Invasive Fruit Pest Guide for Utah

Insect & Disease Identification, Monitoring & Management

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2016 INVASIVE FRUIT PEST GUIDE FOR UTAH

Insect & Disease Identification, Monitoring & Management

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Image Credits

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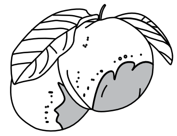
CHAPTER 1  BROWN ROT

Quick Facts
• Brown rot (BR), both *M. laxa* and *M. fructicola*, were found in Utah in the summer of 2013 in peach and nectarine fruit (respectively). • Since 2013, only *M. fructicola* has been found in Utah. • BR overwinters as fruit "mummies" or in stem cankers. • Brown rot can affect most parts of the plant: stem, flower, shoots, and fruit. • Susceptible plants are peach, nectarine, plum, cherry, and other stone fruits (other species of BR not currently found in the U.S. can infect apple and pear). • The most destructive phase of brown rot occurs with infection of maturing fruits just prior to harvest (about 2-3 weeks before). • Effective control of BR includes fungicide applications timed for when blossoms first open and 2-3 weeks before harvest, removal of infected fruit from orchards, and pruning infected shoots.

Background

In Utah, brown rot is a disease caused by two fungal species; *Monilinia fructicola* (Helotiales: Sclerotiniaceae) and *M. laxa*. (Helotiales: Sclerotiniaceae). Brown rot commonly affects stone fruit including peach, nectarine, apricot, plum and cherry. Another species of BR that is not currently found in the U.S. can also infect apple and pear.

The first published description of BR on decaying fruit was in 1796 in Europe. It was first noticed in the US in 1807. *M. fructicola* is the most common species found in North America, Australia, New Zealand, Japan, Brazil and other South American countries. *M. fructicola* was first detected in Utah in the summer of 2013 in a peach fruit.

Brown rot caused by *M. laxa* is known as European brown rot and is especially common in Europe, South Africa, and Chile. This species is relatively widespread in California, and also occurs in midwestern and northeastern states. *M. laxa* was first detected in Utah during the summer of 2013 in a nectarine fruit.

Brown rot is favored by warm and humid weather conditions. The first detections of brown rot in Utah may have been due to heavy rainfall and high temperatures in 2013 during mid-August, two to three weeks before harvest. Both species, *M. fructicola and M. laxa*, are suspected of having been in Utah for some time before the first detection, but had gone unnoticed because they did not cause problems during the usually dry summers.

Disease Identification and Life History

Brown rot shows up in many stages of fruit development including blossoms, stems and fruit.

BLOSSOMS: DISPERSAL AND DAMAGING STAGE

- Known as blossom blight.
- Wilted, brown and wrinkled blossoms and sometimes leaves *(Figs. 1.1-1.7)*.
- Tan- to buff-colored spores develop on infected tissues.
- Blossoms do not progress into fruit and remain on the tree, brown and wilted.

STEMS: DISPERSAL, DAMAGING STAGE, AND OOVERWINTERING STAGE

- Known as stem cankers.
- Brown, collapsed, elliptical shaped lesions (stem cankers) on twigs and small branches *(Figs. 1.3-1.6)*.
- Stem cankers can eventually girdle diseased stems.
- Gumming may occur on stems when cankers appear *(Figs. 1.3-1.4)* (however, gumming is a general stress response and is not always seen in BR infections).
- Leaves surrounding infected stems may also appear brown and wilted *(Figs. 1.6-1.7)*.

FRUIT: REPRODUCTIVE, DISPERSAL, DMAGING, AND OVERWINTERING STAGE

- Sporulation occurs in concentric circles or rings *(Figs. 1.8-1.9)*.
- Spores on fruit are generally brown to gray in color *(Figs. 1.8-1.21)*.
- Initial symptoms may appear as small superficial spots that are brown in color *(Fig. 1.22)*.
- Skin of the fruit may slip easily and has oval- to round-shaped brown lesions *(Figs. 1.14-1.15)*.

