EPA Inquiry

Captan, Usage, Application Methods and Benefits—Multiple Crops and Ornamentals
December 7, 2020

Request from EPA

Questions for USDA on the Use of Captan

Introduction

Captan is a fungicide that is currently undergoing EPA's registration review. The BEAD team assigned to this pesticide is currently in the process of analyzing the benefits and usage of captan. The results of this analysis will inform the development of a risk assessment and mitigation strategy that will be described in a Proposed Interim Decision (PID), which is scheduled for completion in June 2021. The BEAD team has developed a set of detailed use-site specific questions, which have been provided below. The captan team is looking for specific information on current crop production practices. We are specifically interested in information about application methods and rates, product formulation usage, and the timing of post-application activities. We are interested in knowing how large of an area is typically treated with captan in a day. Our primary focus is on orchard crops, grapes, berries, ginseng, and ornamentals. Finally, we are interested in determining if captan is still used in seed treatments, particularly on-farm treatments, and as a preplant root dip for peaches. Please include in your response the production region or state that your response pertains to.

Questions for Stone Fruit:

Cherries (all types), but please specify if the response pertains to use of captan in tart or sweet cherries

1. Is hand thinning a common production practice in cherries? If so, what is the typical frequency and timing of hand thinning relative to crop growth stage?
2. Is chemical or mechanical thinning a commercially feasible option for cherries? Please explain.
3. How common is hand harvest in either type of cherry? It is our understanding that tart cherries are usually mechanically harvested – if this is incorrect, please let us know.
4. Please provide details on the application timing and frequency of captan use in cherries.
    a. How many days before **hand thinning** and **harvest** is captan applied?
    b. How frequently is captan applied during the **hand thinning** and **harvest** periods?
    c. If captan is applied multiple times during the **hand thinning** and **harvest** periods, how many days elapse between applications in each period of worker activity?
    d. How frequently is captan applied between **hand thinning** and **harvest**? If more than once, how many days are there between successive captan applications?
5. The Agency notes that most of the use of captan is in the dry flowable formulation when applied to cherries. What are the strengths and weaknesses of the dry flowable formulation? What, if any, are the strengths and weaknesses of the wettable powder and liquid formulations?
6. Are there post-harvest uses of captan as a fruit dip for cherries of any type? If so, what are the use characteristics? Is this use specific to a particular geographic region and how common is it? Are there alternatives to captan for post-harvest fruit dip? What are the advantages and disadvantages of any alternatives to captan for post-harvest fruit dip in cherries?
7. What are the important target pests of captan in cherries? What are potential alternatives to captan for these pests?
8. What are the advantages and disadvantages of captan relative to other alternatives in cherries?

Peaches and Nectarines

1. Is captan used as a preplant dip treatment for crown gall prevention in peaches? Does captan have efficacy against crown gall? Are there alternatives to captan to prevent crown gall in peach roots? What are their advantages and disadvantages?
2. Is hand thinning a common production practice in peaches and/or nectarines? What is the typical frequency and timing of hand thinning relative to crop growth stage?
3. Is chemical or mechanical thinning or harvest commercially feasible options for peaches/nectarines? Please explain.
4. Please provide details on the application timing and frequency of captan in peaches and nectarines.
    a. How many days before **hand thinning** and **harvest** is captan applied?
    b. How frequently is captan applied during the **hand thinning** and **harvest** periods?
    c. If captan is applied multiple times during the **hand thinning** and **harvest** periods, how many days elapse between applications in each period of worker activity?
    d. How frequently is captan applied between **hand thinning** and **harvest**? If more than once, how many days are there between successive captan applications?
5. The Agency notes that most of the use of captan is in the dry flowable formulation when applied to peaches. What are the strengths and weaknesses of the dry flowable formulation? What are, if any, strengths and weaknesses of the liquid and wettable powder formulations?
6. Are there post-harvest uses of captan as a fruit dip for peaches or nectarines? If so, what are the use characteristics? Is this use specific to a particular geographic region and how common is it? Are there alternatives to captan for post-harvest fruit dip? What are the advantages and disadvantages of any alternatives to captan for post-harvest fruit dip in peaches and nectarines?
7. What are the important target pests of captan in peaches/nectarines? What are potential alternatives to captan for these pests?
8. What are the advantages and disadvantages of captan relative to other alternatives in peaches/nectarines?

Plums/Prunes

1. Is hand thinning a common production practice in plums/prunes? What is the typical frequency and timing of hand thinning relative to crop growth stage?
2. Is chemical or mechanical thinning or harvest a commercially feasible option for plums/prunes? Please explain.
3. Please provide details on the application timing and frequency of captan in plums/prunes.
    a. How many days before **hand thinning** and **harvest** is captan applied?
    b. How frequently is captan applied during the **hand thinning** and **harvest** periods?
    c. If captan is applied multiple times during the **hand thinning** and **harvest** periods, how many days elapse between applications in each period of worker activity?
    d. How frequently is captan applied between **hand thinning** and **harvest**? If more than once, how many days are there between successive captan applications?
4. The Agency notes that most of the use of captan is in the dry flowable or wettable powder formulation when applied to plums and prunes. What are the strengths and weaknesses of the dry flowable and wettable powder formulations? What are, if any, strengths and weaknesses of these formulations? When would a grower choose to use the liquid formulation and why might it be used?
5. Are there post-harvest uses of captan as a fruit dip for plums/prunes? If so, what are the use characteristics? Is this use specific to a particular geographic region and how common is it? Are there alternatives to captan for post-harvest fruit dip? What are the advantages and disadvantages of any alternatives to captan for post-harvest fruit dip in plums and prunes?

6. What are the important target pests of captan in plums/prunes? What are potential alternatives to captan for these pests?
7. What are the advantages and disadvantages of captan relative to other alternatives in plums/prunes?

Questions for Pome Fruit:

1. For apple production - how does captan usage differ between traditional orchards and trellis systems? Please explain.
2. What are the practices/timing around hand harvesting? Does this vary by region? Is mechanical thinning commercially feasible?
3. Is hand thinning a common production practice in apples? What is the typical frequency and timing of hand thinning relative to crop growth stage? (Note: same question for cherry, etc. in the above)
4. What are the important target pests for captan use in apples (Western versus Eastern production)? What are potential alternatives to captan for these pests? What are the advantages and disadvantages of captan relative to other alternatives?
5. Are there post-harvest uses of captan as a fruit dip for apple and pears? If so, what are the use characteristics? What percent of the crop is treated post-harvest? Is this use specific to a particular geographic region? Are there alternatives to captan for post-harvest fruit dip?

Questions for Blueberries:

1. Which captan formulations are favored by blueberry growers? Please explain why certain formulations are preferred over others.
2. What application methods (e.g., airblast, broadcast, groundboom, aerial) do blueberry growers typically use when applying captan? Why?
3. How many times is captan typically applied to blueberries per season? How long do growers wait between captan applications?
4. What are the important target pests of captan in blueberries? What are potential alternatives to captan for these pests?
5. What are the advantages and disadvantages of captan relative to the alternatives in blueberries?

Questions for Caneberries:

1. Which captan formulations are favored by caneberry growers? Please explain why certain formulations are preferred over others.
2. How many times is captan typically applied to caneberries per season? How long do growers wait between each captan application?
3. What are the important target pests of captan in caneberries? What are potential alternatives to captan for these pests?
4. What are the advantages and disadvantages of captan relative to the alternatives in caneberries?

Questions for Grapes:

1. Which captan formulations are favored by grape growers? Can you please explain why certain formulations are preferred over others? Does this preference vary depending on grape (table, wine, etc.)?
2. How many times is captan typically applied to grapes per season? How long do growers wait between each captan application? When during the season are these applications made?
3. Can you comment on what in-field worker activities (including vine tying, training, cane turning, cane girdling, and hand harvesting) usually occur around the time when captan is typically applied to grapes? Does this vary depending on type of grape?

4. Relative to the maximum label rate for a single application, what rate of captan is usually applied by grape growers?
5. What application methods (e.g., airblast, groundboom) do grape growers typically use when applying captan?
6. If responding for wine and juice grapes: (when) do vine tying, training, and leaf pulling occur? If responding for table or raisin grapes: (when) do vine tying, training, leaf pulling, cane turning, and girdling occur? In all grapes, does hand harvesting occur?

Questions for Strawberries:

1. What strawberry pests are controlled by captan?
2. What is the timing of captan application in strawberries? Please explain.
3. What are the advantages and disadvantages of different formulations (dry flowable, wettable powder and liquid) of captan fungicides? Please explain.
4. Are there differences in the efficacies of different formulations of captan in controlling the target fungal pests? Please explain.
5. What alternatives fungicides with multi-site mode of action are available to growers for resistance management in addition to captan? What are the advantages and disadvantages of using captan over other multisite fungicides?

Questions for Ornamental Nurseries:

EPA has little information on the importance and use of captan in nursery ornamental production and would appreciate any information to address the following questions.

1. Is captan used in the following use sites: potted nursery ornamentals; field grown ornamentals; greenhouses? For what use sites is captan most important? Please explain
2. What formulation(s) is used? Please explain.
3. What are the important target pests for captan in nursery ornamental production? What are potential alternatives to captan for these pests?
4. What are the advantages and disadvantages of captan relative to other alternatives?
5. What is the typical single application rate of captan used in ornamental nurseries (in pounds of active ingredient per acre)?
6. Are higher application rates of captan needed for certain situations? Please explain.
7. What is the typical retreatment interval of captan in days?
8. What is the typical number of applications of captan per year?
9. What is the maximum and typical area treated with captan in a day?
10. What application methods are used to apply captan in ornamental nurseries, e.g., groundboom, backpack sprayer, mechanically pressurized handgun, or other type of equipment? Are applications soil-directed or foliar?
11. If used to treat cuttings, tubers and/or corms as a dip tank treatment, how much captan solution volume is typically prepared and used in a day? How much volume is handled by each worker?
12. Are irrigation system components typically handled by workers after a captan application? If yes, how many days after a captan application would workers wait to handset an irrigation system?

Questions for Ginseng [Food Use]:

EPA has little information on the importance and use of captan in ginseng production and would appreciate any information to address the following questions.

1. What are the important target pests for captan in ginseng production? Please explain.
2. What formulation(s) is used? Please explain.

3. What are potential alternatives to captan for these pests?
4. What are the advantages and disadvantages of captan relative to other alternatives?
5. What is the typical single application rate used in ginseng production (in pounds of active ingredient per acre)?
6. Are higher application rates needed for certain situations? Please explain.
7. What is the typical retreatment interval in days?
8. What is the typical number of applications per year or season?
9. What is the maximum and typical area treated with captan in a day?
10. What application methods are used to apply captan in ginseng production? Is it applied by groundboom, backpack sprayer, mechanically pressurized handgun, or any other type of equipment? Are applications soil-directed or foliar?
11. Are irrigation system components typically handled by workers after a captan application? If yes, how many days after a captan application would workers wait to handset an irrigation system?

Questions for Residential Landscape Ornamentals:

EPA has little information on the importance and use of captan in ornamental residential landscapes and would appreciate any information to address the following questions.

1. On what residential ornamentals is captain used? What formulation(s) is used? Please explain.
2. What are the important target pests for captan in residential landscapes? What are potential alternatives to captan for these pests? What are the advantages and disadvantages of captan relative to other alternatives?
3. What is the typical single application rate used in residential landscapes (in pounds of active ingredient per acre or per square footage)?
4. Are higher application rates needed for certain situations? Please explain.
5. What is the maximum and typical area treated with captan in a day?
6. What is the typical retreatment interval in days?
7. What is the typical number of applications per year?
8. What application methods are used to apply captan in ornamental landscapes? What equipment is typically used? Are applications soil-directed or foliar?
9. Do you have knowledge if homeowners usually apply captan on their own?

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USDA Synthesis of Responses

General USDA Comments:

Cherries:

Hand thinning is rare in the commercial production of sweet and tart cherry varieties. There are niche situations (such as in the production of Rainiers, which are a high-value sweet cherry variety produced in the Pacific Northwest) where hand-thinning is plausible, but not widespread. While mechanical thinning options are being researched for cherries, most thinning is generally done using chemicals. Generally, hand-thinning appears to be uncommon, and reentry intervals (REI) are unlikely to affect the early season use of captan.

In the Pacific Northwest, numerous consultants informed USDA that captan is not frequently used on cherries. By contrast, our communication with a Professor in Penn State's Fruit Research and Extension Center suggests that captan appears to be more frequently used on, and more important to, operations growing cherries east of the Mississippi river.

Although there are some exceptions (e.g. sweet cherries grown for processing in Michigan and tart cherries, such as 'Balaton' cherries, which are sold fresh), hand-harvesting tends to be more common in sweet cherry production systems, and mechanical harvesting tends to be more common in tart cherry production systems. USDA contends that REI intervals that preclude use of captan near harvest time could adversely affect 1) a small number of tart cherry producers and 2) sweet cherry producers located east of the Mississippi River. Cherry producers located in the Pacific Northwest are unlikely to be affected.

Both the usage and the application frequency of captan varies regionally. Many growers prefer not to use captan close to harvest time, because dry formulations of captan tend to leave visual residues that marketers and customers find unappealing. However, as fungi and diseases evolve resistance to fenbuconazole, some growers may increase their use of captan despite this concern. Ultimately, USDA believes that it is important to maintain growers' ability to apply captan near harvest. Doing otherwise may force growers to become over-reliant on single-site conventional alternatives and exacerbate resistance issues. Notably, there are some regions in which a single application of captan during the growing season may be adequate. However, depending on disease pressure and favorable environmental conditions for disease development, some growers may make 4-5 captan applications during the growing season before harvest, on a 7-10 day interval.

For areas that commonly use captan east of the Mississippi, the dry flowable (DF) formulation appears to be preferred because the wettable powder (WP) formulation is messy for mixing and loading, although it is cheaper. The liquid formulation is also reported to depreciate equipment and it is not stable when it is stored in the container. No respondents in any region reported using captan as a post-harvest dip for cherries of either type. Common target diseases and alternatives for cherries are summarized in tables 1-4.

Peaches/Nectarines:

Though captan is registered to control crown gall in California, captan is not a known bactericide, and crown gall is caused by a bacterial pathogen. Thus, it seems unlikely that captan would be commonly used for this purpose. A biological product, *Agrobacterium radiobacter* is available to control crown gall (EPA Reg. No. 40230-1), but respondents did not have much experience with it because crown gall is rarely a problem for peach producers, or for nectarine producers. None of the respondents to OPMP's queries reported using captan prior to planting to control crown gall.

Hand-thinning is extremely common in peach and nectarine production. While chemical thinning has been researched for some time, and mechanical thinning of blossoms or young fruit with string thinning machines can be beneficial, neither of these tactics are adequate to properly manage crop load and fruit spacing consistently. Hand-thinning is unavoidable in the vast majority of circumstances. Typically, hand-thinning takes place from post-bloom or shuck split until pit hardening or shortly thereafter, which corresponds to approximately 4-5 weeks after petal fall. captan tends to be applied a week to 10 days after shuck split. Thus, there is overlap between the periods that hand-thinning is employed and that captan is applied. Typically, there are 1-2 applications of captan during thinning periods. The interactions OPMP had with Professors and extension specialists suggests that any REI over 24 hours would limit the ability to effectively hand-thin fruit and would be devastating for peach and nectarine producers.

