fungicides Used to Control Alternaria Leaf Spot and Downy Mildew in Broccoli and Cabbage, 2017-21

Active Ingredient	FRAC Number and Resistance Risk[1]	Average Total Acres Treated (acres)[2]	AI Avg. Cost / Total Area ($/acre)
Alternaria Leaf Spot			
Mancozeb[3,6]	M03; low	20,000	$12
Chlorothalonil[3]	M05; low	31,000	$9
Boscalid	7; medium to high	1,800	$36
Cyprodinil + Fludioxonil[4]	9/12; medium/low to medium	no reports[5]	$18 +
Fluopyram + Tebuconazole[4]	7/3; medium to high/medium	no reports[5]	$15 +
Mefenoxam + Chlorothalonil[3,4]	4/M05; high/low	no reports[5]	$18 +
Downy Mildew			
Mancozeb[3,6]	M03; low	26,000	$11
Chlorothalonil[3]	M05; low	22,000	$8
Copper[3,7]	M01; low	10,000	$3-$36 (dependent on the formulation)

Active Ingredient	FRAC Number and Resistance Risk[1]	Average Total Acres Treated (acres) [2]	AI Avg. Cost / Total Area ($/acre)
Fosetyl-aluminum	P07; low	3,400	$40
Mandipropamid	40; low to medium	9,200	$28
Mefenoxam + Chlorothalonil[3,4]	4/M05; high/low	4,800	$18

Sources: Kynetec 2022a, FRAC 2024

[1] The likelihood that pathogens develop resistance against fungicides within the FRAC group with continued use, as denoted by FRAC, 2024

[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same field.

[3] Multi-site fungicide

[4] Active Ingredient + Active Ingredient. These fungicide active ingredients are available together as part of a premix product, and the usage data presented in this table is from this product. Some of these fungicides are also available as an individual fungicide product or as a premix product with a different fungicide. To prevent "double counting" of treated acreage for a given individual fungicide in the table, the usage data for individual fungicide products (e.g., boscalid) and premix fungicide products (e.g., Boscalid + Pyraclostrobin) were listed as separate lines in the table.

5 There were no reports of these two chemicals being used together as a premix product on these crops. One of the chemicals does have some usage (the first one in each combination + pair), so the cost data in the last column are provided for that one chemical as a price floor.

[6]Mancozeb is not a recommended alternative for either Alternaria or Downy mildew in brassica. It is included in the table above to show price differences, since mancozeb is one of the most used fungicides in these crops.

[7]Copper is sold in several formulations (sulfate, oxide, etc).

Summary of Mancozeb Benefits in Brassica Production

Currently, mancozeb benefits in brassica production are determined to be low, in part because there are two other multisite fungicides available, and because mancozeb is reportedly less efficacious than chlorothalonil. If mancozeb were not available, growers would most likely increase their use of chlorothalonil. However, chlorothalonil is going through the EPA registration review process with proposed mitigation to reduce the maximum annual application rate in brassica, which could result in a reduced number of allowable applications per year. Thus, growers may not be able to increase use of chlorothalonil and would have to replace mancozeb with single site fungicides, at a much higher per acre cost; at which point, mancozeb may become more important in brassica production.

<u>Asparagus</u>

Reported mancozeb usage in asparagus was concentrated in the west coast production areas between 2017-2021. The majority of reported mancozeb usage in asparagus production was applied in California to prevent asparagus rust and in Washington to prevent Cercospora leaf spot (2017-2021; Kynetec, 2022a). Asparagus rust, caused by the fungus *Puccinia asparagi*, typically infects asparagus beginning in early spring with the most economically serious stage occurring after harvest during the fern stage. Asparagus rust during the fern stage in one year will have a negative effect on plant vigor and yield in the following year (Aegerter and Davis, 2009). Cercospora leaf spot, caused by *Cercospora* fungi, receives the greatest amount of mancozeb usage compared to other diseases, and mancozeb is the only fungicide with usage reported for prevention of this disease (2017-2021; Kynetec, 2022a). Like asparagus rust, Cercospora leaf spot affects the fern stage of the asparagus growth cycle, resulting in defoliation and yield loss during the following season (Oklahoma State University, 2023). While a greater amount of asparagus acreage is treated for rust in Michigan, mancozeb is hardly used (<1% TAT with all fungicides) for asparagus rust control in that state. Instead, chlorothalonil and tebuconazole are the most used fungicides for rust in Michigan (Kynetec, 2022a). However, Egel (2023; Midwest Vegetable Production Guide) does recommend both mancozeb and chlorothalonil, and mancozeb mixed with azoxystrobin for rust control in the Midwest, which includes Michigan production. Although Aegerter and Davis (2009) include micronized sulfur in the recommended alternatives list, the authors report that micronized sulfur does not provide adequate efficacy; thus sulfur is not a likely alternative to mancozeb Recommended single site fungicides are limited to myclobutanil (Aegerter and Davis, 2009), tebuconazole, and azoxystrobin (Egel, 2023). However, only tebuconazole has reported usage for asparagus rust (Kynetec, 2022a).

Control recommendations for Cercospora leaf spot include use of mancozeb and chlorothalonil as multi-site fungicidal treatments, either as substitutes or in addition to the single site fungicides tebuconazole and myclobutanil (Egel, 2023; Wyenandt, 2017). However, there is no reported usage for single site fungicide control of Cercospora leaf spot (Table 6), and as previously stated, mancozeb is the only fungicide with reported usage for control of this disease.

Table 6 below provides FRAC numbers, resistance information, usage data, and cost data for fungicides recommended for mancozeb’s top target pests in asparagus, asparagus rust and Cercospora leaf spot.