- Thick layers of brown or gray spores build up on the skin of the fruit *(Figs. 1.16-1.19)*.
- Eventually, fruit become mummified: wrinkled, rock-hard, and often dark brown to gray in color *(Figs. 1.23-1.28)*.
- Fruit mummies are covered with spores.
- Mummified fruit can fall to the ground or remain in the tree to overwinter and spread the disease the following season.
- Mummies may form apothecia: cup-like fruiting bodies with a smooth, fleshy, brown to reddish-brown color *(Fig. 1.29)*.
- Apothecia cup-like structures are held up by a stalk growing up to 2 inches long.
- Apothecia vary in size from ¼ (6.35 mm) to ¾ inch (19 mm) in diameter.

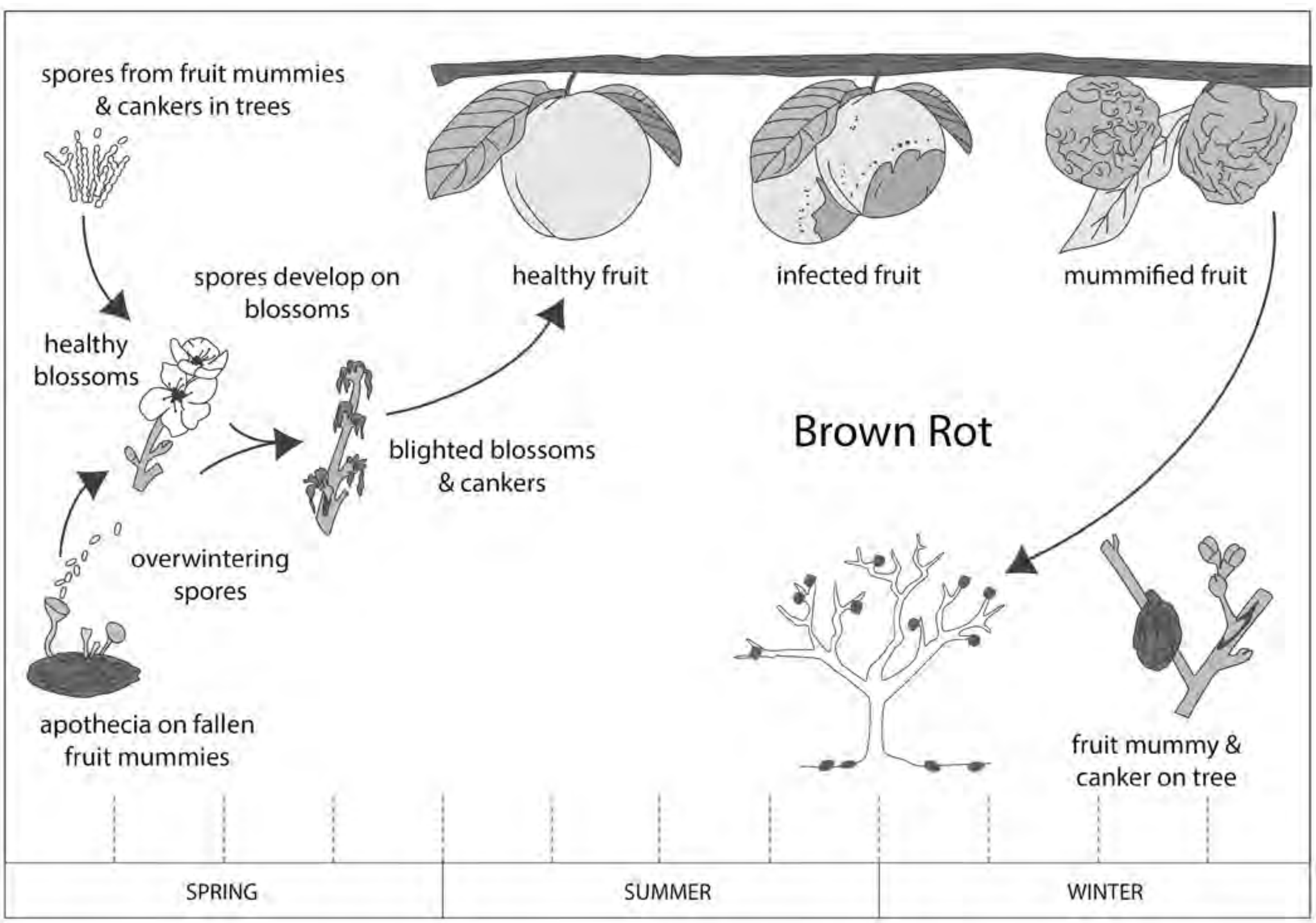
Mummified fruit and stem cankers are the main overwintering sites. Primary spores of BR are produced in apothecia or infected plant tissues where they initiate the disease cycle each year. This includes mummies that remain attached to the tree, and mummies that have fallen to the ground.