The typical number of applications of captan can depend heavily on the cultivar, as early-maturing varieties may require only 2-3 applications, while late maturing varieties can require as many as 8 cover sprays. The spray intervals can depend on the season and weather conditions, with 7-10 day intervals in the early cover sprays after shuck split and 10-14 day intervals later on. Across the board, respondents reported almost no captan would be used in the 21 days prior to harvest as it can negatively impact fruit finish (despite the chemical having a zero-day PHI).

Many peach and nectarine growers prefer the flowable or liquid formulations of captan over the wettable powder, but none of the respondents OPMP contacted reported a difference in the efficacy of these formulations. Liquid formulations have been reported to be hard on equipment. No respondents indicated that captan was ever used in post-harvest fruit dips or sprays. The most commonly used post-harvest tools on peaches include fludioxinil and propiconazole. Common target diseases and chemical alternatives on peaches and nectarines are summarized in tables 5-7.

Plums/Prunes

Hand thinning is not a common practice in plum or prune production. While most plums and prunes are grown in California, there is also a small fresh market plum/prune industry in the eastern United States. A Professor in Penn State's Fruit Research and Extension Center indicated that for the eastern United States, most captan-related usage questions would have the same answers regardless of whether they were asked to plum, prune, or cherry producers.

In California, growers typically only thin prunes mechanically and hand thinning is not practiced. Notably, all captan use in California prunes is pre-bloom, so there is no overlap between the time periods when captan is applied and when hand thinning takes place. There is no reported captan use on plums or prunes post-harvest.

Generally, plum/prune growers have the same concerns about captan formulations as peach and cherry growers. One respondent indicated that storage stability is a problem for the liquid captan formulations. Consequently, many producers prefer the dry flowable formulations. Common target diseases and chemical alternatives for plums are summarized in tables 8-10.

Pome Fruit:

Outreach conducted by OPMP suggests that captan is not used in pome fruit production as frequently in the Pacific Northwest as it is in the eastern United States, where it is relied upon very heavily in apples as a linchpin disease and resistance management tool. This may be due to concerns about captan's phytotoxicity.

Captan use is generally similar in traditional orchards and high-tree-density trellis production systems. However, there appears to be a broad consensus that the open canopy density found in high-tree-density trellis systems makes it easier to get good captan coverage at lower spray volumes. Relative to tree row volume, this can sometimes lead to lower pounds of captan per acre than traditional orchards with larger trees. However, because orchard layouts are highly variable, existing label rates are needed to meet growers' needs. Generally speaking, common diseases and disease management needs do not differ much between traditional/standard orchards and trellis production systems.

In terms of pre-harvest usage, captan is generally not a preferred choice for late season fruit rot control. In part, this may be because captan does not have systemic activity, in part it may be because captan leaves a visible residue on fruit. In the eastern United States, captan is an important option during cover-spray programs in the spring and summer, but it is used very rarely at or near harvest time. Though captan is infrequently applied west of the Mississippi river, USDA's outreach suggests that it may be used at or near harvest time in the Pacific Northwest.

Though methods of mechanical thinning pome fruit are being researched, these methods are not in widespread use. Chemical thinning of blossoms or fruit is relatively common, but does not obviate the need for hand-thinning. Particularly for high-value fresh market varieties, proper apple spacing and crop load management is critically important, not just for fruit quality, but also return-bloom the following season. Therefore, while not all growers thin by hand, retaining the flexibility to do so is critically important. One stakeholder contacted by USDA estimated that almost all apple and 'Bartlett' pear acreage in the Pacific Northwest is thinned by hand, during the summer and early fall, at least once during the multi-year production cycle. Other stakeholders indicated that thinning would take place early in the growing season. Generally, USDA's outreach suggests that pome fruit producers need the flexibility to hand-thin their varieties. USDA believes that any increase in REI for captan on apples would be crippling for growers. Other tasks conducted during the window that captan is applied include: tree training, summer pruning, and the deployment of hand-applied mating disruption dispensers.

In the Pacific Northwest, captan is commonly applied after harvest. It may not be a primary option in most cases, as single-site AI are preferred. A Professor in Washington State University's Plant Pathology Department indicated that captan is less expensive than some of the alternatives, and that is can be a better choice for short-term than for long-term disease/fungal control during storage. He estimated that approximately 70% of fruit are treated with a post-harvest fungicide, but did not know what percentage of these fungicides were captan-based. A Penn State Professor indicated that adding captan to post-harvest dump tank mixes could help prevent common post-harvest diseases, such as blue mold, from evolving resistance to fungicides. Alternatives to captan (for post-harvest disease/fungal control) include pyrimethanil and fludioxinil.

During the growing season, captan plays an indispensable role in preventing the development of fungicide resistance. It is particularly important in controlling apple scab, bitter rot, black rot, white rot, sooty blotch, and flyspeck control in the eastern United States. As a multi-site protectant AI, it is a critical backstop option that is not as prone to resistance as many of the single-site alternatives. In years of high disease pressure where growers may use up their seasonal allowance of other alternatives, captan is also a useful 'gap-filler' in summer disease programs. It is commonly tank mixed for efficacy and resistance management benefits.

Notably, captan is also effective against Marssonina blotch, a relatively new disease that is becoming increasingly problematic for pome fruit producers in the eastern United States. While some researchers are interested in moving away from protectant active ingredients, products such as captan, ziram, and mancozeb remain critically important apple disease management tools. Common target diseases and chemical alternatives for pome fruit are summarized in tables 11-13.

Blueberries/Caneberries:

USDA's outreach suggests that captan is widely viewed as a critically important and indispensable fungicide in blueberry and caneberry production systems. Growers tend to prefer using the flowable, water dispersible granule (WDG) and the liquid formulations of captan to the wettable powder, in part because using the WDG and liquid formulations reduces the risks associated with dust exposure. In the southeastern United States, a respondent preferred to use the combination product "CaptEvate" for Botrytis control after sporadic freeze damage events during bloom. A commercial stakeholder with an operation in the Pacific Northwest noted that the liquid formulation of captan is used to meet export requirements for caneberries.

Most blueberry producers that use captan apply it using ground airblast or ground boom application equipment. Outreach suggests that airblast applications may be more common in the southeastern United States and that ground boom applications may be more common in the Pacific Northwest. Some growers use hand-held equipment on smaller acreage, so retaining access to these application methods is important for blueberries and caneberries.

The application frequency of captan varies considerably by region, and is influenced by disease pressure, favorable conditions for disease development and resistance management considerations. When used in blueberry production to control Botrytis, 1-5 captan applications (with a 10-14 day treatment interval) between bloom and harvest are common. In the southeastern United States, a stakeholder indicated that 6-7 applications per season were common. In the Pacific Northwest, 8-10 applications may be necessary when disease (e.g. mummy berry and Botrytis) pressure is high, but 4 applications made prior to harvest is more typical. Additional applications can be made post-harvest.

When captan is used in caneberry production, application frequencies are similar to those described above. Growers tend to make 1-6 applications between bloom and harvest, depending on disease pressure. Under heavy disease pressure, the treatment intervals can be short (7-10 days), while longer intervals are more common under moderate pressure (10-14 days).

Generally speaking, as with other crops, a primary benefit of captan use on berries is that it is a broad-spectrum protectant with a multi-site mode of action. It is also relatively inexpensive. Outreach suggests that there is not a comparable product that has captan's efficacy, low cost, and resistance management benefits. Common target diseases and chemical alternatives for blueberries and caneberries are summarized in tables 14-19.

Strawberries:

In strawberry production, captan is widely regarded as a critical tool for disease management in the United States. Botrytis fruit rot, anthracnose fruit rots, and leaf spot diseases are the major fungal diseases controlled by captan. In Florida, captan is also used to control *Gnomonia comari,* which causes leaf blotch and stem-end rot disease. One stakeholder describes captan as '… the absolute strategic backbone of Florida strawberry production'. Another stakeholder stressed that 'captan has been a staple product in our business for over 30 years. It continues to exhibit the results we need, which ultimately contributes to our ability to reach peak production, year over year.' A stakeholder located in Florida indicated that captan is usually applied preventatively during weeks when weather conditions are mild and not as conducive to disease development, so that single-site, curative active ingredients can be reserved for periods in the growing season when weather conditions make plants particularly vulnerable. While thiram is an alternative multi-site option for strawberries, captan tends to provide better control and is used more widely and frequently by producers. Ultimately, retention of both captan and thiram is critical for fungicide resistance management in strawberries.

Though the timing of captan applications depends on growers' management practices, disease pressure, and weather, it is typically applied between harvests, once every 3-5 days. There could be as many as 14-21 days between applications and captan applications are often followed by applications of other active ingredients. In California, captan tends to be applied when inclement weather make strawberries more vulnerable to disease. It is also used near harvest time to reduce Botrytis infections that occur during storage and transport. During an extended harvest season (up to 6 months or more) fungicide applications can be made on a 7 to 14 day interval. Captan is often used for this purpose, either alone or tank-mixed with other fungicides. On average, 7-8 applications of captan are made per season.

OPMP's outreach does not suggest that strawberry growers strongly prefer one captan formulation over another. The efficacy of these formulations are generally observed to be similar. There is some evidence that liquid or flowable formulations are preferable to wettable powders.

As was previously discussed, thiram is the only available multi-site alternative to captan, but continued access to both active ingredients is critically important, given the need for season-long disease control in strawberry production. Common target diseases and chemical alternatives for strawberries are summarized in tables 20-22.

Grapes:

Insofar as product formulations are concerned, wettable powders are commonly used both east and west of the Mississippi river. There is also evidence suggesting that granular formulations are used on operations located in the eastern United States. Outreach suggests that variables affecting the choice of formulation include: cost/price, availability, tank-mix compatibility, and overall familiarity. Formulation choices do not appear to be affected by the type of grape produced (wine, table, etc.).

Typically, 1-3 applications of captan are made each season, during bloom to post-bloom stages and early berry set to softening/sugaring stages. The number of captan applications, and the spray intervals, depend on the grape variety, disease pressure, and environmental conditions favorable for disease development (as indicated on the label). The number of applications also depend on the REI, PHI, and resistance management guidelines.

Stakeholders reported that “captan applications could potentially occur during all in-field worker activities (i.e., vine tying, training, shoot thinning, leaf removal (pulling), shoot positioning, cluster thinning, and hand harvesting) depending on variety and disease pressure. This is less so for juice grapes, which are mechanically harvested and have less hand-management intervention than wine grapes. That said, field activities for wine grapes are increasingly mechanized, for example, cluster zone leaf removal done late June to early July used to be done entirely by hand, now is mostly mechanized. Generally, shoot thinning precedes usage period for captan. Very few growers do manual cluster thinning (Gold et al., Cornell and Penn State).”

While stakeholders also indicated that growers are typically able to schedule field activities around the current 3-day REI for captan, extended REIs may interfere with some of these activities. USDA received a separate inquiry from BEAD regarding recent changes to modern table grape trellising systems, and how those relate to the occurrence of girdling and other cultural practices. We believe the information provided to EPA on July 13, 2020 in response to that request would be relevant to captan as well. Ultimately, any increases in REI for captan would likely adversely affect growers and jeopardize the practical utility of captan as a disease management tool on grapes.

Typically, the label rate corresponding to medium or average disease pressure is used in the east for all captan formulations. Airblast methods of application appear to be the most commonly employed. For juice and wine grapes in the east, vine tying and training occur during the dormant stage (about May). Notably, shoot thinning (May), leaf pulling (June-July), shoot positioning (June-August), and cluster thinning (June-August), take place during time periods in which captan is commonly applied to wine grapes. Hand harvesting occurs in both the western and eastern United States.

Ginseng:

The vast majority of commercial U.S. ginseng production occurs in the upper Midwest (Michigan and Wisconsin). In ginseng production, captan is used to control *Phytophthora cactorum*, a destructive soil-borne pathogen that reduces yields and root quality by causing foliar diseases and root rot.

A Professor and Extension Specialist at Michigan State University states that captan is essential because it is inexpensive, does not cause MRL violations, and because there are limits on the number of applications that can be made using captan alternatives such as mandipropamid, fluopicolide, oxathiapiprolin: “Mandipropamid, fluopicolide, oxathiapiprolin [are alternatives to captan]. However, the number of applications are limited and do not cover the lengthy growing season as preventive applications are needed. These alternative products require alternation with fungicides of different modes of action to prevent development of resistance and adhere to the label requirements [and restrictions]. Captan is a cost-effective fungicide whose label allows up to 7 applications per season. The use of captan has not resulted in MRL violations. Captan is highly effective against Phytophthora spp. The other chemical products listed are also used in alternation with Captan but are more expensive, more restricted in the number of applications that can be used, and possible MRL violations are of concern.”

Captan tends to be applied by ground-boom. Applications are made using spray volumes and pressures intended to ensure that captan reaches the crown of the plant. Commercial ginseng is not irrigated, so there are not any re-entry concerns related to handling hand-set irrigation equipment. In terms of typical application practices, the Professor and Extension Specialist of Michigan State University states that:

"Typical (average) acreages would likely be approximately 2 acres (ranging from 0.5 to 20 acres per day). Maximum could be 50 acres but would apply to just 2-3 growers. The issue is that the largest percentage of growers are small with <10 acres and 25% of the growers having <5 acres. There are three growers that have more than 100 acres but less than 300 acres. However, with the amount of water in their sprayers (approx. 100 gal) they cannot cover much ground in a day because they have to return to refill. Also, these sprayers are custom made to travel under the garden's cover so they look really strange (low to the ground) and don't cover a whole lot of acreage like the sprayers for other crops. In regards to the rate, growers could use a lower rate preventively (approximately 80% of the maximum) early in the year and if the pressure builds or the weather becomes wet, they would go to the full rate."

Often, ginseng sprayers are customized to accommodate the height of the shade cover. The boom is also modified to fit between the structural supports.[1] Considering this unique design, and given experts' estimates of the typical and maximum daily acreage treated, USDA suggests that EPA's default treatment assumption of 80 acres per handler for groundboom applications to typical field crops would tend to overestimate the occupational exposure associated with ginseng production.

In most cases, captan is applied to ginseng at the label max rate of 3.75lbs per acre, with re-application intervals of 2-3 weeks, and 6 total applications per season. Common target diseases and chemical alternatives for ginseng are summarized in tables 23 and 24.

Ornamentals:

OPMP outreach suggests that captan is applied in very small quantities in ornamental nurseries and residential landscape ornamentals. In the landscape industry, captan has been displaced by newer and more effective fungicides. In the nursery industry, captan is applied to younger ornamentals and seedlings following label directions, restrictions, and precautionary measures.

Seed Treatments:

Captan-based seed treatments are surface protectants with broad spectrum activity that target seed surface-borne and soilborne pathogens. Captan-based seed treatments provide good control of damping-off disease caused by Rhizoctonia and Pythium spp. and fair control of Fusarium spp.