Table 6. National Total Acres Treated and Average Cost for Fungicides Used to Control Cercospora leaf spot in Asparagus, 2017-2021

Active Ingredient	FRAC Number and Resistance Risk[1]	Average Total Acres Treated (acres)[2]	AI Avg. Cost / Total Area ($/acre)
Asparagus Rust			
Mancozeb[3]	M03; low	1,400	$11
Chlorothalonil[3]	M05; low	13,000	$11
Tebuconazole	3; medium	13,000	$2
Myclobutanil	3; medium	no reports	no reports
Cercospora Leaf Spot			
Mancozeb[3]	M03; low	1,400	$7
Chlorothalonil[3]	M05; low	no reports	no reports
Tebuconazole	3; medium	no reports	no reports
Azoxystrobin	11; high	no reports	no reports

Sources: Kynetec 2022a, FRAC 2024
[1] The likelihood that pathogens develop resistance against fungicides within the FRAC group with continued use, as denoted by FRAC, 2024
[2] Total Acres Treated is defined as the number of acres treated, accounting for multiple treatments to the same field.
[3] Multi-site fungicide

Summary of Mancozeb Benefits in Asparagus Production

The benefits of mancozeb in national asparagus production are likely low; though benefits may be a little higher in California and Washington, where the majority of mancozeb is used in asparagus. If mancozeb were unavailable, growers would likely switch to chlorothalonil with no expected yield loss because chlorothalonil is more efficacious than mancozeb for both diseases. However, chlorothalonil is currently going through the EPA registration review process where potential annual rate reductions have been proposed for asparagus. If these rate reductions are implemented, the benefits of mancozeb may increase in California and Washington but there would most likely be no impact on the rest of production in other states.

IMPACTS OF POTENTIAL MITIGATION

EPA has identified human health and ecological risks of concern from use of mancozeb in various vegetable crops. To reduce human health risks resulting from vegetable crop applications, the Agency is considering risk mitigation measures such as increasing crop-specific restricted entry intervals (REI) to protect workers entering a treated field. For pesticide applicators, the Agency may require an Assigned Protection Factor 10 (APF10) respirator and use of double layer clothing for foliar applications of mancozeb. For workers mixing and loading pesticides, the requirement of a closed loading system is being considered when utilizing dry flowable and wettable powder formulations for aerial and chemigation applications.

Mitigations to Address Risks to Human Health

Increase in Restricted Entry Intervals

To reduce risks to occupational handlers from foliar applications of mancozeb, the Agency may propose increased REIs for bulb onion, green onions grown for seed, garlic, broccoli, and cabbage. The current REI of mancozeb in these crops, regardless of activity, is 24-hours.

Increasing the REI of mancozeb in onions over 48-hours would require posting of warning signs, which may be an increased burden in time and labor for growers. Most activities in onions will not be highly impacted by a 3 – 5-day REI. However, a REI greater than five days is likely to impact scouting for insects. About 80% of all onion/garlic acres treated with insecticides are treated for thrip control (Kynetec, 2022a). Recommendations to control thrips suggest that onions fields be scouted every seven to ten days, but scouting should occur in even shorter durations during periods of heavy infestation. Thus, if insects such as onion thrips are a problem, anything greater than a 5-day REI would be prohibitive to effective insect control and could preclude the use of mancozeb for fungal control during periods of heavy insect infestations. Though BEAD did not assess green/bunch onions that are grown for seed, the REI restriction is expected to have the same impacts of those for bulb onions.

Similarly, a three- to four-day REI for mancozeb use in broccoli and cabbage would likely interfere with scouting for insect pests. For instance, for caterpillar pests in brassicas, Kahn et al. (2017) recommend scouting fields twice per week, or every 3-4 days. In such cases, growers would most likely switch from mancozeb to chlorothalonil, if allowed given a proposed rate reduction in chlorothalonil use in brassicas (Docket # EPA-HQ-OPP-2011-0840) may leave growers with inadequate full season fungal/oomycete control or an increased reliance on single site fungicides which would further encourage resistance. Thus, an increased REI restriction for mancozeb may have greater impacts, potentially resulting in additional yield loss from disease if growers switch to a less effective fungicide, increased risk of resistance with single site fungicides, or yield loss if mancozeb was used and the longer REI was adhered to.

Addition of APF10 Respirators (APF10)

To reduce risks to occupational handlers (i.e., mixers and loaders) from foliar applications of mancozeb in vegetable crops, EPA may propose the use of an APF10 respirator requirement.

Requiring use of a respirator may impose a cost on users for the respirator and fit test unless they already use a respirator for other chemicals. Respirator costs are extremely variable depending upon the protection level desired, disposability, comfort, and the kinds of vapors and particulates being filtered (Fetzer, 2023; Legault and Ayers, 2007). An APF10 respirator include N95 masks which are relatively inexpensive. Under the Worker Protection Standard, users of respirators are also required to have an annual fit test performed; BEAD found the cost of a respirator fit test to be about $350 per applicator per year; this includes fees and the time required to obtain the test (Smearman and Berwald, 2024). In addition to the potential monetary costs of respirators, the use of a respirator can reduce productivity of workers wearing a respirator (Johnson, 2016), which could increase the time required to mix and load tanks, further increasing the cost of production.

Alternatively, growers could hire a commercial applicator, likely at an increase in cost. Growers could also avoid using mancozeb in favor of a strategy that uses fungicides that do not require a use of respirator use of a APF10 respirator.

Addition of Double Layer Clothing and Gloves

Requiring double-layer clothing and hand protection for users applying mancozeb (*i.e.,* typically coveralls over regularly used clothing and chemical resistant gloves) may increase the heat stress of applicators since several fungal diseases are prevalent during high environmental temperatures and high humidity. Double layer clothing and glove protection can reduce the productivity of workers because of the physiological stress when working in high temperatures and/or humid conditions (O'Brien et al. 2011). Workers may need to take more frequent breaks in certain situations than if double layer clothing and gloves were not required. Individuals will respond differently depending on many factors, such as fitness level, hydration, acclimatization, etc. The physiological stress resulting from double layer clothing and gloves could decrease productivity, which could increase the time required for an application to be made and potentially increase costs. Alternatively, applicators may choose to use a different fungicide, which could be more expensive (as shown in Tables 2-6), and potentially less effective than mancozeb.