Spore production begins in the spring at temperatures of 55-77°F (12-25°C). These spores are dispersed by wind and rain. Primary spores are released from apothecia or infected plant tissues and carried through the air to blossoms of susceptible plants.

Optimum temperatures for blossom infection of peach are 72-77°F (22-25°C), although infections can occur at temperatures as low as 41°F (5°C). Very high relative humidity (>94%) is important for infection. It is difficult to see infected blossoms until small fruit start forming, at which point BR symptoms are more noticeable due to the presence of brown, wilted blossoms that do not develop into fruit.

Secondary spore production begins almost immediately after primary spore infection symptoms occur on the blossoms and stems. Disease control opportunities improve when development of secondary inoculum can be reduced by spraying fungicides at the proper time. During dry seasons, spore production on infected flowers may not occur at all or be minimal; however, during wet seasons, spore production will be extensive.

The fungus moves from blossoms or infected fruit to the stems *(Fig. 1.3-1.6)*. From blossom blight and stem cankers, otherwise healthy fruit can then become infected. Occasionally, fruit thinned after pit hardening can be colonized by the fungus and become a source for spores that can infect ripening fruit.



Disease cycle and life history of brown rot in Utah. Adapted from Vickie Brewster drawing, USDA-ARS

If spores are present during wet and warm conditions, infection of ripe fruit is likely, as fruit at this stage is highly susceptible. Pre-harvest brown rot is likely to reach devastating levels when spore numbers are high due to continual infection from fruit to fruit.

Moisture on plant parts (from dew, rain, or irrigation) increases the likelihood of infection. If conditions are optimal, infection can require from one to six hours, and fruit can completely rot within three days. Because infection of BR can occur in such a short period of time, the disease can spread through an orchard quickly leading to high crop losses during wet and warm conditions.

Wind, water, and insects are three main vectors of spore dissemination. Wind can disperse spores to infect leaves, blossoms, or fruit. Splashing water droplets from rain or irrigation, and movement on insect body parts are other mechanisms of spore dispersal.

Plant Hosts and Symptom Development

Both *M. laxa* and *M. fructicola* prefer stone fruits. Fruit, shoots, flowers, stems and leaves can all be infected by *Monilinia* species. Flower and fruit tissues are infected by disseminated spores, while stems are usually infected by spread from diseased blossoms and fruit within a tree. Directly infected leaves and stems by spores is rare, but is more likely to occur in plum and certain ornamental *Prunus* species. Damage, and crop loss, is caused by blossom and twig blights, stem cankers, and fruit rot.

Blossoms

In the blossom blight phase, infection of any part of the flower is possible. Infected tissues turn brown and tan-colored spores develop on the dead tissue.

Stem Cankers

Twigs and small branches are often infected with BR through spreading of the fungus from diseased flower and fruit pedicels. Once infected, stems will form cankers, or brown lesions of collapsed tissue. As these elliptical cankers enlarge, the entire stem may be girdled. This girdling causes the shoot tip to wither and die, while the leaves often remain attached. Gumming of the stem may also occur when cankers appear.

Fruit

Brown rot lesions usually show up on fruit about two to three weeks before harvest. Initial symptoms on ripening fruit are small round spots or lesions that enlarge over time. On mature fruit, lesions develop and enlarge rapidly. New infections create a soft brown spot on which tan to gray colored spores develop. Because green fruit has tough skin and low sugar content, it is usually less susceptible to brown rot unless it is wounded by insect or cold damage. Infected fruits will turn into fruit mummies.

Immature sweet cherries may show symptoms of small (3/16 in or 4.8 mm to ¾ in or 19 mm in diameter), sunken brown spots with a red halo *(Fig. 1.29)*.