OPMP outreach suggests that not much captan is used in the seed treatments applied to major crops such as corn, soybean, and cereals. Captan is registered for seed treatment use on cereals and soybeans but used as a drill box application. Generally, growers have moved to newer chemistries to deploy in their seed treatment mixtures. See tables 25 and 26 for information on the benefits of captan as a seed treatment.

[1] The following video shows a custom ginseng sprayer manufactured in Wisconsin: https://www.youtube.com/watch?v=qvNItmZR9xY.

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Tables

Cherries

Table 1. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in sweet cherries grown west of the Mississippi River

Fungicide (FRAC Code[2])	**Common Diseases on Sweet Cherries[1]**			
	Brown Rot	**Leaf Spot**	**Powdery Mildew**	**Shothole (fungal)**
Multisite Fungicides				
Captan (M4)		G		G
Chlorothalonil (M5)				G
Sulfur (M2)	G	G	G	
Ziram (M3)		G		G
Single Site Fungicides				
Thiophanate-methyl (1)	F-G			
Fenbuconazole (3)	G-E		P	
Flutriafol (3)				
Metconazole (3)				
Myclobutanil (3)			P	
Propiconazole (3)	G		F	
Tebuconazole (3)	F-G		F-G	
Triflumizole (3)			G	
Penthiopyrad (7)			F-G	G
Trifloxystrobin (11)	F-G	F-G	F-G	
Fenhexamid (17)	F-G			
Metrafenone (50)			F	
Quinoxyfen (13)			G-E	
Premix Formulations				
Trifloxystrobin + fluopyram (11 + 7)			G-E	
Pyraclostrobin + fluxapyroxad (11 + 7)			G	
Pyraclostrobin + boscalid (11 + 7)	G	?	G	?

[1]Efficacy Rating scale**:** **E** = excellent (90–100% control) **G** = good (80–90% control) **F** = fair (70–80% control) **P** = poor (< 70% control) **?** = efficacy unknown; more research needed

[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2

Source: Murray and Jepson (2018).

Table 2. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in sweet cherries grown east of the Mississippi River

Product and formulation / Active Ingredient	FRAC Code[2]	Common Diseases of Sweet Cherries[1]			
		Black Knot	Brown rot	Cherry Leaf spot	Powdery mildew
Abound (SC) / azoxystrobin	11	x	G[r]	x	G
Bravo Weather Stik / chlorothalonil	M5	E	F-G	E	G
Cabrio EG (20EG) / pyraclostrobin	11	x	F-E	x	E
Captan 80WDG / captan	M4	x	G	F-G	x
CaptEvate 68WDG / captan + fenhexamid	M+17	x	E	G	x
Cevya / mefentrifluconazole	3	x	E	E	E
C-O-C-S WDG / copper oxychloride	M1	E	F	F	x
Cuprofix Ultra 40 Disperss / basic copper sulfate	M1	E	F	F	P
Elevate 50WDG / fenhexamid	17	x	G-E	x	x
Elite 45DF / tebuconazole	3	x	E [r]	E-G[r]	G[r]
Flint Extra / trifloxystrobin (higher rate)	11	x	E	E	E
Fontelis (SC) / penthiopyrad	7	x	E	F-G	G
Gatten / flutianil	U13	x	x	x	E
Indar 2F / fenbuconazole	3	x	E[r]	E[r]	G[r]
Inspire Super (EW) / difenoconazole + cyprodinil	3+9	x	E	x	E
Kenja 400SC / isofetamid	7	x	E	x	x
Kocide 3000 / copper hydroxide	M1	E	G-F	G	F
Luna Experience (SC) / fluopyram + tebuconazole	7+3	x	G-E	x	E

Luna Privilege fluopyram	7	E	E-G	s	G
Luna Sensation (SC) fluopyram + trifloxystrobin	7+11	x	E	E-G	G
Merivon XBF fluxapyroxad + pyraclostrobin	7+11	x	E	E-G	G
PhD polyoxin D	19	x	x	x	G
Pristine pyaclostrobin + boscalid	7+11	x	G	E	E
Procure 480SC2 triflumizole	3	x	G	G[r]	E
Quadris Top azoxystrobin + difenoconazole	11+3	x	E	F-G	G
Quash metconazole	3	x	G	G[r]	E
Quilt Xcel azoxystrobin + propiconazole	11+3	x	E	G	G
Quintec (2 .08F) quinoxyfen	13	x	x	x	G
Rally 40WSP2 myclobutanil	3	x	E	E[r]	E
Rovral 4F iprodione	2	x	E	F-G	E
Microthiol Disperss sulfur	M2	x	F	x	G
Syllit F2 dodine	U12	x	G	G	x
Tilt (EC) propiconazole	3	x	G[r]	G[r]	E[r]
Topguard Specialty Crop flutriafol	3	x	E	G	G
Topsin M70 WSB 2 thiophanate-methyl	1	E	G	F-G	F[r]
Vanguard WG (75WG) cyprodinil	9	x	G	x	u
Ziram 76DF ziram	M3	E	F-i	F-i	x

[1]Efficacy Rating: E= excellent control; G=good control; F= fair control. [r] = Fungicide/Insecticide resistance possible. s= suppression only, i= not effective, u= effectiveness unknown, x= pest not on the label
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Midwest Fruit Pest Management Guide 2021-2022.

Table 3. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in tart cherries grown in Michigan

Management Tools	Diseases of Tart Cherries in Michigan					
	Brown rot (blossom blight)	Brown rot (fruit rot)	Cherry leaf spot	Powdery Mildew	Black Knot	Bacterial canker
Organophosphates and Carbamates register Ed in MI						
captan (Captan)	F	F	F	N	N	–
chlorothalonil (Bravo)	F-G	–	E	N	E	–
iprodione (Rovral)	E	N	N	–	–	–
Sterol inhibiting fungicides						
fenarimol (Rubigan)	N	N	F	G	–	–
fenbucanazole (Indar)	E	E	F	G	–	–
myclobutanil (Nova)	E	–	F	E	–	–
propiconazole (Orbit)	E	E	F	F	–	–
tebuconazole (Elite)	E	E	F	G	N	–
Alternative products registered in MI						
dodine (Syllit)	–	P	G	N	–	–
ferbam (Carbamate) + sulfur	–	F	F	F	–	–
Fixed coppers	–	–	E	F	P	F
Sulfur	F	P	P	F	F	–
thiophanate-methyl (Topsin-M)	–[a]	–[a]	–[a]	F	F	–
Alternative products registered in MI (cont.)	**Brown rot (blossom blight)**	**Brown rot (fruit rot)**	**Cherry leaf spot**	**Powdery mildew**	**Black knot**	**Bacterial canker**
cyprodinil (Vangard)	G	N	N	N	N	N
Ziram	F	F	P	–	–	
NewerChemistries						
trifloxystrobin (Gem)	E	G	E	G	–	N
pyraclostrobin + boscalid (Pristine)	N	G	E	E	–	N

[1]Control ratings: e = excellent, g = good, f = fair, p = poor, and n = not labeled or no activity against this pest.

–[a] = widespread resistance to benomyl and thiophanate-methyl in Michigan, neither fungicide is recommended for this use.

Table 4. Advantages and disadvantages of captan relative to the conventional alternatives in the management of diseases in cherries.

Fungicide (FRAC Code)	Advantages	Disadvantages
Multisite Fungicides		
Captan, bloom only (M4)	-Low risk for resistance -Broad spectrum -Inhibits spore germination	-Bloom applications with fair control of brown rot -Contact mode of action and coverage critical -Not compatible with oil at bloom -No effect on sporulation
Chlorothalonil, bloom only (M5)	-Bloom applications with fair to good control of brown rot -Low risk for resistance -can be applied on trees after harvest -Broad spectrum -Inhibits spore germination	-Contact mode of action and coverage critical -Not compatible with oil at bloom -Unknown effect on sporulation
Copper-based (M1)	-Low risk for resistance -Broad spectrum -Bactericidal and fungicidal -Inhibits spore germination	-Poor efficacy on brown rot -Contact mode of action and coverage critical -Can cause leaf bronzing and russeting -Do not apply when temperatures are predicted to exceed 80°F -Do not apply later than white bud stage, flower injury can occur -No effect on sporulation
Sulfur (M2)	-Low risk for resistance -can be used between petal and harvest -Fungicidal and insecticidal -Vapor active -Inhibits spore germination	-Poor efficacy on brown rot -Contact mode of action and coverage critical -Not compatible with oil at bloom -must be reapplied frequently in wet seasons -No effect on sporulation
Ziram (M3)	-Low risk for resistance -Broad spectrum -Inhibits spore germination	-No effect on sporulation
Single Active Ingredients		
Thiophanate-methyl (1)	-systemic mobility -broad spectrum of activity -inhibits mycelial growth and sporulation	-High risk for resistance
Iprodione (2)	-systemic mobility -inhibits mycelial growth and sporulation	-Medium to high risk for resistance

Difenoconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Fenbuconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Flutriafol (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not used in PNW
Metconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Myclobutanil (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-Fair control of brown rot
Tebuconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Triflumizole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-Go-to product in PNW
Propiconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-Used in rotation to compensate for plant growth regulation in PNW
Penthiopyrad (7)	-Good control of brown rot -Systemic mode of action -Reduced risk fungicide -Broad spectrum	-Medium to high risk for resistance -Reduced efficacy is noted in the last 1–2 years in PNW
Cyprodinil (9)	-medium resistance risk -reduced risk fungicide -local systemic mobility -inhibits mycelial growth and suppresses spore germination	-narrow spectrum of activity -no effect on sporulation

Pyrimethanil (9)	-medium resistance risk -reduced risk fungicide -local systemic mobility -inhibits mycelial growth and suppresses spore germination	-narrow spectrum of activity -no effect on sporulation
Azoxystrobin (11)	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-High risk for resistance -Known to cause phytotoxicity on certain apple cultivars -no effect on sporulation
Pyraclostrobin (11)	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-High risk for resistance -not used in PNW
Trifloxystrobin (11)	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high risk for resistance -no effect on sporulation
Fludioxonil (12)	-Low to medium risk for resistance -Reduced risk fungicide -Inhibits mycelial growth and germination; reduces sporulation	-Postharvest use only -Contact mode of action
Fenhexamid (17)	-low to medium resistance risk -reduced risk fungicide -systemic mobility inhibits spore germination and mycelial growth	-Narrow spectrum -No effect on sporulation
Polyoxin-D (19)	-broad to narrow spectrum of activity -medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth -reduced risk fungicide -systemic mode of action	
Fosetyl-al (P07)	-low resistance risk -foliar applications provide systemic treatment -systemic mobility -inhibits mycelial growth and suppresses sporulation	Not efficacious on brown rot
Dodine (U12)	-low to medium risk for resistance -broad spectrum of activity -systemic mobility	-prolonged humidity or slow drying conditions following the application of dodine may result in fruit russet
Pre-Mixture Formulations		
Azoxystrobin/difenoconazole (11/3)	-Good to excellent control of brown rot -Built in resistance management	-Azoxystrobin component known to cause phytotoxicity on certain apple cultivars
Azoxystrobin/propiconazole (11/3)	-Good to excellent control of brown rot -Built in resistance management -Broad to narrow spectrum	-Azoxystrobin component known to cause phytotoxicity on certain apple cultivars

Cyprodonil/difenoconazole (9/3)	-Good to excellent control of brown rot -Built in resistance management	
Fluopyram/tebuconazole (7/3)	-Good to excellent control of brown rot -Built in resistance management -Broad to narrow spectrum	
Boscalid/pyraclostrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Broad spectrum	
Fluopyram/trifloxystrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Broad spectrum	Used early for powdery mildew due to MRL issues in PNW
Fluxapyroxad/pyraclostrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Broad spectrum	-Up to 2 weeks before harvest, do not use with crop oil concentrate (COC), methylated seed oil (MSO) adjuvants -Within 2 weeks of harvest, use with nonionic adjuvants that do not acidify and/or enhance penetration -Used early for powdery mildew due to MRL issues in PNW; expensive

Sources: Murray and Jepson (2018), Midwest Fruit Pest Management Guide 2021-2022, and Tart Cherry Pest Management Strategic Plan, 2006.

Peaches/Nectarines

Table 5. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in peaches and nectarines grown west of the Mississippi River

Fungicide (FRAC Code[2])	Common Diseases of Peaches and Nectarines[1]						
	Brown Rot (Blossom)	Brown Rot (Fruit)	Powdery mildew	Scab	Rust	Leaf curl	Shot hole
Multisite Fungicides							
Captan (M4)	++	++	----	+++	----	----	+++
Copper (M1)	+/-	----	----	----	----	+++	+++
Sulfur (M2)	+/-	+/-	+++	+++	+++	----	----
Thiram (M3)	+/-	----	----	+++	----	++++	+++
Ziram (M3)	+/-	----	----	+++	----	++++	+++
Chlorothalonil (M5)	++	----	----	+++	+	+++	+++
Single Site Fungicides							
Thiophanate-methyl (1)	++++	++++	+++	+++	+	----	----
Iprodione (2)	+++	NL	----	----	----	----	----
Iprodione (2) + oil	++++	NL	+	+	++	----	++
Fenbuconazole (3)	++++	++++	+++	++	ND	----	+/-
Flutriafol (3)	+++	++	+++	ND	ND	----	+
Metconazole (3)	++++	++++	+++	ND	+++	----	+++
Myclobutanil (3)	+++	+++	++++	----	----	----	----
Propiconazole (3)	++++	++++	+++	++	+++	----	+/-
Tebuconazole (3)	++++	++++	+++	++	+++	----	+
Penthiopyrad (7)	++++	+++	++++	+++	ND	----	+++
Cyprodinil (9)	++++	+++7	ND	ND	ND	----	+
Pyrimethanil (9)	++++	+++7	ND	ND	ND	----	+
Azoxystrobin (11)	++	+	++	++++	+++	----	++
Triloxystrobin (11)	++	+	++	++++	+++	----	++
Dicloran (14)	++	+	ND	ND	ND	ND	ND
Fenhexamid (17)	+++	+++	ND	ND	ND	ND	ND
Polyoxin-D (19)	++	++	++	ND	ND	ND	ND
Dodine (U12)	+	----	-----	+++	----	++	+++
Premix Formulations							

Tebuconazole/fluopyram (3/7)	++++	++++	+++	----	+++	----	+/-
Difenoconazole/cyprodinil (3/9)	++++	++++	+++	++	ND	----	+/-
Difenoconazole/azoxystrobin (3/11)	++++	++++	+++	----	+++	----	+/-
Propiconazole/azoxystrobin (3/11)	++++	++++	+++	----	+++	----	+/-
Fluopyram/trifloxystrobin (7/11)	++++	++++	+++	+++	+++	ND	++++
Fluxapyroxad/pyraclostrobin (7/11)	++++	++++	+++	+++	+++	ND	++++
Boscalid/pyraclostrobin (7/11)	++++	++++	+++	+++	ND	ND	++++

[1]Efficacy Rating: ++++ = excellent and consistent, +++ = good and reliable, ++ = moderate and variable, + = limited and/or erratic, +/- = minimal and often ineffective, ---- = ineffective, ND = no data, and NL = not on label
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Adaskaveg et al. (2017).