Closed loading for Mixers and Loaders Utilizing Certain Mancozeb Formulations

The Agency is considering requiring that a closed pesticide delivery system be used for mixing and loading when preparing dry flowable (DF) and wettable powder (WP) formulations of mancozeb. This requirement may only be required for growers preparing for aerial or chemigation applications because these are the only application methods for which risks were identified. As reported in Table 7 below, most applications in most crops assessed in this memo were made via groundboom and therefore most growers may be unaffected by the closed pesticide delivery system requirement (Kynetec, 2022a). While nearly one third of broccoli acreages treated with mancozeb over the 2017 to 2021 period were treated aerially, most growers opted to utilize the liquid formulation in that crop. In onions, nearly one third of acreages treated received an application aerially or with chemigation and in this case many growers utilized the dry flowable or wettable powder formulations. Therefore, onion growers may be most impacted by the closed system requirement.

Table 7. Portion of Total Acres Treated with Mancozeb by Application Method and Formulation 2017-2021

	Lettuce	Onion	Garlic	Broccoli	Cabbage	Asparagus
Method of application						
Aerial	2%	23%	1%	32%	0%	0%
Ground	98%	70%	99%	68%	100%	100%
Chemigation	0%	6%	0%	0%	0%	0%
Formulation						
Dry flowable	54%	52%	40%	5%	100%	63%
Wettable powder	0%	35%	0%	0%	0%	0%
Liquid	46%	13%	60%	95%	0%	37%

Source: Kynetec, 2022a

A closed pesticide delivery system for these formulations may entail that the pesticide be enclosed in a water-soluble packet that can then be inserted into water within the pesticide delivery system. Then the container is closed to protect the worker as the packet and pesticide dissolves in water. This requirement means the product cost is likely to increase due to packaging costs and these costs may be passed to growers. Additionally, water-soluble packets mean that the pesticide would be sold in discrete amounts and therefore could further lead to increased costs and increased complications of disposing of excess pesticide. Moreover, agitation equipment may also be required to ensure the product mixes in water uniformly but does not expose the mixer/loader. Alternatively, growers could use the liquid formulation of mancozeb for the crops assessed in this memo but at higher costs than the dry flowable or wettable power formulations (Kynetec, 2022a). If the costs of utilizing the DF increase and outweigh the cost of utilizing the liquid formulation, applicators may opt to use the liquid formulation. In either scenario, growers who previously relied on these formulations are anticipated to bear an increased cost of use of mancozeb.

Mitigations to Address Ecological Risks

To human bystanders and ecological risks, the Agency may consider mitigation designed to lessen the likelihood of pesticide drift, this mitigation could include restrictions on windspeed to 10 mph, droplet sizes of medium to courser, prohibiting applications during wet weather, adding application buffers, and mandating a groundboom spray release height of 3-feet or less.

Mitigation to reduce bystander exposure, as described above, is considered sufficient to address most ecological risks. However additional mitigation may be needed to further reduce ecological risks to nontarget organisms, including the mandatory use of Bulletins Live! Two.

Windspeed Restriction

Currently some mancozeb labels require that an applicator not make an application when the windspeed is greater than 15 mph. To mitigate spray drift risk to non-target species, EPA is considering prohibiting groundboom and aerial applications when the wind speed is greater than 10 mph. Wind conditions vary across the U.S. and wind speed restrictions could prevent timely applications of mancozeb.

Mandatory wind speed restrictions complicate pest and crop management by reducing the available time to make applications and make it more likely that a grower may need to alter pest control plans. Changing plans may result in additional costs. If applications are not made in a timely manner, pest control could decline, potentially leading to additional applications, which may result in yield losses, and/or accelerate the development of resistance. In the case of fungicides in particular, disease prevention and early control are critically important because irreversible crop damage can occur very quickly if a disease goes uncontrolled.

In conclusion, a 10-mph wind speed maximum may prevent, in some cases, the timely application of chemical controls, resulting in reduced yield and quality of the crop and increase costs to growers. The Agency welcomes comments from growers and applicators about their fungicide application practices considering wind speeds.

Use of Medium or Coarser Droplet Size

The Agency is considering a restriction on spray droplet size of medium to coarse. The current droplet size requirement for mancozeb is fine to coarser. Coarser droplets have been demonstrated to decrease off-target spray drift compared to a finer droplet size. Therefore, an increased droplet size may reduce potential exposures to non-target species. As a contact fungicide, mancozeb's efficacy is dependent on coverage and smaller droplet sizes provide greater leaf coverage than do larger droplets. Generally, fungicides are applied using fine to medium droplets (Grisso *et al*., 2019). Consequently, potential negative impacts to growers from requiring larger droplets could include reductions in efficacy. Growers could compensate by increasing application rates, if allowed by the label; making more applications; or using alternative fungicides products. If these growers choose to use alternative fungicides, then this could be impactful to their vegetable production operations as was described above, for example, the alternative fungicides may be more expensive than mancozeb (as shown in Tables 2-6). Mandating a larger droplet size could also limit growers' ability to tank mix multiple chemicals if partner chemicals require smaller droplet sizes to be efficacious. This could result in growers making sequential applications, increasing labor and fuel costs.

Overall, a requirement for a medium droplet size, would likely have low impacts since a grower or user can get proper coverage with their mancozeb applications. A requirement for a coarse droplet size could result in poor coverage causing poor disease control. EPA encourages comments on any potential impacts to growers from specifying a mandatory minimum droplet size on product labels, or from situations when medium droplet sizes might not be appropriate or provide proper coverage to control target pests.

No Applications of Mancozeb When it is Raining

To reduce the potential for runoff, EPA is considering prohibiting mancozeb applications during or prior to a rainfall event. EPA does not anticipate that a restriction which prohibits mancozeb applications while it is raining will affect applicators. While fungicide applications may be made prior to a rainfall event, applicators would not apply during a rainfall event, as this would not be desirable for the product staying in place and preventing disease.