Mummified Fruit

Monilinia can completely colonize an entire fruit of stone fruit crops. As the disease progresses, fruit turns into “mummies” that are dark brown to gray in color, shriveled and eventually hardened. Mummified fruit overwinter by either dropping to the ground or remaining attached to the tree.

Apothecia will only develop on mummies partially buried in the soil *(Fig. 1.30)*. Apothecia have not been found in Utah.

Monitoring

Scouting is important to minimize the risk of brown rot infection. At least 20 trees per block should be checked for fruit mummies and cankers during or after pruning in the spring (before white bud stage). One to ten mummies and/or cankers per 20 trees is considered a moderate risk level for blossom infection. Greater than 10 mummies and/or cankers indicate a high risk level. Both risk levels are based on the assumption of appropriate environmental conditions for brown rot. If stem cankers are found, they should be removed immediately through pruning.

Although apothecia have not been found in Utah, scouting for fallen mummies with apothecia should be conducted during bloom. Apothecia develop when mummified fruit are partially buried under moist soil or debris. If apothecia are present, risk of blossom blight infection may be high.

During shuck fall, scout ten shoots of 20 trees for blossom infections. Petals of infected blossoms will be brown and dry, and the blossoms will remain hanging in the tree. A moderate risk level for fruit infection is reached when one to ten blossom infections per 20 trees is present. More than ten blossom infections indicates a high risk of fruit infection.

As fruit ripens and becomes softer, the risk for infection increases. Two symptomatic fruit found per 10 acres during scouting before harvest is considered high risk for a brown rot outbreak. If possible, fruit should be checked every three to five days prior to harvest to catch potential infections early before they spread through the orchard. Feeding injury from insects and birds as well as hail damage can provide easy colonization areas for *Monilinia*.

Infected fruit may not show symptoms during harvest, but may develop symptoms of brown rot in storage or during transportation to customers. Fruit in storage should be checked at least every other day to detect brown rot.

Management

It is important to maintain disease management practices because when environmental conditions favorable for blossom blight combine with lack of disease management (due to spring crop loss), overwintering of brown rot inoculum may increase to high levels. Abundance of overwintering inoculum can lead to heavy crop losses in subsequent years.

Reducing blossom blight can reduce pre-harvest brown rot levels. Blossom blight will likely occur in orchards that had brown rot in the previous year. **(Figs. 1.27-1.28)**.

Brown rot causes significant losses when infections occur just prior to harvest. One lesion on an infected fruit can produce thousands of spores, each capable of causing a new infection.

Cultural Control

An important cultural control method is sanitation. Removing infected fruit from the orchard after harvest can drastically reduce inoculum and the potential for blossom infections in the following year. Blossom blight infections are another important area of control because fruit frequently becomes infected from spores that are produced on blighted blossoms and cankers.

FALL-SPRING

- Reduce humidity in the tree canopy for good air movement. Lower humidity decreases spore germination and subsequent infection of blossoms and fruit.
- Before bloom or during the dormant season, remove mummified fruit from trees and the orchard floor. This will reduce *Monilinia* inoculum in the orchard.
- In late winter, while trees are still dormant, prune out twigs that have died from brown rot and branches with cankers. This will reduce overwintering sites for brown rot inoculum.

GROWING SEASON

- Thin fruit before pit hardening because fruit that falls to the orchard floor at this time is more likely to decay before significant numbers of brown rot spores have a chance to develop. Fruit that has fallen to the orchard floor *after* pit hardening is more likely to develop BR spores.
- Remove and dispose of thinned fruit to reduce presence of spores, if infected fruit are present.
- Watch for fruit injury. Ripening fruit with wounds can be quickly colonized by brown rot *(Fig. 1.13)*.
- Cool, refrigerate or process fruit directly following harvest.
- Within 1-2 weeks after harvest, pick and dispose of remaining fruit before mummification can occur.

ONGOING

- Avoid the presence of alternative hosts of brown rot by removing abandoned, volunteer or wild stone fruit trees near orchards.
- Reduce populations of insects that may cause wounds on fruit to reduce early brown rot infections.

Chemical Control

Fungicides may be needed in areas where brown rot has caused severe fruit rot in previous seasons. Even with sanitation and pruning, fungicides will likely be needed for acceptable control.