Table 6. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in peaches and nectarines grown east of the Mississippi River

	Common Diseases of Peaches and Nectarines[1]							
Fungicide [FRAC Code[2]]	**Leaf curl**	**Blossom blight**	**Scab**	**Anthracnose**	**Red spot**	**Sooty peach**	**Brown rot**	**Rhizopus rot**
Multisite Fungicides								
Captan [M4]	-	++	++++	+++	-	++	+++	+
Coppers [M1]	+++	-	-	-	-	-	-	-
Sulfur [M2]	-	+	+++	-	-	-	+	-
Ferbam [M3]	+++++	-	-	-	+++	-	-	-
Thiram [M3]	+++	-	-	-	+++	-	-	-
Ziram [M3]	+++	-	+	-	+++	+++	-	-
Chlorothalonil [M5]	++++	+++	++++	-	-	-	-	-
Single Site Fungicides								
Thiophanate-methyl [1]	-	++++ Resistance a threat	++++ Resistance a threat	-	-	-	+++ Resistance a threat	-
Iprodione [2]	-	++++	-	-	++	++	-	-
Tebuconazole [3]	-	+++++	-	-	-	-	+++++ Resistance a threat	-
Metconazole [3]	-	+++++	-	-	-	-	+++++ Resistance a threat	-
Fenbuconazole [3]	-	+++++	++	-	-	-	+++++ Resistance a threat	-
Mefentrifluconazole [3]	-	+++++	++	-	-	-	+++++ Resistance a threat	-
Myclobutanil [3]	-	+++	-	-	-	-	+ Resistance a threat	-
Propiconazole [3]	-	++++	-	-	-	-	++++ Resistance a threat	-

Flutriafol [3]	-	++++	-	-	-	-	++++ Resistance a threat	-
Penthiopyrad [7]	-	++++	++	+	-	-	++++ Resistance a threat	+
Cyprodinil [9]	-	++++	-	-	-	-	-	-
Pyrimethanil [9]	-	++++	-	-	-	-	-	-
Azoxystrobin [11]	-	-	++++ Resistance a threat	++++	-	-	++++ Resistance a threat	-
Trifloxystrobin [11]	-	-	++++ Resistance a threat	++++	-	-	++++ Resistance a threat	-
Fludioxonil [12]	-	-	-	-	-	-	+++++	++++
Dicloran [14]	-	+	-	-	-	-	+	++
Premix Formulations								
Difenoconazole/cyprodinil [3, 9]	-	+++++	+++	?	-	-	+++++	?
Difenoconazole/cyprodinil [3, 9] plus propiconazole [3]	-	+++++	+++	++++	-	-	+++++	?
Pyraclostrobin/fluxapyroxad [11, 7]	-	++++++	++++	++++	-	-	++++++	+++
Trifloxystrobin/fluopyram [11, 7]	-	++++++	++++	++++	-	-	++++++	+++
Pyraclostrobin/boscalid [11, 7]	-	+++++	++++	++++	-	-	+++++	+++
Azoxystrobin/difenoconazole [11, 3]	-	++++	++++	+++	-	-	++++	++

[1]Efficacy Ratings: (++++++ = superior; +++++ = excellent, ++++ = good, +++ = fair, ++ = poor, + = suppression, - = no benefit)
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: 2021 Southeastern Peach, Nectarine, and Plum Pest Management and Culture Guide.

Table 7. Advantages and disadvantages of captan relative to the conventional alternatives in the management of diseases in peaches and nectarines.

Fungicide (FRAC Code)	Advantages	Disadvantages
Multisite Fungicides		
Captan (M4)	-low risk for resistance -broad spectrum of activity -inhibits spore germination -cover sprays the previous growing season less affected by leaf curl (southeast) -cover sprays reduces brown rot of fruits (eastern) -the fungicide of choice for suppression of gummosis (southeast) -use during the cover sprays is recommended where anthracnose is a problem (southeast) -more efficacious than sulfur, thiram and ziram for both scab and brown rot control -few spray incompatibilities -as dormant treatment, highly effective for shot hole control	-not effective if used as a dormant treatment -do not use in combination with or shortly before or after oil treatment -weak against powdery mildew -use of captan too close to harvest has been associated with inking and discoloration of fruit -oil and captan cause phytotoxicity (northeast) -captan residues on peaches at harvest may cause increased skin discoloration from abrasions that occur during picking and packing (northeast) -captan will be most effective in sprays solutions when the pH is 5.0; the higher the pH, the less effective captan will be -combinations with sulfur may result in increased injury under high temperatures and high relative humidity -no systemic action -no effect on sporulation
Copper (M1)	-low risk for resistance -broad spectrum of activity -inhibits spore germination -as dormant treatment, highly effective for shot hole control	-no systemic action -no effect on sporulation
Sulfur (M2)	-low risk for resistance	-do not use in combination with or shortly before or after oil treatment -may result in increased injury under high temperatures and high relative humidity -can flare up mites -no systemic action -no effect on sporulation
Thiram (M3)	-low risk for resistance -broad spectrum of activity -inhibits spore germination	-or use on peach only; not registered on nectarine -no systemic action -no effect on sporulation
Ziram (M3)	-low risk for resistance -broad spectrum of activity -inhibits spore germination -ziram is the preferred fungicide for sooty peach (southeast) -as dormant treatment, highly effective for shot hole control	-no systemic action -no effect on sporulation
Chlorothalonil (M5)	-low risk for resistance -broad spectrum of activity -inhibits spore germination	-do not use in combination with or shortly before or after oil treatment -do not use after jacket (shuck) split -no systemic action -severe eye irritant -unknown effect on sporulation
Single Site Fungicides		

Thiophanate-methyl (1)	-systemic mobility -broad spectrum of activity -inhibits mycelial growth and sporulation	-high risk for resistance
Iprodione (2)	-systemic mobility -inhibits mycelial growth and sporulation	-blossom blight only; not registered for use after petal fall -medium to high resistance risk
Fenbuconazole (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Flutriafol (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not effective if used as a dormant treatment
Metconazole (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not effective if used as a dormant treatment -for shot hole management, dormant treatments with copper, ziram, and dodine are highly effective; petal fall treatments should be used to complement the management program
Myclobutanil (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Propiconazole (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation -postharvest fruit registrations in California (Section 18) -propiconazole is not registered for use in cover sprays (southeast)	
Tebuconazole (3)	-medium risk for resistance -systemic mode of action -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not registered, label withdrawn or inactive in California
Penthiopyrad (7)	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-not effective if used as a dormant treatment -for shot hole management, dormant treatments with copper, ziram, and dodine are highly effective; petal fall treatments should be used to complement the management program -medium to high resistance risk-unknown effect on sporulation
Cyprodinil (9)	-medium risk for resistance -systemic mode of action -inhibits mycelial growth and suppresses spore germination -reduced risk fungicide	-high summer temperatures and relative humidity reduce efficacy -no effect on sporulation

Pyrimethanil (9)	-postharvest fruit registrations in California (Section 18) -medium risk for resistance -systemic mode of action -inhibits mycelial growth and suppresses spore germination -reduced risk fungicide	-high summer temperatures and relative humidity reduce efficacy -no effect on sporulation
Azoxystrobin (11)	-systemic mode of action -reduced risk fungicide -broad spectrum of activity -inhibit spore germination	-high risk for resistance -no effect on sporulation -phytotoxic to certain apple varieties
Triloxystrobin (11)	-systemic mode of action -reduced risk fungicide -broad spectrum of activity -inhibit spore germination	-high risk for resistance -no effect on sporulation
Dicloran (14)	-low to medium risk for resistance -systemic mode of action	
Fenhexamid (17)	-low to medium resistance risk -reduced risk fungicide -systemic mobility inhibits spore germination and mycelial growth	-narrow spectrum of activity -no effect on sporulation
Polyoxin-D (19)	-medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth	-no effect on sporulation
Dodine (U12)	-low to medium risk for resistance -systemic action -as dormant treatment, highly effective for shot hole control	-resistance known in *Venturia inaequalis.*
Premix Formulations		
Fluopyram/tebuconazole (3/7)	-medium risk for resistance built in formulation for broader spectrum of control and resistance management -systemic action	
Difenoconazole/cyprodinil (3/9)	-medium risk for resistance -built in formulation for broader spectrum of control and resistance management -systemic action	
Difenoconazole/azoxystrobin (3/11)	-medium risk for resistance -built in formulation for broader spectrum of control and resistance management -systemic action	
Propiconazole/azoxystrobin (3/11)	-medium risk for resistance -built in formulation for broader spectrum of control and resistance management -systemic action	
Fluopyram/trifloxystrobin (7/11)	-built in formulation for broader spectrum of control and resistance management -systemic action	-high risk for resistance -not effective if used as a dormant treatment -for shot hole management, dormant treatments with copper, ziram, and dodine are highly effective; petal fall treatments should be used to complement the management program

Fluxapyroxad/pyraclostrobin (7/11)	-built in formulation for broader spectrum of control and resistance management -systemic action	-high risk for resistance -not effective if used as a dormant treatment -for shot hole management, dormant treatments with copper, ziram, and dodine are highly effective; petal fall treatments should be used to complement the management program
Boscalid/pyraclostrobin (7/11)	-built in formulation for broader spectrum of control and resistance management -systemic action	-high risk for resistance -not effective if used as a dormant treatment -for shot hole management, dormant treatments with copper, ziram, and dodine are highly effective; petal fall treatments should be used to complement the management program

Sources: Adaskaveg et al. (2017) and 2021 Southeastern Peach, Nectarine, and Plum Pest Management and Culture Guide.

Plums/Prunes

Table 8. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in prunes/plums grown west of the Mississippi River

	Common Diseases of Plums and Prunes[1]						
Fungicide (FRAC Code)	**Brown Rot**	**Russet Scab**	**Rust**	**Bacterial Canker**	**Armillaria Root Rot**	**Phytophthora Crown & Root Rot**	**Crown Gall**
Multisite Fungicides							
Captan, bloom only (M4)	F	E	NE	NE	NE	NE	NE
Coppers (M1)	P,?	NE	NE	P	NE	NE	NE
Sulfur (M2)	P,?	NE	G	NE	NE	NE	NE
Chlorothalonil, bloom only (M5)	F-G	F-P	[G]	NE	NE	NE	NE
Single Site Fungicides							
Thiophanate methyl (1)	G [E]	NE	NE	NE	NE	NE	NE
Iprodione (2)	G [E]	NE	P [G]	NE	NE	NE	NE
Difenoconazole (3)	E	NE	E	NE	NE	NE	NE
Fenbuconazole (3)	G	NE	NE	NE	NE	NE	NE
Flutriafol (3)	G-E	NE	G	NE	NE	NE	NE
Metconazole (3)	E	NE	E	NE	NE	NE	NE
Myclobutanil (3)	F	NE	P	NE	NE	NE	NE
Propiconazole (3)	E-G	NE	E	NE	NE	NE	NE
Tebuconazole (3)	E	NE	E	NE	NE	NE	NE
Penthiopyrad (7)	G	NE	NE	NE	NE	NE	NE
Cyprodinil (9)	E	NE	U	NE	NE	NE	NE
Pyrimethanil (9)	E	NE	U	NE	NE	NE	NE
Azoxystrobin (11)	G	NE	G	NE	NE	NE	NE
Trifloxystrobin (11)	G	NE	G	NE	NE	NE	NE
Fludioxonil (12)	F,?	NE	NE	NE	NE	NE	NE
Dicloran (14)	E	NE	U	NE	NE	NE	NE
Fenhexamid (17)	F-G	NE	NE	NE	NE	NE	NE
Polyoxin-D (19)	F-G	NE	NE	NE	NE	NE	NE
Fosetyl-Al (P07)	NE	NE	NE	NE	NE	?	NE
Premix Formulations							
Azoxystrobin/difenoconazole (11/3)	G-E	NE	G-E	NE	NE	NE	NE

Azoxystrobin/propiconazole (11/3)	G-E	NE	G-E	NE	NE	NE	NE
Boscalid/pyraclostrobin (7/11)	G-E	NE	G-E	NE	NE	NE	NE
Fluopyram/trifloxystrobin (7/11)	G-E	NE	G	NE	NE	NE	NE
Fluxapyroxad/pyraclostrobin (7/11)	G-E	NE	G	NE	NE	NE	NE
Fluopyram/tebuconazole (7/3)	G-E	NE	G	NE	NE	NE	NE
Cyprodonil/difenoconazole (9/3)	G-E	NE	G	NE	NE	NE	NE

[1]Efficacy Rating System: E=Excellent, G=Good F=Fair, P=Poor, U=Unknown, NE=Not Efficacious, ?=No data but suspected of being efficacious.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: A Pest Management Strategic Plan for California Prune Production. 2018.

Table 9. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in prunes/plums grown east of the Mississippi River

Product and Formulation / Active Ingredient	FRAC Code[2]	Common Diseases of Plums/Prunes[1]					REI / PHI	Max amt / Max app
		Bacterial Spot	Black Knot	Brown Rot	Plum Pockets	Powdery Mildew		
Abound (SC) / azoxystrobin	11	x	x	F-E[r]	x	G	4h / 0d	90 fl . oz. / 5
Badge SC / copper oxychloride+copper hydroxide	M1	G-F	x	i	G-F	F	24h / 0d	18 lb . / NA
Bravo WeatherStik / chlorothalonil	M5	x	x	G	G	F	12h / shuck split	20 .5 pt . / NA
C-O-C-S WDG / copper oxychloride	M1	F	G	u	G	u	48h / N/A	36 lb . / NA
Captan 80WDG / captan	M4	x	x	G	G	F	24h / 0d	33 .75 lb . / NA
Cevya / mefentrifluconazole	3	x	x	E	x	E-s	12h / 0d	NA / 3
Cuprofix Ultra 40 Disperss / copper hydroxide	M1	G-F	G	F	G	x	48h / N/A	45 lb . / NA
Elevate 50WDG / fenhexamid	17	x	x	G	x	x	12h / 0d	6 lb . / NA
Flint Extra / trifloxystrobin (higher rate)	11	x	x	G-s	x	E-s	12h / 1d	15 .2 oz . / 4
Fontelis (SC) / penthiopyrad	7	x	x	E-G	x	F	12h / 0d	61 fl . oz . / NA
Indar 2F / fenbuconazole	3	x	x	E[r]	x	E	12h / 0d	24 fl . oz . / 4
Inspire Super (EW) / difenoconazole + cyprodinil	3+9	x	x	E	x	F	12h / 2d	80 fl . oz . / 4
Kocide 3000, Champ / copper hydroxide	M1	x	G	F	G	x	48h / 0d	60 lb . / NA
Luna Privilege / fluopyram	7	x	u	E	x	u	12h / 0d	34 fl .oz / 6
Luna Sensation (SC) / fluopyram + trifloxystrobin	7+11	x	x	E	G	E	12h / 1d	27 .1 fl . oz . / 4
Merivon / fluxapyroxad + pyraclostrobin	7+11	x	x	E	x	E	12h / 0d	20 .1 fl . oz . / 3
Miravis / pydiflumetofen	7	x	x	E	x	G	4h / 30d	13 .6 fl . oz . / 4
OSO 5% SC / polyoxin D	19	x	u	G	x	G	NA / 0d	78 fl . oz . / NA

Pristine (38WG)								
pyraclostrobin + boscalid							0d	5
Quash	3	x	x	E	x	E	12h	10 .5-12 oz .
metconazole							14d	3
Quilt Xcel							12h	70 fl . oz .
azoxystrobin+propiconazole							0d	5
Rally 40WSP	3	x	x	G	x	E	24h	10 oz .
myclobutanil							0d	NA
Rovral (50WP)	2	x	x	E	x	x	24h	4 pt .
iprodione							not after petal fall	2
Scala (SC)	9	x	x	E-G	x	x	12h	54 fl . oz .
pyrimethanil							2d	3
Sulfur (Wettable sulfur 90%)	M2	x	x	F	i	G	NA	NA
sulfur							See label	NA
Tilt (3.6EC)	3	x	x	E	x	G	12h	20 fl . oz .
propiconazole							0d	5
Topguard EQ	3+11	x	x	G-E	x	E	12h	N/A
flutriafol + azoxystrobin							7d	4
Topguard Specialty Crop (SC)	3	x	x	G	x	E	12h	56 fl . oz .
flutriafol							7d	4
Topsin-M WSB	1	x	x	E	i	G	48h	4 lb .
thiophanate-methyl							1d	NA
Vangard WG	9	x	x	G-E	x	x	12h	30 oz .
cyprodinil							2d	4

[1]Efficacy Rating: E= excellent control; G=good control; F= fair control; [r] = Fungicide/Insecticide resistance possible; s= suppression only, i= not effective, u= effectiveness unknown, x= pest not on the label.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Midwest Fruit Pest Management Guide 2021-2022.