48-Hour Rainfall Restriction

BEAD expects a 48-hour restriction on applications prior to rainfall can be highly impactful to users of mancozeb, as periods of wet weather are when plants are most vulnerable to foliar diseases. Coating plants with a protective fungicide such as mancozeb prior to rain events helps to prevent the initiation infection and spread of disease; for this reason, fungicide applications are commonly recommended to be applied before a rainfall event (Egel, 2021; Quesada-Ocampo, 2023). Protectant fungicides such as mancozeb work best when applied during sunny and dry conditions (Cato, 2020; Schilder, 2010). When allowed ample time to dry (at least a few hours), protectants will continue to protect until rain events occur. While older formulations of protectants are more susceptible to wash-off, newer formulations with stickers/adjuvants are more resistant to wash-off by rain. In general, university agricultural extension recommendations advise that growers apply contact fungicides at least a few hours or up to 24 hours before rain (Cato, 2020; Paul, 2016; Schilder, 2010; Warmund, 2018). However, to restrict mancozeb applications 48 hours before a rain event limits users' flexibility in using mancozeb to protect crops against fungal diseases during vulnerable wet weather events, which could lead to suboptimal disease control and/or prompt users to switch to an alternative fungicide. In the case of mancozeb, growers may have no other synthetic multisite fungicide options available to turn to during these periods; this may be the case when mancozeb is already being utilized for other applications over the growing season.

The likelihood of a grower being impacted by a 48-hour restriction on applications prior to rainfall would vary based on the time of year when mancozeb (which will vary by crop as some crops rely on mancozeb applications throughout the growing season) is being applied and the prevailing frequency and intensity of rainfall in the area.

Groundboom Spray Release Height

For groundboom applications, spray release height is important to obtain proper coverage. If nozzles are placed too low, the spray pattern may be too narrow, and coverage could be uneven. A grower may have to purchase new nozzles to accommodate a spray height or apply a different chemical that does not have this restriction. However, a review of manufacturer recommendations found that many nozzles and spray equipment require release heights of 2 ft or greater (Tindall and Hanson, 2018), so a 3 ft release height should not be impactful to most growers. For aerial applications, the agency considers this to be standard application practice and does not anticipate any impacts from the requirement for a 10 ft release height.

Buffer Requirements

To mitigate spray drift risk to non-target species, EPA is considering implementing buffer restrictions. In this section, BEAD describes the impacts on mancozeb users of requiring buffers. EPA is considering buffers of 50 ft for aerial applications and 15 ft for groundboom applications.

Aerial applications were common in broccoli, with over 30% of acres treated aerially out of all mancozeb treated acres for this crop; aerial applications were also common in onions where the percent of aerial applications was 23% (Kynetec, 2022a). Aerial applications were not common in lettuce (<5% TAT), cabbage (<1% TAT), garlic (<1% TAT), or asparagus (<1% TAT) (Kynetec, 2022a). USDA OPMP (2022) feedback regarding the importance of aerial applications of mancozeb broadly noted that aerial applications can have high importance in situations where field conditions preclude ground applications. This is important because the need for broad-spectrum protectant fungicides such as mancozeb can be very important after wet weather. For these reasons, ground applications are generally not a viable alternative to aerial applications. Therefore, if mancozeb could not be applied by air, then these growers would have to turn to an alternative pest control strategy, which could have moderate to high impacts depending on the crop.

BEAD anticipates that broccoli and onion producers could be impacted if risk mitigation results in large buffers for aerial mancozeb applications. Growers who would be required to implement a buffer have three main options, all of which result in the loss of mancozeb as a control method in the buffer area: 1) replace mancozeb with an alternative control method for treatment of the entire field, 2) replace mancozeb with an alternative control method in just the buffer area while treating the interior field with mancozeb, or 3) use mancozeb to treat only the interior of the field and leave the buffer areas untreated. Given that the most likely alternative to mancozeb (chlorothalonil) may also be subject to increased buffers, growers may need to rely on another alternative chemistry or combination of chemistries, that would likely come at an increased cost and could be more susceptible to resistance, as shown in Tables 2-6 above in the benefits analysis. The second option listed would likely necessitate extra trips through the field. Extra trips through a field imposes a burden beyond just the time it takes a grower to make the extra trip because growers must clean equipment before switching to another chemical. Also, environmental factors (e.g., wind and rain) and equipment availability may further limit the feasibility of making separate applications to buffers. Beyond the increased application costs, growers would potentially also incur the impacts from using alternatives, as with the first option. Yield or quality losses would be highly likely if the buffer area was left completely untreated as with the third option. In some situations, these losses may be large enough that it is no longer worth cultivating the buffer and growers remove the land from production.

Spray drift buffers can affect a substantial portion of a field, especially when fields are small. Larger buffers impact a larger proportion of the field than smaller buffers. To characterize the effect that buffers may have on growers, BEAD shows how different sizes of no-spray buffers can impact growers who want to use mancozeb on different sized fields (Table 7). To illustrate the effect of a buffer, consider a rectangular field with length equal to twice its width, with the buffer on the long side of the field. In this scenario, the field is immediately adjacent to the sensitive area. A 50-foot buffer results in the loss of about 3% of a 100-acre field, but 34% of a 1-acre field. If the buffer were to fall on the short side, the affected area would be substantially less. Irregularly shaped fields could be affected substantially more. In situations where the field to be treated is not immediately adjacent to the protected area, the part of the field affected by the spray buffers is smaller/narrower than if the field edge is immediately next to the habitat.

Table 7. Percent of fields* of various sizes lost to in-field buffers of various sizes.

Field Size (Acres)	1	10	50	100
Buffer Size	Percent of Field Impacted by Buffer			
25 Feet	12%	4%	2%	1%
50 Feet	34%	11%	5%	3%
100 Feet	68%	21%	10%	7%

*Calculations based on a rectangular field with length equal to twice its width, with the in-field buffer on the long side of the field.

EPA may only require spray drift buffers when winds are blowing in the direction of a non-target site. In this case, growers will have the additional option to apply mancozeb in the buffer area when winds are not blowing towards a non-target site. This would increase grower flexibility, reducing the burden of imposing spray drift buffers that are not wind directional. However, if growers wait for the wind to blow away from the non-target site to apply mancozeb, they may risk missing the opportunity to apply mancozeb in a timely manner for effective disease control.

Growers who do not currently own a device for measuring wind speed and wind direction will have to purchase and install a windsock, an anemometer, or an aircraft smoke system. There are likely differences in cost in purchasing each of these technologies. BEAD expects that purchasing and installing a windsock is the least expensive option, followed by an anemometer and an aircraft smoke system. There are likely minimal differences in the complexity to interpret the wind speed and wind direction outputs generated by these technologies. BEAD does not anticipate impacts to users of mancozeb who already own and use a windsock, an anemometer, or an aircraft smoke system to detect the sustained wind speed and/or direction at the application site.