To control brown rot effectively, apply fungicides during bloom (to reduce blossom blight) and during a two-three week period prior to harvest. Additional sprays may be necessary between bloom and fruit ripening during wet weather.

There are many fungicides registered for brown rot management. The label provides information for the most efficient stages to treat during the growing season. To avoid fungicide resistance, rotate among fungicide chemistries with different modes of action. Most fungicide labels now include the mode of action classification number at the top of the label.

Consider weather conditions and previous brown rot inoculum levels to determine fungicide application rates, timings, and intensity. More frequent applications may be needed during warm, wet weather than during cool and dry conditions. So far brown rot has only been found on peach and nectarine fruits in Utah; however, this guide includes fungicide recommendations for other stone fruit species as well.

For effective treatment, apply fungicides at the following two times:

1. **Blossom blight protection:** treat blossoms when they first begin to open. Apply at 20 to 40% bloom, and repeat at 80 to 100% bloom. Reapply sprays according to label instructions until petal fall, and consider the favorability of weather conditions in selecting a reapplication interval.
2. **Fruit rot protection:** treat with fungicide sprays 2-3 weeks prior to harvest as fruit is ripening. Repeat sprays according to label instructions until harvest.

After fruit color break (when maturing fruit changes color from green to yellow to red), examine fruit trees weekly or bi-weekly for brown rot symptoms. Monitor fruit to assess damage levels and effectiveness of control efforts. This information can be useful when determining the effectiveness of each year's management methods, and to guide improvements in subsequent years.

Apply fungicides with ground rather than aerial equipment for greater efficacy. However, aerial applications may be necessary when the orchard floor is too wet to allow ground equipment.

Recommended Fungicides

Table 1.1. Fungicides recommended for control of BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT production in Utah.

Table 1.2. Fungicides recommended for control of BROWN ROT TWIG BLIGHT IN COMMERCIAL FRUIT production in Utah.

Table 1.3. Fungicides recommended for control of BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT production in Utah.

Table 1.4. Fungicides recommended for control of BROWN ROT BLOSSOM BLIGHT IN HOME FRUIT production in Utah.

Table 1.5. Fungicides recommended for control of BROWN ROT TWIG BLIGHT & FRUIT ROT IN HOME FRUIT production in Utah.

For Additional Information, Search the Internet for:

Peach - Brown Rot, Pacific Northwest Plant Disease Management Handbook

Cherry - Brown Rot Blossom Blight and Fruit Rot, Pacific Northwest Plant Disease Management Handbook

Cherry, Flowering – Brown Rot Blossom Blight, Pacific Northwest Plant Disease Management Handbook

Brown Rot Management in a Wet Growing Season: Part I, Rutgers Cooperative Extension

Brown Rot Management in a Wet Growing Season: Part II, Rutgers Cooperative Extension

Brown Rot of Stone Fruits, UMaine Extension

Brown Rot of Stone Fruits, APS

Brown Rot, University of Minnesota Extension

Brown Rot Pre-Harvest Alert, PennState Extension

Brown Rot of Peach and Nectarine, Utah State University Extension

Peach Brown Rot Blossom and Twig Blight, UC Davis IPM

Brown Rot of Stone Fruits, British Columbia Ministry of Agriculture

Brown Rot, Kearneysville Plant Disease Fact Sheet, West Virginia University

Brown Rot, University of Georgia

Brown Rot on Peach and Other Stone Fruits, Virginia Cooperative Extension

Control of Brown Rot of Stone Fruits by Brief Heated Water Immersion Treatments, UC Davis

Reduced-risk Fungicides Help Manage Brown Rot and Other Fungal Diseases of Stone Fruit, UC Davis