Table 10. Advantages and disadvantages of captan relative to the conventional alternatives in the management of diseases in prunes/plums.

Fungicide (FRAC Code)	Advantages	Disadvantages
Multisite Fungicides		
Captan, bloom only (M4)	-Bloom applications with excellent control of russet scab -Low risk for resistance -Inhibits spore germination -Broad spectrum of activity -Bloom applications with fair to good control of brown rot -Good control of plum pockets	-Contact mode of action and coverage critical -Not efficacious on rust -Do not use in combination with or shortly before or after oil treatment
Chlorothalonil, bloom only (M5)	-Bloom applications with fair to good control of brown rot -Low risk for resistance -Good control of rust -Good control of plum pockets -Inhibits spore germination -Broad spectrum of activity	-Bloom applications with fair to poor control of russet scab -Contact mode of action and coverage critical -Do not use after jacket (shuck) split (California) -Do not use in combination with or shortly before or after oil treatment
Copper-based (M1)	-Low risk for resistance -Good control of plum pockets -Inhibits spore germination -Broad spectrum of activity	-Poor efficacy on brown rot -Not efficacious on russet scab and rust -Contact mode of action and coverage critical
Sulfur (M2)	-Low risk for resistance -Good control of rust and powdery mildew -Inhibits spore germination	-Poor efficacy on brown rot -Not efficacious on russet scab and plum pockets -Contact mode of action and coverage critical -Do not use in combination with or shortly before or after oil treatment -No effect on sporulation
Single Active Ingredients		
Thiophanate-methyl (1)	-Good to excellent control of brown rot -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and sporulation	-Not efficacious on russet scab and rust -High risk for resistance
Iprodione (2)	-Good to excellent control of brown rot -Systemic mode of action -Good to poor control of rust -Inhibits mycelial growth and sporulation	-Not efficacious on russet scab -Medium to high risk for resistance -Blossom blight only; not registered for use after petal fall (California)

Difenoconazole (3)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Excellent control of rust	Not efficacious on russet scab
Fenbuconazole (3)	-Good control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation	Not efficacious on russet scab and rust
Flutriafol (3)	-Good to excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Good control of rust	Not efficacious on russet scab
Metconazole (3)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Excellent control of rust	Not efficacious on russet scab
Myclobutanil (3)	-Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation	-Fair control of brown rot -Not efficacious on russet scab -Poor control of rust
Tebuconazole (3)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Excellent control of rust -Registered for pre- and postharvest applications	Not efficacious on russet scab
Propiconazole (3)	-Good to excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Excellent control of rust	Not efficacious on russet scab

Mefentrifluconazole (3)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Broad spectrum of activity -Inhibits mycelial growth and suppresses sporulation -Newest generation of triazole	
Penthiopyrad (7)	-Good control of brown rot -Systemic mode of action -Broad spectrum of activity -Reduces mycelial growth -Reduced risk fungicide	-Not efficacious on russet scab and rust -Medium to high risk for resistance -Unknown effect on sporulation
Pydiflumetofen (7)	-Excellent control of brown rot -Systemic mode of action -Broad spectrum of activity -Reduces mycelial growth -Newest generation of SDHI	-Medium to high risk for resistance -Unknown effect on sporulation
Fluopyram (7)	-Excellent control of brown rot -Systemic mode of action -Broad spectrum of activity -Reduces mycelial growth	-Medium to high risk for resistance -Unknown effect on sporulation
Cyprodinil (9)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Inhibits mycelial growth and suppresses spore germination -Reduced risk fungicide	-Not efficacious on russet scab -Unknown efficacy on rust -High summer temperatures and relative humidity reduce efficacy -No effect on sporulation
Pyrimethanil (9)	-Excellent control of brown rot -Medium risk for resistance -Systemic mode of action -Inhibits mycelial growth and suppresses spore germination -Reduced risk fungicide	-Not efficacious on russet scab and rust -High summer temperatures and relative humidity reduce efficacy -No effect on sporulation
Azoxystrobin (11)	-Good control of brown rot -Systemic mode of action -Good control of rust -Reduced risk fungicide -Broad spectrum of activity -Inhibit spore germination	-Not efficacious on russet scab -High risk for resistance -No effect on sporulation -Phytotoxic to certain apple varieties
Trifloxystrobin (11)	-Good control of brown rot -Systemic mode of action -Good control of rust -Reduced risk fungicide -Broad spectrum of activity -Inhibit spore germination	-Not efficacious on russet scab -High risk for resistance -No effect on sporulation
Fludioxonil (12)	-Low to medium risk for resistance -Reduced risk fungicide -Reduces sporulation -Inhibits mycelial growth and germination	-Fair control of brown rot -Not efficacious on russet scab and rust -Contact mode of action

Dicloran (14)	-Excellent control of brown rot -Low to medium risk for resistance -Systemic mode of action	-Not efficacious on russet scab -Unknown efficacy on rust
Fenhexamid (17)	-Fair to good control of brown rot -Low to medium risk for resistance -Systemic mode of action -Reduced risk fungicide -Inhibits spore germination and mycelial growth	-Not efficacious on russet scab and rust -Contact mode of action -Narrow spectrum of activity -No effect on sporulation
Polyoxin-D (19)	-Fair to good control of brown rot -Medium risk for resistance -Reduced risk fungicide -Inhibits spore germination and mycelial growth	-Not efficacious on russet scab and rust -Contact mode of action -No effect on sporulation
Fosetyl-al (P07)	-Low risk for resistance -Systemic mode of action -Inhibits mycelial growth and suppresses sporulation	Not efficacious on brown rot, russet scab and rust
Pre-Mixture Formulations		
Azoxystrobin/difenoconazole (11/3)	-Good to excellent control of brown rot -Built in resistance management -Good to excellent control of rust	Not efficacious on russet scab
Azoxystrobin/propiconazole (11/3)	-Good to excellent control of brown rot -Built in resistance management -Good to excellent control of rust	Not efficacious on russet scab
Cyprodonil/difenoconazole (9/3)	-Good to excellent control of brown rot -Built in resistance management -Good control of rust	Not efficacious on russet scab
Fluopyram/tebuconazole (7/3)	-Good to excellent control of brown rot -Built in resistance management -Good control of rust	Not efficacious on russet scab
Boscalid/pyraclostrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Good to excellent control of rust	Not efficacious on russet scab
Fluopyram/trifloxystrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Good control of rust	Not efficacious on russet scab
Fluxapyroxad/pyraclostrobin (7/11)	-Good to excellent control of brown rot -Built in resistance management -Good control of rust	Not efficacious on russet scab

Sources: A Pest Management Strategic Plan for California Prune Production, 2018 and Midwest Fruit Pest Management Guide 2021-2022.

Non-chemical tools that aid in an integrated disease management of brown rot in plums/prunes include pruning/canopy management, irrigation management, weed control, sanitation, and nutrition. However, none of the IPM tools to manage russet scab in plums/prunes was known to be effective. Thus, the only effective method of control is through the application of fungicides such as captan (PMSP, 2018)

Pome Fruit

Table 11. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in apples grown west of the Mississippi River

Fungicide	FRAC Code[2]	Common Diseases of Apples[1]		
		Apple scab	Powdery mildew	Bull's eye rot
Multisite Fungicides				
Captan	M4	Good- excellent	None	Good
Copper*	M1	Moderate, variable	Ineffective	??
Lime sulfur	M2	Good- excellent	Good	??
Sulfur	M2	Fair	Good	??
Mancozeb	M3	Good	None	??
Metiram	M3	Good	None	??
Ziram	M3	Fair	None	??
Single Site Fungicides				
Thiophanate-methyl	1	Fair**	Fair-good**	Excellent**
Fenbuconazole	3	Good**	Good**	??
Fenarimol*	3	Excellent, consistent	Good, reliable	??
Flutriafol	3	Good**	Excellent**	??
Myclobutanil	3	Good**	Fair-good**	??
Tebuconazole*	3	Good, reliable	Good, reliable	??
Triflumizole	3	Good**	Excellent**	Slight-fair
Benzovindiflupyr	7	Fair-good	Slight - Fair	??
Penthiopyrad	7	Fair-good**	Good**	??
Cyprodinil	9	Fair**	None	??
Pyrimetjhanil*	9	Good, reliable	Limited, erratic	??
Kresoxim-methyl*	11	Good, reliable	Good, reliable	??
Trifloxystrobin	11	Good*	Good-excellent**	Slight-fair

Polyoxin-D*	19	Moderate, variable as protectant	Good, reliable	??
Fluazinam	29	Good	Slight	??
Cyflufenamid	U6	None	Good-excellent	??
Dodine	U12	Good**	None	??
Premix Formulations				
Difenoconazole + cyprodinil	3 + 9	Good	Excellent**	??
Fluopyram + trifloxystrobin	7 + 11	Good- excellent**	Excellent	??
Fluopyram + pyrimethanil	7 + 9	Good**	Excellent	??
Fluxapyroxad + pyraclostrobin	7 + 11	Good- excellent**	Excellent	??
Boscalid + pyraclostrobin	7 + 11	Good**	Excellent**	??

[1]Efficacy ratings: ?? = no information available; * indicates data obtained from California by Adaskaveg et al. 2017; **Resistant pathogens will lower the effectiveness of these fungicides.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Wiman et al. 2020. Willamette Valley: Pest Management Guide for Apples. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8418.pdf

Table 12. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in apples grown east of the Mississippi River.

Fungicide (FRAC Code[2])	Common Diseases of Apples[1]										
	Alternaria leaf blotch	Apple scab	Bitter rot	Black rot	Calyx-end rot	Fire blight	Flyspeck	Powdery mildew	Rusts	Sooty blotch	White rot
Multisite Fungicides											
Captan (M4)	6	2	2	1	3	6	3	5	5	2	1
Copper-based (M1)	6	2	6	6	6	3	6	6	6	6	6
Sulfur, lime (M2)	6	3	6	6	6	3	6	2	6	6	6
Sulfur (M2)	3	3	3	3	3	6	3	2	4	3	3
Ferbam (M3)	3	3	3	2	4	6	3	5	2	3	2
Mancozeb (M3)	2	2	2	2	2	6	4	5	2	4	2
Ziram (M3)	3	3	2	2	6	6	3	6	2	2	2
Single Site Fungicides											
Thiophanate-methyl (1)	6	4	6	3	2	6	1	2	6	1	3
Fenbuconazole(3)	6	1	6	6	6	6	1	3	1	1	6
Fenarimol (3)	6	3	6	6	6	6	6	2	2	6	6
Flutriafol (3)	6	2	6	6	6	6	6	1	2	6	6
Myclobutanil (3)	6	2	6	6	6	6	6	1	1	6	6
Triflumizole (3)	6	2	6	6	6	6	6	1	1	6	6
Benzovindiflupyr (7)	3	1	3	3	3	6	2	3	3	2	3
Fluxapyroxad (7)	2	1	6	3	6	6	3	1	3	3	3
Isofetamid (7)	6	1	6	6	6	6	6	3	6	6	6
Penthiopyrad (7)	6	1	6	6	6	6	6	3	1	6	6
Cyprodinil (9)	6	1	6	6	6	6	6	6	6	6	6
Pyrimethanil (9)	6	1	6	6	6	6	6	6	6	6	6
Kresoxim-methyl (11)	1	1	5	2	6	6	2	1	3	1	2
Trifloxystrobin (11)	6	1	5	2	6	6	2	1	3	1	6
Polyoxin D zinc salt (19)	3	3	3	3	6	6	2	3	6	2	3
Fluazinam (29)	3	2	3	2	6	6	2	6	3	2	3

Fenazaquin (39)	6	6	6	6	6	6	6	1	6	6	6
Cyflufenamid (U6)	6	6	6	6	6	6	6	1	6	6	6
Dodine (U12)	6	1	6	6	6	6	6	3	2	6	6
Premix Formulations											
Difenoconazole (3) + Cyprodinil (9)	1	1	6	6	6	6	1	2	1	1	6
Fluopyram (7) + Pyrimethanil (9)	6	1	6	6	6	6	6	1	6	6	6
Pyraclostrobin (11) + Boscalid (7)	1	1	1	1	1	6	1	1	2	1	1
Pyraclostrobin (11) + Fluxapyroxad (7)	1	1	1	1	1	6	1	1	2	1	1
Trifloxystrobin (11) + Fluopyram (7)	6	1	5	1	6	6	1	1	2	1	1

[1]Efficacy Ratings or degree of control: 1 = best, 2 = good, 3 = fair, 4 = slight, 5 = none, 6 = no registration; not labeled.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Penn State Tree Fruit Production Guide 2020-2021. https://extension.psu.edu/tree-fruit-production-guide

Table 13. Advantages and disadvantages of captan relative to the conventional alternatives in the management of diseases in apples

Multisite Fungicides	Advantages	Disadvantages
Captan (M4)	-low risk for resistance -broad spectrum of activity -very good fruit finish on yellow apple varieties - show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs -with adjuvant, reduces scab and bitter rot under moderate to high disease pressure (east)	-contact, non-systemic and coverage critical -may cause phytotoxicity to pears -not compatible with oil
Copper-based (M1)	-low risk for resistance -broad spectrum of activity -bactericidal and fungicidal - show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs	-contact, non-systemic and coverage critical - copper products may cause fruit scarring or russeting -copper sulfate can russet Anjou pears -copper sprays applied to Bosc pears to induce russet may cause fruit cracking -poor fruit finish on yellow apple varieties
Sulfur, lime (M2)	-low risk for resistance -broad spectrum of activity -vapor active - show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs - in-season application eradicates powdery mildew	-contact, non-systemic and coverage critical -use of sulfurs may result in phytotoxicity when temperatures exceed 90F following application -poor fruit finish on yellow varieties - incompatible with most other pesticides when used after budbreak
Sulfur (M2)	-low risk for resistance -broad spectrum of activity -vapor active	-contact, non-systemic and coverage critical -use of sulfurs may result in phytotoxicity when temperatures exceed 90F following application -poor fruit finish on yellow varieties
Mancozeb (M3)	-low risk for resistance -broad spectrum of activity -some mancozeb products have a higher rate allowed for suppression of pear psylla show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs	-contact, non-systemic and coverage critical