EPA may require smaller buffers when using drift reduction tools for applications made by groundboom, such as hooded sprayers or windbreaks and shelterbelts. This would reduce the burden of the mitigation by giving growers additional flexibility in applying mancozeb; however, growers may incur some up-front costs to use these tools, which may not be worthwhile for smaller buffers. The burden of purchasing a hooded sprayer or installing windbreaks and shelterbelts may be greater for smaller operations, which may face higher per-acre costs for equipment and potentially higher financing costs.

Use of Bulletins Live! Two Labelling

EPA may require that growers obtain and follow Bulletins Live! Two (BLT) ahead of an application of mancozeb. This internet-based system will inform the user of additional label requirements that they need to follow when making an application of mancozeb in their specific geographic area. Because some of the mitigation measures needed to protect threatened and endangered species (referred to as listed species) may be applicable only in particular geographic regions where listed species occur, and/or because listed species may require different mitigations for the of mancozeb to protect them from exposure, a physical label that contains all the mitigation information would be many pages long and difficult to use. The complexity of a paper label would likely be compounded by the future changes to the listed species and their ranges. To simplify this process, EPA will provide information on what mitigations are required for each application site depending on its location in Bulletins Live! Two (BLT). This online tool will assist pesticide users in identifying the mitigations relevant to their situation instead of requiring the user to conduct this effort themselves.

The BLT system has been in place for many years but the requirement to access BLT before using a pesticide is relatively new for many pesticide products. As discussed in the ESA Workplan Update issued by the Agency in November 2022, the requirement to access BLT will eventually apply to most pesticides (EPA, 2022). Therefore, over time and with wider implementation, BLT will become a tool that growers are familiar with, and consulting BLT ahead of a pesticide application will become routinely integrated into a user's application process. Growers must obtain the relevant bulletin and check for additional mitigation no earlier than six months prior to the intended application. Some requirements may be more stringent measures than the potential mitigation measures described in this memo and could even prohibit use for the designated area. If land use practices (additional mitigation measures) are required, growers may need substantial time (potentially more than six months) and careful planning to implement them. Growers must obtain the relevant bulletin and check for additional mitigation no earlier than six months prior to the intended application. Some requirements may be more stringent in a Pesticide Use Limitation Area and could even prohibit use for the designated area. If land use practices (additional mitigation measures) are required, growers may need substantial time (potentially more than six months) and careful planning to implement them. The requirement to obtain and follow Bulletins that could change over time, adds additional complexity and uncertainty for operating a farm business.

A recent USDA (2023) report on farm computer usage and ownership reported that 85 percent of farms have internet access, and a similar proportion of farms own smart phones and/or computers. However, fewer farms reported using the internet to conduct business. As mentioned earlier, growers not accustomed to accessing BLT as a part of their regular farm business, especially those not used to using online tools to conduct business could face a learning curve, but with time and as users become acquainted with this system, this burden will diminish.

<u>Mitigation Measures for Preventing Runoff/Erosion</u>

The Agency is considering the inclusion of a menu of mitigation options to reduce field runoff or erosion of mancozeb treated fields to protect terrestrial/aquatic animals in adjacent waterbodies or specified conservation areas. Mitigation options may include for example, use of a vegetative filter strip, field terracing, or use of a cover crop. EPA may require growers to use one or more mitigation measure(s) on fields receiving applications of mancozeb regardless of production acreage.

A menu of mitigation options offers flexibility to growers to adopt practices that are best suited to their fields rather than requiring that all users of mancozeb to adopt the exact same runoff mitigations. However, several options on the menu of mitigation have substantial burdens associated with implementation. For instance, vegetative filter strips (VFS) take land out of production and are also costly to establish and maintain. The establishment costs for VFS range from $165-$927 per acre of VFS, and maintenance costs range from $40-$240 annually per acre of VFS (USDA OPMP, 2018). Additionally, not all practices are feasible for all fields. For example, terraced fields are not able to be implemented on flat ground. While some of the menu of mitigation practices can be implemented on an annual basis (e.g., cover cropping), other menu mitigation practices require significant planning and require some engineering to implement (e.g., runoff retention pond). Once the growing season has started, none of the practices can be feasibly adopted without substantial interruptions to production. Growers will need to carefully plan their pest management programs to adopt runoff/erosion mitigations and will lose some flexibility in changing pest management programs in response to unexpected pest pressures. This menu of mitigation will not impose a burden on any grower who is already using one or more of the practices from the menu of mitigation.

Growers who rent or lease land may be constrained in their ability to implement mitigations, especially structural mitigations (*e.g.*, terraces, vegetative filter strips) due to the terms of existing rental agreements. Determining whether the landlord or tenant will bear the costs of implementing mitigations may further complicate the ability of farmers who rent or lease land to implement mitigations. If growers who rent or lease land are unable to implement land modifications for runoff reduction, then they may be unable to use mancozeb, facing impacts as described in the benefits section.

CONCLUSION

Mancozeb is a broad-spectrum multisite pesticide that is used to control fungal, bacterial, and oomycete pests in agricultural and non-agricultural use sites. This memorandum described the use, usage, benefits, alternatives, and potential impacts from mitigation for mancozeb in various registered vegetable crops including lettuce, garlic, onions, broccoli, cabbage, and asparagus.

- Mancozeb is the most used fungicidal control for downy mildew in lettuce production, and a large percentage of lettuce acres are treated with mancozeb. And though several single site fungicides are available for downy mildew control, mancozeb is the only multisite fungicide available with acceptable efficacy. Mancozeb enhances disease control when applied with other chemistries and works to prevent or delay resistance in single site fungicides which can be highly efficacious but resistant prone. In addition, mancozeb is less expensive than other alternatives. Thus, the benefits of mancozeb in lettuce production are considered high.
- Mancozeb is the most used fungicidal treatment for downy mildew and purple blotch in onion and garlic production, and a substantial amount of these crop's acreage is treated with mancozeb. Considering current disease prevention in these crops, mancozeb has high benefits nationally, but especially in New York where about 98% of all onion acres were treated with mancozeb. In the absence of mancozeb, growers may be able to use chlorothalonil but at a reduced efficacy and possible yield loss, in addition to paying a higher cost for recommended and multiple single site fungicides.
- Currently, mancozeb benefits in brassica production are low, in part because there are two other multisite fungicides available (*i.e*., chlorothalonil and copper), and chlorothalonil is reportedly more efficacious than mancozeb.
- The benefits of mancozeb in national asparagus production are likely low; though benefits may be a little higher in California and Washington, where the majority of mancozeb is used in asparagus. If mancozeb were unavailable, growers would likely switch to chlorothalonil with no expected yield loss because chlorothalonil is a recommended treatment for both diseases.