Brown Rot

Pest Management Tables for Commercial and Home Use

Table 1.1. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Fungicide Group[F]				
Group 1				
thiophanate-methyl	Cercobin, Incognito 4.5F, Incognito 85 WDG, Nufarm T-Methyl 4.5 F, Thiohanate Methyl 85-WDG	**Apricot:** Apply at early bloom (red bud). Make a second application at full bloom. If needed, under severe disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. **Cherry:** Apply at early bloom (early popcorn). Make a second application at full bloom. If needed under severe disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. **Nectarine & Peach:** Apply at early bloom (pink bud). Make a second aplication at full bloom if conditions favor disease development. If needed under sever disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. **Plum & Prune:** Apply at early bloom (green tip). Make a second application at full bloom if conditions favor disease development. **PLUS** Apply at shuck split and at first cover sprays.	10-14 d	See [E]Environmental Hazards information at the bottom of the chart.
Group 2				
iprodione	Iprodione 4L AG Fungicide, Meteor, Nevado 4F, Rovral 4 Flowable	Should be initially applied when the bud tissue favors development of the disease. This is usually indicate by a pink, white or red bud. If favorable disease conditions linger, or repeat, the product should be applied during full bloom or petal fall. Do not apply after petal fall.	NL	Toxic to invertebrates.
Group 3				
fenbuconazole	Indar 2F	**Plum & Prune:** Begin applications at early red bud stage before infection occurs. If conditions are favorable for disease development, apply again at full bloom and petal fall. **Apricot, Nectarine, Peach, & Cherry:** Begin applications at early red bud stage before infection occurs. If conditions are favorable for disease developmen, apply again at full bloom and at petal fall.	7-14 d	Toxic to fish and shrimp. Toxic to fish and shrimp.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Group 3, continued				
metconazole	Quash	**Cherry:** Begin applications at green tip. If conditions are favorable for disease development, make additional applications at full bloom and at petal fall. **Apricot, Nectarine, Peach, Plum, Plumcot, Prune:** Begin applications at early pink bud stage before infection occurs. If conditions are favorable for disease development, make additional applications at full bloom and at petal fall.	NL	Toxic to fish and shrimp. Toxic to fish and shrimp.
myclobutanil	Eagle 20EW, Eagle 40WP, Rally 40W SP Fungicide	Apply at early bloom stage. Make one repeat aplication under low disease pressure. Make two additional applications under high disease pressure (or if variety is particularly sensitive to disease) first at 75-100% bloom and then at petal fall.	7-14 d	
propiconazole	Amtide Propiconazole 41.8% EC, Bumper 41.8 EC, Bumper ES, Fitness, Orbit, Propi-Star EC, Propimax EC, Shar-Shield PPZ, Tide Propiconazole 41.8%, Tilt, Topaz			
tebuconazole	Elite 45-WP, Orius 20AQ			
Group 3; Group 1				
propiconazole; thiophanate-methyl	Protocol	Apply at early bloom stage. If disease pressure is low, a second application may be made as needed through petal fall. Under conditions of high disease pressure and/or very susceptible varieties, make a second application from 75% to 100% bloom and a third application at petal fall.	NL	Toxic to fish and shrimp; refer to product labeing for use restrictions to protect endangered species.
Group 3; Group 11				
tebuconazole; trifloxystrobin	Adament	Begin applications when conditions are favorable for disease but before infection. Apply on a 7- to 14-day spray schedule.	7-14 d	Toxic to mammals, fish and aquatic invertebrates.
Group 7				
penthiopyrad	Fontelis	Begin applications prior to disease development and continue on a 7- to 14-day interval. Use higher rate and shorter interval when disease pressure is high.	7-14 d	Toxic to mammals, fish and aquatic invertebrates.
Group 7; Group 11				
fluopyram; trifloxystrobin	Luna Sensation	Labeled for use for cherries. Begin application preventatively or at white bud on cherry. Apply again at 50% bloom and at petal fall if conditions continue to be favorable for disease development.	7 d	Toxic to mammals, fish and aquatic invertebrates