Ferbam (M3)	-low risk for resistance -broad spectrum of activity - show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs	-contact, non-systemic and coverage critical -poor fruit finish on yellow varieties
Ziram (M3)	-low risk for resistance -broad spectrum of activity -good fruit finish on yellow varieties - show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs	-contact, non-systemic and coverage critical -may cause irritation of eyes, nose, throat and skin
Single Site Fungicides		
Thiophanate-methyl (1)	-systemic mobility -broad spectrum of activity -inhibits mycelial growth and sporulation	-high risk for resistance
Fenbuconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Fenarimol (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not registered, label withdrawn or inactive in California
Flutriafol (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-labeled on apple only in California
Myclobutanil (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-use higher rate for powdery mildew control
Triflumizole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-use higher rate for powdery mildew control
Benzovindiflupyr (7)	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high risk for resistance -do not apply more than 2 sequential applications -unknown effect on sporulation
Fluxapyroxad (7)	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high risk for resistance -do not apply more than 2 sequential applications -unknown effect on sporulation

Isofetamid (7)	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high risk for resistance -do not apply more than 2 sequential applications -unknown effect on sporulation
Penthiopyrad (7)	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high risk for resistance -do not apply more than 2 sequential applications -unknown effect on sporulation
Cyprodinil (9)	-medium resistance risk -reduced risk fungicide -local systemic mobility -inhibits mycelial growth and suppresses spore germination	-narrow spectrum of activity -no effect on sporulation
Pyrimethanil (9)	-medium resistance risk -reduced risk fungicide -local systemic mobility -inhibits mycelial growth and suppresses spore germination	-narrow spectrum of activity -no effect on sporulation
Kresoxim-methyl (11)	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-high risk for resistance -no effect on sporulation
Trifloxystrobin (11)	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high risk for resistance -no effect on sporulation
Polyoxin D zinc salt (19)	-broad to narrow spectrum of activity -medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth	
Fluazinam (29)	-low risk for resistance -narrow spectrum of activity -systemic mobility	
Fenazaquin (39)	-narrow spectrum of activity -systemic mobility	-resistance not known
Cyflufenamid (U6)	-narrow spectrum of activity -systemic mobility	-unknown target site of action -resistance known in *Sphaerotheca*
Dodine (U12)	-low to medium risk for resistance -broad spectrum of activity -systemic mobility	-prolonged humidity or slow drying conditions following the application of dodine may result in fruit russet
Premix Formulations		
Difenoconazole (3) + Cyprodinil (9)	-broad to narrow spectrum of activity -systemic mobility -inhibit mycelial growth and suppresses spore germination -medium risk for resistance -reduced risk fungicide (cyprodinil)	-no effect on sporulation (cyprodinil) -suppresses sporulation (difenoconazole) -do not apply more than 2 sequential applications

Pyraclostrobin (11) + Boscalid (7)	-reduced risk fungicide (boscalid) -systemic mobility -broad spectrum of activity	-medium to high resistance risk - do not use with horticultural mineral oil - do not apply more than 2 sequential applications
Pyraclostrobin (11) + Fluxapyroxad (7)	-broad to narrow spectrum of activity -systemic mobility	-medium to high resistance risk -do not apply more than 2 sequential applications -do not use with EC formulations, methylated seed oil, or horticultural mineral oil
Trifloxystrobin (11) + Fluopyram (7)	-broad to narrow spectrum of activity -systemic mobility -reduced risk fungicide (trifloxystrobin)	-medium to high resistance risk -do not apply more than 2 sequential applications or with horticultural mineral oil
Fluopyram (7) + Pyrimethanil (9)	-broad to narrow spectrum of activity -systemic mobility -reduced risk fungicide (pyrimethanil)	-medium to high resistance risk -narrow spectrum of activity

Sources: Wiman et al. (2020) and Penn State Tree Fruit Production Guide 2020-2021.

Blueberries

Table 14. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in the management of key diseases in blueberries grown east of the Mississippi River

Fungicide	FRAC Code[2]	Common Diseases of Blueberries[1]									
		Exobasidium leaf & fruit spot	**Mummy Berry**	**Phomopsis twig blight**	**Botrytis (gray mold)**	**Alternaria rot**	**Ripe rot (Anthracnose)**	**Septoria leaf spot**	**Anthracnose leaf spot**	**Rust**	**Phytophthora root rot**
Multisite Fungicides											
Captan **(WP, or 4L, or 80 WDG)**	M4	**VG**	F	F	F	G	G	F	G	NA	NA
Calcium polysulfide	M2	**E**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ziram	M3	UN	P	G	F	F	F	UN	F	UN	NA
Chlorothalonil	M5	UN	NA	NA	NA	NA	NA	**VG*** **Post harvest only**	**VG*** **Post harvest only**	G* **Post harvest only**	NA
Single Site Fungicides											
Fosetyl-Al	P07	NA	NA	P	NA	NA	P	**VG**	**VG**	NA	G
Phosphorous acid and salts	P07	UN	NA	NA	NA	NA	NA	**VG**	**VG**	NA	**VG**
Fenbuconazole	3	G-**VG** **(with captan)**	**E**	**E**	NA	NA	NA*	**E**	**E**	G	NA
Metconazole	3	UN	**E**	**E**	UN	**E**	**E**	**E**	**E**	**VG**	NA
Propiconazole	3	UN	**E**	**E**	NA	NA	NA	**VG**	UN	G	NA
Prothioconazole	3	UN	**E**	**E**	NA	NA	UN	G	UN	**E**	NA
Mefenoxam	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	G
Azoxystrobin	11	UN	F	F	NA	**E**	E^R	**VG**	**VG**	G	NA
Fenhexamid	17	UN	F	NA	**E**	NA	NA	NA	NA	NA	NA
Fluazinam	29	UN	NA	G	F	G	G	NA	NA	NA	NA
Premix Formulations											

Fluopyram + pyrimethanil	7+9	NA	**VG**	NA	NA	NA	NA	NA	NA	NA	NA
Pydiflumetofen + fludioxonil	7+12	NA	UN	UN	UN	UN	**VG**	NA	NA	NA	NA
cyprodinil + fludioxonil	9+12	UN	F	G	**E**	**E**	**E**	G	G	NA	NA
Azoxystrobin + propiconazole	11+3	NA	**E**	**E**	NA	**E**	E[R]	**E**	**E**	**E**	NA
Pyraclostrobin + boscalid	11+7	E[R]	VG	**E**	**E**	**E**	E[R]	**E**	**E**	F	NA
Fenhexamid + captan	17+M4	**VG**	F	F	**E**	G	G	F	UN	NA	NA

[1]Efficacy Ratings: E = excellent, VG = very good, G = good, F = fair, P = poor, NA = not recommended, UN = control unknown;
[R]Isolates of this pathogen with resistance to this fungicide have been identified in the southeastern U.S. If pathogen with resistance to this fungicide is present, this fungicide will not be effective.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: 2021 Southeast Regional Blueberry Integrated Management Guide.

Table 15. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in the management of key diseases in blueberries grown west of the Mississippi River

Fungicide	FRAC Code[2]	Common Diseases of Blueberries[1]						
		Mummy berry (primary)	Mummy berry (secondary)	Botrytis blight	Anthracnose fruit rot	Alternaria fruit rot	Pseudomonas bacterial canker	Phytophthora root rot
Multisite Fungicides								
Captan	M4	Poor	Moderate	Moderate	Moderate	Moderate	Not effective	Not effective
Copper-based products	M1	Poor	Not effective	Moderate–Poor	??	??	Good**	Not effective
Ziram	M3	Poor	Poor	Moderate–Poor	Moderate	Moderate	Not effective	Not effective
Chlorothalonil	M5	Moderate	Poor	Moderate	Moderate–Poor	Not effective	Not effective	Not effective
Single Site Fungicides								
Iprodione	2	Moderate–Poor	Moderate–Poor	Good**	??	??	Not effective	Not effective
Fenbuconazole	3	Good	Good	?	Poor	??	Not effective	Not effective
Metconazole	3	Excellent	Excellent	Moderate**	Good	??	Not effective	Not effective
Propiconazole	3	Good	Moderate	Poor	Poor	??	Not effective	Not effective
Prothioconazole	3	Excellent	Excellent	Poor	??	??	Not effective	Not effective
Metalaxyl	4	Not effective	Not effective	Not effective	Not effective	Not effective	Not effective	Excellent**
Isofetamid	7	??	??	Good**	??	??	Not effective	Not effective
Fluopyram	7	??	??	Good**	??	??	Not effective	Not effective
Azoxystrobin	11	Poor–Moderate	Moderate	Moderate	Excellent	??	Not effective	Not effective
Fenhexamid	17	Moderate	Moderate	Moderate–Good**	Poor	??	Not effective	Not effective
Polyoxin-D	19	Poor	Poor	Moderate–Good	Poor	Moderate–Good	Not effective	Not effective

Fluazinam	29	Good	Moderate–Good	Poor–Moderate	Good	??	Not effective	Not effective
Fosetyl-Al	33	Not effective	Not effective	Not effective	Poor	??	Not effective	Good
Phosphorous acid and salts	33	Not effective	Not effective	Not effective	Poor	??	Not effective	Good
Premix Formulations								
Difenoconazole+ cyprodinil	3 + 9	Moderate–Good	Good	Moderate	??	Moderate	Not effective	Not effective
Fluopyram+ Pyrimethanil	7 + 9	Good	Good	Excellent	??	??	Not effective	Not effective
Fludioxonil+ cyprodinil	12 + 9	Good	Poor	Good–Excellent**	Good	??	Not effective	Not effective
Difenoconazole+ azoxystrobin	3 + 11	Moderate–Good	Good	??	Excellent	??	Not effective	Not effective
Propiconazole+ azoxystrobin	3 + 11	Moderate–Good	Good	Moderate	Excellent	??	Not effective	Not effective
Boscalid+ pyraclostrobin	7 + 11	Good	Good	Moderate–Good**	Excellent	??	Not effective	Not effective
Captan+ Fenhexamid	M4 + 17	Moderate	Poor	Good–Excellent	Moderate	Moderate	Not effective	Not effective

**Resistant pathogens will lower the effectiveness of these fungicides.

[1]These ratings are relative rankings based on labeled application rates, good spray coverage, and proper spray timing. Actual levels of disease control will be influenced by these factors in addition to cultivar susceptibility, disease pressure, and weather conditions.

[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2

Source: DeFrancesco et al. (2018).

Table 16. Advantages and disadvantages of captan in comparison to conventional alternatives in the management of diseases in blueberries

	Advantages	Disadvantages
Multisite Fungicides		
Captan	-low resistance risk -broad spectrum of activity -inhibits spore germination -tank mix with fenbuconazole during bloom prevents rots	-contact activity and coverage critical -no effect on sporulation
Sulfur	-low resistance risk -inhibits mycelial growth and spore germination	-contact activity and coverage critical -phytotoxicity can occur at higher temperatures -can flare up mites
Ziram	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact activity and coverage critical -no effect on sporulation
Chlorothalonil	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact activity and coverage critical -unknown effect on sporulation -do not use prior to harvest because of potential to damage fruit
Single Site Fungicides		
Iprodione	-systemic mobility -inhibits mycelial growth and sporulation	-medium to high resistance risk
Fenbuconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Metconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-no effect on spore germination
Propiconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not for use in nurseries, on nursery transplants, or greenhouses
Prothioconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Mefenoxam/metalaxyl	-reduced risk fungicide -systemic mobility -inhibits mycelial growth, sporangial development, and zoospore viability	-high resistance risk -SL is the only formulation registered
Fluopyram	-Velum One formulation for chemigation and soil applications for nematode management -local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high resistance risk -Velum One formulation only suppresses powdery mildew -unknown effect on sporulation
Isofetamid	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high resistance risk -unknown effect on sporulation

Azoxystrobin	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibits spore germination -plant dip (nurseries) or foliar spray (field use)	-high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses -no effect on sporulation -phytotoxic to certain apple varieties
Fenhexamid	-low to medium resistance risk -reduced risk fungicide -systemic mobility inhibits spore germination and mycelial growth	-no effect on sporulation
Polyoxin-D	-medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth	-no effect on sporulation
Fosetyl-Al	-low resistance risk -foliar applications provide systemic treatment -plant dip (nurseries) or foliar spray (field use) -systemic mobility -inhibits mycelial growth and suppresses sporulation	
Phosphorous acid and salts	-low resistance risk -systemic mobility -inhibits mycelial growth and suppresses sporulation	-phytotoxicity may occur
Fluazinam	-low resistance risk -systemic mobility -broad spectrum of activity	
Premix Formulations		
Azoxystrobin + propiconazole	-reduced risk fungicide (azoxystrobin) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Azoxystrobin + difenoconazole	-reduced risk fungicide (azoxystrobin) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Pydiflumetofen + fludioxonil	-reduced risk fungicide (fludioxonil) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for residential use -not for use in the state of Hawaii and in Nassau and Suffolk counties of New York
Fluoypram + pyrimethanil	-reduced risk fungicide (pyrimethanil) -systemic mobility -broad spectrum of activity	-medium to high resistance risk
Boscalid + pyraclostrobin	-reduced risk fungicide (boscalid) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Cyprodinil + fludioxonil	-medium resistance risk -reduced risk fungicides	-contact activity and coverage critical (fludioxonil)
Cyprodinil + difenoconazole	-medium resistance risk -reduced risk fungicide (cyprodinil)	
Captan + fenhexamid	-medium resistance risk -reduced risk fungicide (fenhexamid)	-contact activity and coverage critical (captan)

Sources: : DeFrancesco et al. (2018) and 2021 Southeast Regional Blueberry Integrated Management Guide.