Chlorothalonil, the primary multi-site alternative to mancozeb in these crops, is currently undergoing registration review and there are proposed annual rate reductions for all crops analyzed in this memo, except for lettuce. In circumstances where proposed mitigation may decrease the annual maximum application rate of chlorothalonil, the importance and benefits of mancozeb may increase (EPA, 2023).

EPA has identified occupational human health risks of concern from use of mancozeb in vegetable crops. To reduce these risks, the Agency is considering risk mitigation measures such as increasing crop-specific restricted entry intervals (REI) to protect workers entering a treated field. For pesticide applicators, the Agency may require an Assigned Protection Factor 10 (APF10) respirator and use of double layer clothing for foliar applications of mancozeb. For workers mixing and loading pesticides, the requirement of a closed loading system is being considered when utilizing dry flowable and wettable powder formulations for use in aerial and chemigation applications. A closed loading system may entail the requirement that these formulations come in closed packaging that can be inserted into water in a pesticide delivery system and mixed with the container closed.

The impacts of these potential mitigations are described below.

- REIs of five days or more in onion and garlic will be highly impactful during periods when insect pest pressure is high in these crops, due to the need to scout every 3-5-days. In such a case, if insects could not be controlled, yield loss would be expected. This impediment would likely result in growers using a fungicide that has less of an REI restriction but may not be as efficacious, possibly leading to yield loss.
- Increasing REIs in broccoli and cabbage are likely low because growers have more efficacious multisite alternatives which means mancozeb provides low benefits, and there are several single site fungicides that can be used, albeit some may be more expensive.
- The cost of an APF10 respirator and the associated fit test cost may have an economic impact on growers that do not already use this type of respirator. The double layer clothing requirement could result in heat stress during times of high temperatures and/or humidity, effecting the applicators health and prolonging the time needed for applications.
- Requiring a closed loading system will increase packaging costs and may also require that applicators utilize equipment that can agitate/ mix while the system is closed. Costs of mancozeb use will therefore increase if this requirement were to apply. While growers could opt to switch to utilizing a liquid formulation, it is more expensive than the dry flowable and wettable powder formulations.

Additionally, EPA has identified bystander and ecological risks of concern from use of mancozeb in vegetable crops. To reduce these risks, the Agency may consider mitigation designed to lessen the likelihood of pesticide drift, this mitigation could include restrictions on windspeed, droplet size, applications during wet weather, application buffers, and groundboom height. Mitigation to reduce bystander exposure, as described above, is considered sufficient to address most ecological risks. However additional mitigation may be needed to further reduce ecological risks, including the mandatory use of Bulletins Live! Two to protect non-target species.

The impacts of these potential mitigations are described below.

- Restrictions that require a medium to courser droplet size, disallowance of applications during periods of rain, and a 3-foot groundboom height are seen as best production practices for these crop sites, so there should be little to no impact to growers that use mancozeb in vegetable production as described in this memo.
- A 10-mph wind speed maximum may prevent the timely application of mancozeb, potentially resulting in impacts to growers if alternative fungicides cannot be used to effectively manage diseases in these crops.
- A requirement for application buffers may require that growers treat the buffer portion of the field with an alternative fungicide that does not have this requirement or leave the field untreated. In either scenario, growers are likely to have costs associated with a

second application of an alternative fungicide or suffer yield losses in the untreated buffer area. The overall effect will vary depending on the size of the field affected and the impacts could be high.

- Even though Bulletins Live! Two has been in place for many years, the requirement that a grower access and follow Bulletins is relatively new. Therefore, users may face a learning curve when becoming acquainted with the system. Moreover, growers may be subject to additional and potentially more stringent mitigation measures than those described in this memo which can require significant planning and may be costly to implement and maintain. Therefore, users may face a learning curve when becoming acquainted with the system. Moreover, growers may be subject to additional and potentially more stringent mitigation measures than those described in this memo which can require significant planning and may be costly to implement and maintain.

The Agency is considering the inclusion of a menu of mitigation options to reduce field runoff or erosion of mancozeb treated fields to protect terrestrial/aquatic animals in adjacent waterbodies or specified conservation areas.

- These strategies may have an economic impact, dependent on which strategy is adopted, as some measures can be quite costly. No impact is expected for growers that already have a sufficient number of mitigation strategies in place.

REFERENCES

Aegerter, B.J. and R.M. Davis. 2009. UC IPM Pest Management Guidelines: Asparagus. A University of California publication. Accessed January 2024. Available at: https://ipm.ucanr.edu/agriculture/asparagus/rust/

Boucher, J. 2012. Two Common, Late-Season, Cole Crop Diseases. A University of Connecticut publication. Accessed June 2024. Available at: https://ipm.cahnr.uconn.edu/two-common-late-season-cole-crop-diseases/

Bradford, B.Z., Colquhoun, J.B., Chapman, S.A., Gevens, A.J., Groves, R.L., Heider, D.J., Nice, G.R.W., Ruark, M.D., and Y. Wang. 2023. Commercial Vegetable Production in Wisconsin. A University of Wisconsin-Madison publication. Accessed April 2024. Available at: https://learningstore.extension.wisc.edu/products/commercial-vegetable-production-in-wisconsin

Egel, D. 2021. Ten Useful Rules for Fungicide Applications. Accessed February 2024. Available at: https://vegetablegrowersnews.com/news/10-useful-rules-for-fungicide-applications/