Caneberries

Table 17. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in the management of common diseases in caneberries grown east of the Mississippi River

Fungicide (FRAC Code)[2]	Common Diseases on Caneberries[1]						
	Anthracnose	Cane blight/ spur blight	Septoria leaf spot	Botrytis fruit rot	Rusts (orange and late leaf	Powdery mildew	Phytophthora root rot
Multisite Fungicides							
Captan WDG (M4)	G	F	F	G	x	x	x
Captan 4L (M4)	G	G	F	G	x	x	x
Copper sulfate + oxychloriode (M1)	F	F	F	x	F	x	x
Copper sulfate (M1)	F	F	F	x	x	i	x
Copper hydroxide (M1)	x	F	x	x	x	x	u
Cuprous oxide (M1)	F	F	x	x	x	x	x
Calcium polysulfide (M2)	E	G	G	x	x	x	x
Sulfur (M2)	G	x	x	x	x	F	x
Single Site Fungicides							
Iprodione (2	x	x	x	E	x	x	x
Myclobutanil (3)	x	x	x	x	E	E	x
Propiconazole (3)	x	G	x	x	E	E	x
Mefenoxam (4)	x	x	x	x	x	x	E
Fluopyram (7)	x	x	G	E	x	E	x
Isofetamid (7)	x	x	x	E	x	s	x
Azoxystrobin (11)	E	E	G	G	E	E	x
Pyraclostrobin (11)	E	E	E	s	s	E	x
Fenhexamid (17)	x	x	x	E	x	x	x
Polyoxin-D (19)	x	x	x	E	x	G	x
Fosetyl-Al (P07)	x	x	x	x	x	x	E
Phosphorous acid and salts (P07)	x	u	x	x	x	x	E

Pyriofenone (U8)	x	u	x	x	x	E	x
Oxathiapiprolin (U15)	x	i	x	x	x	x	E
Premix Formulations							
Captan + fenhexamid (M4 + 17)	G	G	G	E	G	x	x
Cyprodinil + fludioxonil (9 + 12)	x	u	x	E	x	x	x
Fluopyram + pyrimethanil (7 + 9)	G	x	E	x	x	G	x
Azoxystrobin + propiconazole (11+3)	E	E	E	G	G	G	x
Pyraclostrobin + boscalid (11 + 7)	E	E	E	E	s	E	x
Famoxadone + cymoxanil (11+27)	s	G	G	x	x	x	X

[1]Efficacy Ratings: E= excellent control; G=good control; F= fair control; [r] = Fungicide/Insecticide resistance possible; s= suppression only; i= not effective; u= effectiveness unknown; x= pest not on the label

[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2

Source: Midwest Fruit Pest Management Guide 2021-2022.

Table 18. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in the management of common diseases in caneberries grown west of the Mississippi River

Fungicide (FRAC Code[2])	Common Diseases of Caneberries[1]										
	Anthracnose	Cane Blight	Downy Mildew	Fruit Rot	Powdery Mildew	Purple Blotch	Root Rot	Septoria Cane/Leaf Spot	Spur Blight	Stamen Blight	Yellow Rust
Multisite Fungicides											
Captan (M4)	F-G	P	?	F-G		F-G		F	G	F	
Copper (M1)	F					P-F		F-G			P-G
Fixed copper (M1)	F				F-G	P-G		F-G			
Sulfur (M2)					F			G			
Calcium polysulfide (M2)	G-E				F	F		F	G-E	P	P-G
Ziram (M3)				P-F							
Single Site Fungicides											
Iprodione (2)				G*					G		
Azoxystrobin (11)	G	G			F	G		G-E	G-E		
Pyraclostrobin (11)	F-G				?	G-E		G	G-E		P-F
Myclobutanil (3)					G-E			G			G-E
Propiconazole (3)											G-E
Fenhexamid (17)				E					G*		
Fosetyl-Al (P07)			G-E				F-G				
Phosphorous acid (P07)			G-E				?				
Mefenoxam (4)							F-E				

Premix Formulations											
Captan + fenhexamid (M4 + 17)				P							
Cyprodinil + fludioxonil (9 + 12)				E					G-E		
Famoxadone + cymoxanil (11 + 27)						G		G-F			
Boscalid + Pyraclostrobin (7 + 11)	F-G	G		E	G	G		G	G-E		F-G

[1]Efficacy Rating Scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control);

P = poor (<70% control); ? = efficacy unknown, more research needed; blank space = not used for this pest; * = used but not a stand-alone management tool.

[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2

Source: Pest Management Strategic Plan for Caneberry Production in Washington and Oregon 2003.

Table 19. Advantages and disadvantages of captan in comparison to conventional alternatives in the management of diseases in caneberries (blackberries and raspberries).

Fungicide (FRAC Code)	Advantages	Disadvantages
Multisite Fungicides		
Captan (M4)	-low resistance risk -broad spectrum of activity -inhibits spore germination -with fenhexamid resistance, captan should always be applied -widespread use due to cost effectiveness	-contact activity and coverage critical -no effect on sporulation
Calcium Polysulfide/Sulfur (M2)	-low resistance risk -inhibits mycelial growth and spore germination -can be used in organic production	-contact activity and coverage critical -phytotoxicity can occur at higher temperatures -can flare up mites
Copper-based (M1)	-low risk for resistance -bactericidal and fungicidal -broad spectrum of control -can be used in organic production	-contact fungicide and coverage critical -can cause phytotoxicity on black raspberry cultivars if used with formulated phosphorous acid products; an occasional problem on red raspberries
Single Site Fungicides		
Azoxystrobin (11)	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibits spore germination -plant dip (nurseries) or foliar spray (field use)	-high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses -no effect on sporulation -phytotoxic to certain apple varieties
Fenhexamid (17)	-low to medium resistance risk -reduced risk fungicide -systemic mobility inhibits spore germination and mycelial growth	-resistance issue in many southeastern states and resistance monitoring is recommended
Fosetyl-Al (P07)	-low resistance risk -foliar applications provide systemic treatment -plant dip (nurseries) or foliar spray (field use) -systemic mobility -inhibits mycelial growth and suppresses sporulation	-not registered for use in California on blueberries - do not tank-mix with copper compounds and adjuvants due to phytotoxicity
Iprodione (2)	-iprodione-based products must be mixed with a protectant (captan) -systemic mobility -inhibits mycelial growth and sporulation	-medium to high risk for resistance
Mefenoxam (4)	-reduced risk fungicide -systemic mobility	-high resistance risk -SL is the only formulation registered

	-inhibits mycelial growth, sporangial development, and zoospore viability	
Phosphorous acid and salts (P7)	-low resistance risk -systemic mobility -inhibits mycelial growth and suppresses sporulation	-fruit burn potential at temperatures above 90F, shortly after a rain event, or during color break of the fruit - can cause phytotoxicity on black raspberry cultivars and occasionally on red raspberries if used with copper products or foliar fertilizers - due to the acidic nature, do not use acidifying type compatibility agents
Myclobutanil (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Polyoxin D zinc salt (19)	-medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth	- not for homeowner use to treat food crops - not registered for use in California as a root dip at transplanting -no effect on sporulation
Propiconazole (3)	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not for use in nurseries, on nursery transplants, or greenhouses
Pyraclostrobin (11)	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Premix Formulation		
Azoxystrobin + Propiconazole (11+3)	-reduced risk fungicide (azoxystrobin) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Cyprodinil + Fludioxonil (9+12)	-systemic mobility and contact -medium resistance risk -reduced risk fungicides	-contact activity and coverage critical (fludioxonil)
Fluopyram + Pyrimethanil (7+9)	-reduced risk fungicide (pyrimethanil) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not registered in Louisiana
Pyraclostrobin + Boscalid (11+7)	-reduced risk fungicide (boscalid) -systemic mobility -broad spectrum of activity	medium to high risk for resistance -resistance to pyraclostrobin and boscalid is an issue in the Southeast, and resistance monitoring is recommended -not for use in nurseries, on nursery transplants, or greenhouses

Sources: Midwest Fruit Pest Management Guide 2021-2022 and Pest Management Strategic Plan for Caneberry Production in Washington and Oregon, 2003.

Strawberries

Table 20. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in strawberries grown in Florida

	FRAC Code[2]	Common Diseases of Strawberries[1]						
		Phytophthora crown rot	Colletotrichum crown rot	Botrytis fruit rot	Anthracnose	Powdery mildew	Leather rot	Angular leaf spot
Multisite Fungicides								
Captan	M4	-	++	+	++	-	-	-
Copper-based	M1	-	-	-	-	-	-	+
Sulfur	M2	-	-	-	-	+	-	-
Thiram	M3	-	+	++	+	-	-	-
Single Site Fungicides								
Thiophanate-methyl	1	-	++	-	-	-	-	-
Iprodione	2	-	-	++	-	-	-	-
Propiconazole	3	-	?	-	++	+	-	-
Tetraconazole	3	-	?	-	+	+	-	-
Myclobutanil	3	-	-	-	-	+	-	-
Triflumizole	3	-	-	-	-	+	-	-
Mefenoxam	4	+++	-	-	-	-	+++	-
Penthiopyrad	7	-	-	++	-	++	-	-
Isofetamid	7	-	-	+++	-	-	-	-
Pyrimethanil	9	-	-	+	-	-	-	-
Azoxystrobin	11	-	++	+	++	+	-	-
Pyraclostrobin	11	-	++	+	++	+	-	-
Trifloxystrobin	11	-	++	+	++	+	-	-
Fluoxastrobin	11	-	++	+	++	+	-	-
Quinoxyfen	13	-	-	-	-	+++	-	-
Fenhexamid	17	-	-	++	-	-	-	-
Fosetyl-Al	P07	+	-	-	-	-	+	-
Phosphorous acid	P07	++	-	-	-	-	+	-
Acibenzolar-s-methyl	P01	-	-	-	-	-	-	++
Cyflufenamid	U6	-	-	-	-	+++	-	-
Premix Formulations								
Azoxystrobin + propiconazole	3+11	-	++	-	++	++	-	-
Fluoypram + pyrimethanil	7+9	-	-	+++	-	?	-	-
Fluxapyroxad + pyraclostrobin	7+11	-	++	++	++	+++	-	-
Boscalid + pyraclostrobin	7+11	-	++	+	++	++	-	-
Cyprodinil + fludioxonil	9+12	-	++	+++	++	-	-	-

Captan + fenhexamid	M4+17	-	+	++	+	-	-	-

[1]**Efficacy Rating**: (+++) = good efficacy; (++) = moderate efficacy; (+) = low efficacy; (-) = no efficacy or not registered; (?) = not tested, or inconclusive. Efficacy based on 2 or more trials conducted by the UF/IFAS GCREC Strawberry Pathology program.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Oliveira and Peres (2019).

Table 21. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in strawberries grown in California

Fungicide	(FRAC Code)[2]	Common Diseases of Strawberries[1]									
		Powdery mildew	Gray mold	Anthrac nose	Angular leaf spot	Common leaf spot	Mucor rot	Rhizopus rot	Leather rot	Crown rot	Red stele
Multisite Fungicides											
Captan	(M4)	+/-	++++	+++	----	----	+	----	----	----	----
Copper-based	(M1)	----	----	----	+++[5]	----	----	----	----	----	----
Sulfur	(M2)	+++	----	----	----	----	----	----	----	----	----
Thiram	(M3)	----	++	++	----	----	----	----	----	----	----
Chlorothalonil	(M5)	----	NR	++	NR	+++	NR	NR	NR	NR	NR
Single Site Fungicides											
Thiophanate-methyl	(1)	+++	+++	----	----	++	----	----	----	----	----
Iprodione	(2)	----	+++	----	----	----	++	----	----	----	----
Propiconazole	(3)	++++	----	++	----	+++	----	----	----	----	----
Tetraconazole	(3)	++++	NR	ND	ND	ND	ND	ND	----	----	----
Triflumizole	(3)	++++	----	+	----	----	----	----	----	----	----
Myclobutanil	(3)	++++	----	++	----	++++**	----	----	----	----	----
Flutriafol	(3)	++++	----	NR	----	NR	NR	NR	NR	NR	NR
Mefenoxam	(4)	----	----	----	----	----	----	----	+++[4]	++	++
Fluopyram	(7)	++++	++++	ND	----	ND	ND	ND	ND	ND	ND
Penthiopyrad	(7)	+++	++++	ND	ND	ND	ND	ND	ND	ND	ND
Isofetamid	(7)	+++	++++	ND	ND	ND	ND	ND	ND	ND	ND
Azoxystrobin	(11)	+++	++	+++	----	----	ND	ND	ND	ND	ND
Pyraclostrobin	(11)	+++	++	++	----	----	ND	ND	ND	ND	ND
Fluoxastrobin	(11)	+++	++	++	----	----	ND	ND	ND	ND	ND
Quinoxyfen	(13)	++++	----	---	----	----	----	----	----	----	----
Fenhexamid	(17)	+/-	++++	+	----	----	----	----	----	----	----
Polyoxin-D	(19)	+++	++	++	ND	ND	----	----	----	----	----
Fosetyl-Al	(P07)	----	----	----	----	----	----	----	+++	++	++
Phosphorous acid and salts	(P07)	----	----	----	----	----	----	----	+++	++	++
Premix Formulations											
Difenoconazole/ azoxystrobin	(3/11)	++++	++	+++	----	----	ND	+	ND	ND	ND
Propiconazole/ azoxystrobinl	(3/11)	++++	++	+++	----	----	ND	+	ND	ND	ND
Fluopyram/ trifloxystrobin	(7/11)	++++	++++	ND	----	ND	ND	ND	ND	ND	ND
Fluxapyroxad/ pyraclostrobin	(7/11)	+++	++++	ND	----	----	ND	ND	ND	ND	ND
Boscalid/	(7/11)	+++	++++	ND	----	----	ND	ND	ND	ND	ND

pyraclostrobin											
Fluopyram/ pyrimethanil	(7/9)	++++	++++	ND	----	ND	ND	ND	ND	ND	ND
Cyprodinil/ fludioxonil	(9/12)	----	++++	+++	----	----	+	+++	----	----	----
Captan+ fenhexamid	(M4/17)	----	+++	+++	----	----	+	----	----	----	----

[1]**Efficacy Rating:** ++++ = excellent and consistent; +++ = good and reliable; ++ = moderate and variable; + = limited and/or erratic; +/- = minimal and often ineffective; ---- = ineffective; NR = not registered; and ND = no data.
[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2
Source: Adaskaveg et al. (2017).

Table 22. Advantages and disadvantages of captan in comparison to conventional alternatives in the management of diseases in strawberries.