Egel, D. 2023. Diseases. Published in the Midwest Vegetable Production Guide. Accessed February 2024. Available at: https://mwveguide.org/uploads/pdfs/2023-MW-Veg-Guide-full-draft-20221020.pdf

EPA (Environmental Protection Agency). 2022. ESA Workplan Update: Nontarget Species Mitigation for Registration Review and Other FIFRA Actions, November 2022. Available at: https://www.epa.gov/system/files/documents/2022-11/esa-workplan-update.pdf

Environmental Protection Agency (EPA). 2023. Chlorothalonil Proposed Interim Registration Review Decision Case Number 0097. Docket # EPA-HQ-OPP-2011-0840). Available at: https://www.regulations.gov/document/EPA-HQ-OPP-2011-0840-0141

Fetzer, L. 2023. Farm Respiratory Protection. A PennState Extension publication. Accessed March 2024. Available at: https://extension.psu.edu/farm-respiratory-protection

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

Fungicide Resistance Action Committee (FRAC). 2018. Importance of multisite fungicides in managing pathogen resistance. Accessed February 2024. Available at: https://www.frac.info/docs/default-source/publications/statement-on-multisite-fungicides/frac-statement-on-multisite-fungicides-2018.pdf?sfvrsn=3c25489a_2

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

Grisso, R., Askew, S.D., McCall, D. 2019. Virginia Polytechnic Institute and State University. Nozzles: Selection and Sizing. Available at: https://vtechworks.lib.vt.edu/bitstream/handle/10919/93422/BSE-262.pdf

Hansel, J., C. Chen, R. Waterworth, W. Opgrand, and R. Fovargue. 2023. EPA Memorandum: Chlorothalonil (PC Code 081901) Use, Usage, Pest Management Benefits, and Impacts of Potential Mitigation for Agricultural Use Sites. Available at: https://www.regulations.gov/document/EPA-HQ-OPP-2011-0840-0148

Hartman, J. and K. Seebold. 2005. Phosphrous Acid Fungicides Explained. A University of Kentucky publication. Accessed April 2024. Available at: https://www.uky.edu/Ag/kpn/kpn_05/pn050613.htm

Hausbeck, M. 2014. Downy Mildew and Purple Blotch are Here in Michigan Onion Fields. A Michigan State University publication. Accessed January 2024. Available at: https://www.canr.msu.edu/news/downy_mildew_and_purple_blotch_are_here_in_michigan_onion_fields

Hoepting, C. 2020. VEGEdge. A Cornell Cooperative Extension publication. Accessed June 2024. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://rvpadmin.cce.cornell.edu/pdf/v eg_edge/pdf200_pdf.pdf

Hoepting, C. 2022. Brassicas, Alternaria Leaf Spot. A University of Massachusetts Amherst publication. Accessed February 2024. Available at: https://ag.umass.edu/vegetable/fact-sheets/brassicas-alternaria-leaf-spot

Hoepting, C. 2023a. The 2023 Cornell Onion Fungicide Cheat Sheet for Control of Leaf Diseases in New York. A Cornell Cooperative Extension and Vegetable Program publication. Accessed April 2024. Available at: https://cvp.cce.cornell.edu/submission.php

Hoepting, C. 2023b. Fungicide “Cheat Sheet” for Alternaria Leaf Spot and Head Rot in Broccoli and Other Cole Crops, 2023. A Cornell Cooperative Extension publication. Accessed June 2024. Available at: https://rvpadmin.cce.cornell.edu/uploads/doc_1029.pdf

Hoidal, N. 2023. Alternaria Leaf Spot and Head Rot of Brassica Crops. A University of Minnesota publication. Accessed June 2024. Available at: https://extension.umn.edu/disease-management/alternaria-leaf-blight/

Johnson, A.T. 2016. Respirator masks protect health but impact performance: a review. Journal of Biological Engineering 10:4, DOI 10.1186/s13036-016-0025-4. Accessed July 2018. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4748517/pdf/13036_2016_Article_25.pdf

Kahn, B.A., Rebek, E.J., and J.P. Damicone. 2017. Cole Crop Production (Broccoli, cabbage, and Cauliflower). An Oklahoma State University Extension publication. Accessed January 2024. Available at: https://extension.okstate.edu/fact-sheets/cole-crop-production.html

Koike, S.T., and K.V. Subbarao. 2007a. Alternaria Leaf Spot. UC IPM Pest Management Guidelines: Cole Crops. A University of California publication. Accessed January 2024. Available at: https://ipm.ucanr.edu/agriculture/cole-crops/alternaria-leafspot/

Koike, S.T., and K.V. Subbarao. 2007b. Downy Mildew. UC IPM Pest Management Guidelines: Cole Crops. A University of California publication. Accessed January 2024. Available at: https://ipm.ucanr.edu/agriculture/cole-crops/downy-mildew/

Koike, S.T. and K.V. Subbarao. 2008. Cole Crops Pest Management Guidelines: Downy Mildew. A University of California publication. Accessed June 2024. Available at: https://ipm.ucanr.edu/agriculture/cole-crops/downy-mildew/#gsc.tab=0

Koike, S.T. and T.A. Turini. 2017. UC IPM Pest Management Guidelines: Lettuce. Accessed January 2024. Available at:

https://ipm.ucanr.edu/agriculture/lettuce/downy-mildew/#gsc.tab=0

Kynetec USA, Inc. 2022a. "The AgroTrak® Study from Kynetec USA, Inc." iMap Software. Database Subset: 2017-2021 [Accessed June 2023].

Kynetec USA, Inc. 2022b. "The AgroTrak® Study from Kynetec USA, Inc." Microsoft Access Database. Database Subset: 2017-2021 [Accessed June 2023].