	Advantages	Disadvantages
Multisite Fungicides		
Captan	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact activity and coverage critical -no effect on sporulation
Copper-based	-low resistance risk -broad spectrum of activity -bactericidal and fungicidal -inhibits spore germination	-contact activity and coverage critical -phytotoxicity can occur -no effect on sporulation
Sulfur	-low resistance risk -inhibits spore germination	-contact activity and coverage critical -phytotoxicity can occur at higher temperatures -can flare up mites -no effect on sporulation
Thiram	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact activity and coverage critical -no effect on sporulation
Chlorothalonil	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact activity and coverage critical -unknown effect on sporulation
Single Site Fungicides		
Thiophanate-methyl	-systemic mobility -broad spectrum of activity -inhibits mycelial growth and sporulation	-high resistance risk
Iprodione	-systemic mobility -inhibits mycelial growth and sporulation	-medium to high resistance risk
Propiconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	-not for use in nurseries, on nursery transplants, or greenhouses
Tetraconazole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Myclobutanil	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Triflumizole	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Mefenoxam	-reduced risk fungicide -systemic mobility -inhibits mycelial growth, sporangial development, and zoospore viability	-high resistance risk -SL is the only formulation registered
Fluopyram	-Velum One formulation for chemigation and soil applications for nematode management -local systemic mobility -broad spectrum of activity	-medium to high resistance risk -Velum One formulation only suppresses powdery mildew -unknown effect on sporulation

	-reduces mycelial growth	
Penthiopyrad	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high resistance risk -unknown effect on sporulation
Isofetamid	-local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high resistance risk -unknown effect on sporulation
Pyrimethanil	-medium resistance risk -reduced risk fungicide -local systemic mobility -inhibits mycelial growth and suppresses spore germination	-no effect on sporulation
Azoxystrobin	-plant dip (nurseries) or foliar spray (field use) -reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses -no effect on sporulation -phytotoxic to certain apple varieties
Pyraclostrobin	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Trifloxystrobin	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Fluoxastrobin	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Quinoxyfen	-medium resistance risk -reduced risk fungicide -suppresses spore germination, early germ tube development and/or appressorium formation	-contact activity and coverage critical -narrow spectrum of activity -no effect on sporulation
Fenhexamid	-low to medium resistance risk -reduced risk fungicide -systemic mobility inhibits spore germination and mycelial growth	-narrow spectrum of activity -no effect on sporulation
Polyoxin-D	-medium resistance risk -systemic mobility -inhibits spore germination and mycelial growth	-no effect on sporulation
Fosetyl-Al	-low resistance risk -foliar applications provide systemic treatment -plant dip (nurseries) or foliar spray (field use) -systemic mobility -inhibits mycelial growth and suppresses sporulation	
Phosphorous acid and salts	-low resistance risk -systemic mobility -inhibits mycelial growth and suppresses sporulation	
Acibenzolar-s-methyl	-systemic mobility	-resistance not known -unknown effect on mycelial growth and sporulation
Cyflufenamid	-narrow spectrum of activity -systemic mobility	-resistance in *Sphaerotheca* -unknown mechanism

Premix Formulations		
Azoxystrobin + propiconazole	-reduced risk fungicide (azoxystrobin) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Azoxystrobin + difenoconazole	-reduced risk fungicide (azoxystrobin) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Fluoypram + pyrimethanil	-reduced risk fungicide (pyrimethanil) -systemic mobility -broad spectrum of activity	-medium to high resistance risk
Fluxapyroxad + pyraclostrobin	-systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Boscalid + pyraclostrobin	-reduced risk fungicide (boscalid) -systemic mobility -broad spectrum of activity	-medium to high resistance risk -not for use in nurseries, on nursery transplants, or greenhouses
Cyprodinil + fludioxonil	-medium resistance risk -reduced risk fungicides -plant dip (nurseries) or foliar spray (field use)	-contact activity and coverage critical (fludioxonil)
Captan + fenhexamid	-medium resistance risk -reduced risk fungicide (fenhexamid)	-contact activity and coverage critical (captan)

Sources: Adaskaveg et al. (2017) and Oliveira and Peres (2019).

Ginseng

Table 23. Target diseases and efficacy ratings of captan in comparison to conventional alternatives in the management of common diseases in ginseng grown in Great Lakes region

Fungicide (FRAC Code[2])	Common Diseases of Ginseng[1]								
	Alternaria leaf blight	Botrytis leaf blight	Damping-off (including *Rhizoctonia*, *Pythium*)	Disappearing root rot	Phytophthora foliar blight and root rot	Powdery mildew	Sclerotinia white mold	Stromatinia black rot	Verticillium wilt
Multisite Fungicides									
Captan (M4)	G-F	F-G	G	G	E	–	–	–	–
Copper compounds (M1)	P-F	F	F	–	–	G	–	–	–
Mancozeb (M3)	G	F	–	–	F-P	P	–	–	–
Chlorothalonil (M5)	G	G-E	–	–	P	E	–	–	–
Single Site Fungicides									
Fosetyl-Al (P07)	P	–	P	–	F	–	–	–	–
Phosphorous acid salts (P07)	–	–	–	–	P-F	–	–	–	–
Iprodione (2)	F	F-P	–	–	–	–	–	–	–
Difenoconazole (3)	E	–	–	–	–	?	–	–	–
Mefenoxam (4)			E-P		E-P				
Boscalid (7)	E	G	–	–	–	E	E	–	–
Pyrimethanil (9)	G	G	–	–	–	?	–	–	–
Azoxystrobin (11)	G	F	F	G	–	E	?	–	–
Fenamidone (11)	P	–	G	–	G	–	–	–	–
Pyraclostrobin (11)	G-E	F	P	–	–	G	–	–	–
Trifloxystrobin (11)	G-E	F	?	–	–	?	–	–	–
Fludioxonil (12)	F	F	F-G	G	–	–	–	–	–
Fenhexamid (17)	P	E	–	–	–	–	–	–	–
Polyoxin D (19)	F-G	G	P-E	P	–	P	–	–	–
Ethaboxam (22)	–	–	E	–	G	–	–	–	–
Fluazinam (29)	F-G	E	–	–	P	E	G	–	–
Dimethomorph (40)	–	–	P	–	G	–	–	–	–
Mandipropamid (40)	–	–	–	–	G	-	–	–	–

Premix Formulations									
Azoxystrobin/Difenoconazole (11/3)	G	G	–	–	–		–	–	–
Azoxystrobin/Mancozeb (11/M3)	G	F-G	–	–	F-P	–	–	–	–
Cyprodinil/Fludioxonil (9/12)	F-G	F	–	–	–	–	–	–	?
Pyraclostrobin/Fluxapyroxad (11/7)	G	F-G	–	–	–	?	?	–	–
Zoxamide/Chlorothalonil (22/M5)	–	–	–	–	E	–	–	–	–

[1]Efficacy Ratings: E = excellent (90-100% control), G = good (75-89% control), F = fair (60-74%), P = poor (<60% control), ? = no data, but successful on related organisms, – = not applicable and /or used, U = unknown.

[2]FRAC Code List. 2020. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2020-finalb16c2b2c512362eb9a1eff00004acf5d.pdf?sfvrsn=54f499a_2

Source: Hausbeck, M.K. (2017).

Table 24. Advantages and disadvantages of captan in comparison to conventional alternatives in the management of diseases in ginseng

	FRAC Code	Advantages	Disadvantages
Multisite Fungicides			
Captan	M4	-relatively nontoxic to insects -low risk for resistance -broad spectrum of activity	-contact fungicide and coverage critical -B2 carcinogen -toxic to fish -do not contaminate or apply to water
Chlorothalonil	M5	-relatively nontoxic to honeybees -low risk for resistance -broad spectrum of activity	-contact fungicide and coverage critical B2 carcinogen -toxic to aquatic invertebrates and wildlife -do not contaminate or apply to water -may leach through permeable soils to ground water
Mancozeb	M3	-low risk for resistance - good efficacy -practically nontoxic to honeybees -broad spectrum of activity	-contact fungicide and coverage critical - toxic to aquatic organisms -do not contaminate or apply to water
Copper compounds	M1	-low risk for resistance -bactericidal and fungicidal -broad spectrum of activity	-potential for phytotoxicity especially under high temperature -contact fungicide and coverage critical limited efficacy -toxic to most fish and aquatic invertebrates -do not contaminate or apply to water
Single Site Fungicides			
Aluminum tris (fosetyl-Al)	P07	-low risk for resistance -systemic mobility -practically nontoxic to honeybees	limited efficacy -not effective against Alternaria • -toxic to aquatic/estuarine invertebrates -do not contaminate or apply to water
Phosphorous acid salts	P07	-low risk for resistance -systemic mobility	-limited efficacy -pathogen-specific

		- biopesticide -no adverse environmental effects to nontarget organisms	-toxic to fish and aquatic organisms -do not contaminate or apply to water
Iprodione	2	-systemic mobility -effective against sensitive pathogen populations -relatively nontoxic to bees	-medium to high risk for resistance -B2 carcinogen -toxic to invertebrates -do not contaminate or apply to water
Difenoconazole	3	-medium risk for resistance -systemic mobility	
Mefenoxam	4	-reduced-risk fungicide -systemic mobility	-high risk for resistance -Phytophthora resistance documented and widespread -do not contaminate or apply to water
Boscalid	7	-reduced-risk pesticide -systemic mobility -broad spectrum of activity	-medium to high risk for resistance -residue issues -do not contaminate or apply to water -not for use in greenhouse or transplant production systems
Pyrimethanil	9	-medium risk for resistance -reduced risk pesticide -systemic mobility - fair to good efficacy -no known cross resistance issues with other chemistries	-do not contaminate water supply with product
Azoxystrobin	11	-reduced-risk pesticide -systemic mobility -low acute/chronic toxicity to birds, mammals, bees -broad spectrum of activity	-high risk for resistance -extremely phytotoxic to certain apple varieties -resistance issues with *A. panax* -toxic to freshwater and estuarine/marine fish and aquatic invertebrates -do not contaminate or apply to water -may leach through permeable soils to ground water
Fenamidone	11	-reduced-risk pesticide -systemic mobility -broad spectrum of activity	-high risk for resistance -toxic to fish, aquatic invertebrates, shrimp, oysters

			-do not contaminate or apply to water
Pyraclostrobin	11	-systemic mobility -broad-spectrum activity -excellent efficacy -broad spectrum of activity	-high risk for resistance -not for use in greenhouse or transplant production -toxic to fish and aquatic invertebrates -do not contaminate or apply to water
Trifloxystrobin	11	-reduced risk pesticide -systemic mobility -good efficacy -low toxicity to honeybees -broad spectrum of activity	-high risk for resistance -toxic to fish and aquatic invertebrates -do not contaminate or apply to water
Fludioxonil	12	-reduced-risk pesticide -low to medium risk for resistance	-contact fungicide -toxic to fish and aquatic invertebrates -do not contaminate or apply to water
Fenhexamid	17	-reduced-risk pesticide -practically nontoxic to honeybees -low to medium risk for resistance -systemic mobility practically nontoxic to honeybees	- nonfood use only -cannot be used on crop to be harvested -limited range of pathogens controlled -only 4 applications allowed per season -toxic to fish and aquatic organisms -do not contaminate or apply to wate
Polyoxin D zinc salt	19	-biopesticide -no toxicity to insects -medium risk for resistance -systemic mobility	-moderately toxic to fish and aquatic invertebrates -do not contaminate or apply to water
Ethaboxam	22	-low to medium risk for resistance -protective, curative and antisporulant activities -systemic mobility -good efficacy	-toxic to aquatic invertebrates -only two applications per season
Fluazinam	29	-reduced-risk pesticide -low risk for resistance -systemic mobility	-toxic to fish and aquatic invertebrates -do not contaminate or apply to water -expensive

Dimethomorph	40	-low to medium risk for resistance -systemic mobility - excellent efficacy	-do not contaminate or apply to water
Mandipropamid	40	-reduced-risk pesticide -low to medium risk for resistance -systemic mobility - good efficacy	- do not contaminate or apply to water -surfactant recommended
Premix Formulations			
Azoxystrobin/Difenoconazole	11/3	-built in resistance management -systemic mobility	-high and medium risk for resistance -toxic to freshwater and estuarine/marine fish and aquatic invertebrates -do not contaminate or apply to water -may leach through permeable soils to ground water
Pyraclostrobin/Fluxapyroxad	11/7	-built in resistance management -medium to high risk for resistance -systemic mobility good efficacy	-toxic to fish and aquatic organisms -do not contaminate water supply
Azoxystrobin/Mancozeb	11/M3	-built in resistance management -high and low risk for resistance -systemic mobility good efficacy	-B2 carcinogen (mancozeb) -toxic to aquatic organisms -do not contaminate or apply to water
Cyprodinil/Fludioxonil	9/12	-reduced-risk fungicides -built in resistance management -low to medium risk for resistance -systemic mobility and contact	-toxic to fish, aquatic invertebrates, shrimp, oysters -do not contaminate or apply to water
Zoxamide/Chlorothalonil	22/M5	-built in resistance management -medium and low risk for resistance -systemic mobility and contact	

Source: Hausbeck, M.K. 2017.

Seed Treatment

Table 25. Target diseases and effectiveness of captan and conventional alternatives used as seed treatments.

Table 1. Target diseases and effectiveness of captan and conventional alternatives used as seed treatments.

Fungicide	FRAC Code	Target Disease[2]	Target pathogen and effectiveness[1]			
			Pythium spp.	Rhizoctonia spp.	Fusarium spp.	Phytophthora spp.
Multisite Fungicides						
Captan	M4	Damping-off	++	++	+	-
Thiram	M3	Damping-off	+	++	+	-
Mancozeb	M3	Other	V	V	V	V
Single-site Fungicides						
Thiophanate-methyl	1	Damping-off	-	+++	+++	-
Iprodione	2	Damping-off	-	+++	+++	-
Difenoconazole	3	Other	V	V	V	V
Tebuconazole	3	Other	V	V	V	V
Triadimenol	3	Other	V	V	V	V
Prothioconazole	3	Other	V	V	V	V
Triticonazole	3	Other	V	V	V	V
Mefenoxam/metalaxyl	4	Damping-off	+++	-	-	+++
Carboxin	7	Other	V	V	V	V
Azoxystrobin	11	Damping-off	-	+++	-	-
Pyraclostrobin	11	Other	V	V	V	V
Trifloxystrobin	11	Other	V	V	V	V
Fludioxonil	12	Damping-off	-	+++	+++	-

[1]Table modified from Lamichhane et al. (2020); efficacy ratings: excellent (+++); good (++); fair (+); poor or no activity (–); variable (V), depending on the target pathogen

[2] Other diseases include root rots, smuts, bunts, seed and seedling blights, tan spots, powdery mildew, and spot blotch

Source: Lamichhane et al. (2020).

Table 26. Advantages and disadvantages of captan in comparison to conventional alternatives used as seed treatments.

Fungicide	FRAC Code	Advantages	Disadvantages
Multisite Fungicides			
Captan	M4	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact, non-systemic -no effect on sporulation
Thiram	M3	-low resistance risk -broad spectrum of activity -inhibits spore germination	-contact, non-systemic -no effect on sporulation
Mancozeb	M3	-low risk for resistance -broad spectrum of activity -inhibits spore germination	-contact, non-systemic -no effect on sporulation
Single Site Fungicides			
Thiophanate-methyl	1	-systemic mobility -broad spectrum of activity -inhibits mycelial growth and sporulation	-high resistance risk
Iprodione	2	-systemic mobility -inhibits mycelial growth and sporulation	-medium to high resistance risk
Difenoconazole	3	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Tebuconazole	3	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Triadimenol	3	-older triazole/DMI chemistry -medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	

Prothioconazole	3	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Triticonazole	3	-medium resistance risk -systemic mobility -broad spectrum of activity -inhibits mycelial growth and suppresses sporulation	
Mefenoxam/metalaxyl	4	-reduced risk fungicide -systemic mobility -inhibits mycelial growth, sporangial development, and zoospore viability	-high resistance risk
Carboxin	7	-older SDHI chemistry -local systemic mobility -broad spectrum of activity -reduces mycelial growth	-medium to high resistance risk -unknown effect on sporulation
Azoxystrobin	11	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Pyraclostrobin	11	-local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Trifloxystrobin	11	-reduced risk fungicide -local systemic mobility -broad spectrum of activity -inhibit spore germination	-high resistance risk -no effect on sporulation
Fludioxonil	12	-reduced risk fungicide -low to medium risk for resistance -broad spectrum act. -inhibits mycelial growth and germination -reduces sporulation	-contact mode of action

Source: Lamichhane et al. (2020).