Legault, M. and P.D. Ayers. 2007. Agricultural Respiratory Protective Equipment – 5.020. A Colorado State University Extension publication. Accessed March 2024. Available at: https://extension.colostate.edu/topic-areas/agriculture/agricultural-respiratory-protective-equipment-5-020

Mahr, S. no date. Leeks. A University of Wisconisn publication. Accessed June 2024. Available at: https://hort.extension.wisc.edu/articles/leeks/

Masabni, J. and P. Lillard. 2009. Leeks and Shallots. Subsections In the Texas Vegetable Handbook Guide. A Texas A&M AgriLife publication. Accessed June 2024. Available at: https://aggie-horticulture.tamu.edu/vegetable/guides/specialty-vegetables/shallots/

Matheron, M.E. 2015. Biology and Management of Downy Mildew of Lettuce. A University of Arizona College of Agriculture & Life Sciences, Cooperative Extension publication. Accessed January 2024. Available at: https://cales.arizona.edu/crop/vegetables/advisories/docs/az1682-2015.pdf

O'Brien, C., L.A. Blanchard, B.S. Cadarette, T.L. Endrusick, X. Xu, L.G. Berglund, M.N. Sawka, and R.W. Hoyt. 2011. Methods of Evaluating Protective Clothing Relative to Heat and Cold Stress: Thermal Manikin, Biomedical Modeling, and Human Testing. Journal of Occupational and Environmental Hygiene 8: 588-599.

Ocamb, C.M. 2024a. Cabbage and Cauliflower (*Brassica oleracea*) - Downy Mildew (Staghead). A Pacific Northwest Pest Management Handbook publication. Accessed June 2024. Available at: https://pnwhandbooks.org/plantdisease/host-disease/cabbage-cauliflower-brassica-oleracea-downy-mildew-staghead

Ocamb, C.M. 2024b. Cabbage and Cauliflower (*Brassica oleracea*) – Alternaria Diseases (Black Spot, Gray Leaf Spot, Pod Spot). A Pacific Northwest Pest Management Handbook publication. Accessed June 2024. Available at:https://pnwhandbooks.org/plantdisease/host-disease/cabbage-cauliflower-brassica-oleracea-alternaria-diseases-black-spot-gray-leaf-spot-pod-spot

Oklahoma State University. 2023. Cercospora Blight of Asparagus. An Oklahoma State University Extension publication. Accessed January 2024. Available at: https://extension.okstate.edu/programs/digital-diagnostics/plant-diseases/cercospora-blight-of-asparagus.html

Reeves, E., Sharpe, S., and I. Meadows. 2021. Downy Mildew on Brassica Crops. A North Carolina State Extension publication. Accessed April 2024. Available at: https://content.ces.ncsu.edu/downy-mildew-on-brassica-crops

Rutgers University. 2024. 2022/2023 Mid-Atlantic Commercial Vegetable Production Recommendations, 2024/2025. Rutgers New Jersey Agricultural Experiment Station. Accessed January 2024. Available at: https://njaes.rutgers.edu/pubs/publication.php?pid=e001

Scheufele, S. 2021. Lettuce, Downy Mildew. A University of Massachusetts Extension Vegetable Program publications. Accessed January 2024. Available at: https://ag.umass.edu/vegetable/fact-sheets/lettuce-downy-mildew

Smearman, S. and D. Berwald. 2024. Estimates by the Biological and Economic and Analysis Division, Office of Pesticide Programs, Environmental Protection Agency and available upon request.

Smart, C. and M. Suderman. 2024. Alternaria Leaf Spot of Brassicas. A Cornell Colleg of Agriculture and Life Sciences publication. Accessed June 2024. Accessed at: https://www.vegetables.cornell.edu/pest-management/disease-factsheets/alternaria-leaf-spot-of-brassicas/#:~:text=Fungicides%20are%20available%20to%20help,York%20include%20chlorothalonil%20and%20azoxystrobin.

Swett, C.L., Aegerter, B.J., Turini, T.A., and A.I. Putman. 2019a. Onion and Garlic Pest Management Guidelines: Down Mildew. A University of California publication. Accessed January 2024. Available at: https://ipm.ucanr.edu/agriculture/onion-and-garlic/downy-mildew/#:~:text=To%20reduce%20the%20incidence%20and,leaf%20wetness%20between%20irrigation%20events.

Swett, C.L., Aegerter, B.J., Turini, T.A., and A.I. Putman. 2019b. Onion and Garlic Pest Management Guidelines: General Properties of Fungicides. A University of California publication. Accessed January 2024. Available at: https://ipm.ucanr.edu/agriculture/floriculture-and-ornamental-nurseries/general-properties-of-fungicides/

Tindall, K. and Hanson, C. 2018. Qualitative Benefits and Usage Assessment of Diflufenzopyr (PC Code 005108) and Diflufenzopyr-Sodium (PC Code 005107). Available at: https://www.regulations.gov/document/EPA-HQ-OPP-2011-0911-0022

University of Massachusetts. 2024. Cabbage, Broccoli, Cauliflower, and Other Brassica Crops. A New England Vegetable Management Guide published by the University of Massachusetts Amherst. Accessed April 2024. Available at: https://nevegetable.org/crops/cabbage-broccoli-cauliflower-and-other-brassica-crops

United States Department of Agriculture (USDA). 2023. Technology Use (Farm Computer Usage and Ownership). Published August 17, 2023. Available at:

https://downloads.usda.library.cornell.edu/usda-esmis/files/h128nd689/4j03fg187/fj237k64f/fmpc0823.pdf

USDA NASS (USDA National Agricultural Statistics Service). 2022 Census of Agriculture. Accessed February 2024. Complete data available at: www.nass.usda.gov/AgCensus

USDA OPMP (United States Department of Agriculture, Office of Pest Management Policy). 2018. Comments on the National Marine Fisheries Service Biological Opinion Issued under Endangered Species Act: Chlorpyrifos, Diazinon, and Malathion. (EPA-HQ-OPP-2018-0141). Available online: https://www.regulations.gov/document?D=EPA-HQ-OPP-2018-0141-0106

USDA OPMP (United States Department of Agriculture, Office of Pesticide Management Program). 2022. This citation represents a statement made by USDA OPMP following an EPA inquiry into the usage, application methods, and alternatives of mancozeb. Inquiry submitted to USDA OPMP 09/28/2021 and feedback was received 01/2022.

Wyenandt, A. 2017. Controlling Important Fungal Diseases in Asparagus During the Summer. A Rutgers Cooperative Extension publication. Accessed June 2024. Available at: https://plant-pest-advisory.rutgers.edu/controlling-important-fungal-diseases-in-asparagus-during-the-summer/