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Group 7; Group 11, continued				
fluxapyroxad; pyraclostrobin	Merivon	Begin application at pink bud or prior to onset of disease development and continue on a 7 to 14 day interval.	7-14 d	Toxic to mammals, fish and aquatic invertebrates
boscalid; pyraclostrobin	Pristine Fungicide			
Group 9				
pyrimethanil	Scala SC	Apply when bud tissue is susceptible to infection (i.e., pink, white or red bud). If conditions favorable for disease development persist or recur, apply at full bloom or at petal fall.	7 d	See [E]Environmental Hazards information at the bottom of the chart.
Group 9; Group 3				
cyprodinil; difenoconazole	Inspire Super	Begin applications at early bloom and make a second application at full bloom.	7 d	Do not apply to sweet cherries; toxic to fish, mammals and aquatic invertebrates.
Group 11				
azoxystrobin	Abound, Aframe, Azoxystar, Heritage, Equation SC, Satori Fungicide	Begin applications at early bloom and continue through petal fall.	7-14 d	Toxic to freshwater and estuarine/marine fish and aquatic invertebrates.
Group 11; Group 3				
azoxystrobin; difenoconazole	Quadris Top	Begin applications at early bloom and continue through petal fall. Make additional applications on a 10- to 14-day interval from the end of petal fall to harvest.	7 d	Toxic to fish, mammals, aquatic invertebrates, freshwater and estuarine/marine fish.
azoxystrobin; propiconazole	Quilt Xcel	Apply at early bloom stage. If disease pressure is low, a second application may be made as needed through petal fall. Under conditions of high disease pressure and/or very susceptible varieties, make a second application from 50-75% bloom and a thir	NL	Toxic to freshwater and estuarine/marine fish and aquatic invertebrates.
Group 14				
DCNA dicloran	Botran 75-W Fungicide	**Peach & Nectarine:** Apply at pink bud and full bloom. **Plum & Prune:** Apply at popcorn and full bloom. **Sweet Cherry:** Apply at popcorn, bloom, full bloom and petal fall.	18 d	Toxic to fish.
Group 44				
bacillus subtilis strain QST 713	Serenade ASO[O], Serenade Max[O], Serenade-ASO[O]	Begin application at early bloom and repeat through petal fall on a 7-day interval or as needed.	7 d	See [E]Environmental Hazards information at the bottom of the chart.

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Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Group 44, continued				
fenhexamid	Elevate 50 WDG Fungicide	Apply at early bloom, late bloom, and 2 weeks after petal fall.	NL	Apply in minimum of 50 gallons by ground; toxic to fish and aquatic invertebrates.
Group M1				
basic copper sulfate	Basic Copper 53, Cuprofix-Ultra 40 Disperss, Cuproxat	**Apricot & Cherry:** Apply at popcorn to full bloom as a full cover spray for apricot and cherry. To avoid spray injury, do no apply after bloom. **Peach & Nectarine:** Apply as a full cover spray at pink bud. (Application at this time also affords some control of Leaf Curl and Coryneum Blight.) **Note:** Do not spray later than three weeks prior to harvest. Do not use at rates above those recommended **Plum & Prune:** Apply full cover application at pink, red or early white bud stage. Use the higher rate when disease pressure is heavy or conditions favor disease development.	5-7 d	Toxic to fish and aquatic invertebrates.
Copper Hydroxide	Champ Formula 2 Flowable, Champ DP Dry Prill, Champ WG, Champion++, Kocide 2000, Kocide 3000, Kocide 3000 Fungicide, Kocide-2000, Kocide-DF, Nu-Cop 3 L, Nu-Cop 50DF, Nu-Cop HB			
copper octanoate	Cueva[O]			
copper sulfate pentahydrate	Copper Sulfate Crystals, Copper Sulfate Crystals REI=24, Mastercop, Quimag Copper Sulfate Crystal	Apply when buds begin to swell.	5-7 d	
cuprous oxide	Nordox	**Apricot:** Apply in dormant/delayed-dormant sprays through popcorn stage. Do not apply after bloom. **Peach & Nectarine:** Apply before bud swell in the full pink bud stage. **Plum & Prune:** Apply as a dormant spray before heavy rains begin. Apply at early green bud to full popcorn stages.	28 d	
basic copper sulfate; copper oxychloride	C-O-C-S WDG	**Apricot, Peach, Nectarine, Plums, & Prunes:** Apply pre-blossom, blossom and petal fall periods. **Cherry:** Apply in popcon, bloom and in petal fall periods.	5-7 d	Toxic to fish and aquatic invertebrates. Toxic to fish and aquatic invertebrates.

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[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

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Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Group M1; Group M1				
copper hydroxide; copper oxychloride	Badge SC, Badge X2	**Apricot, Cherry, Plum, & Prune:** Apply during early bloom. Do not apply after full bloom or injury may occur. **Apricot, Nectarine, & Peach:** Full cover spray at pink bud for. **Badge X2:** Use the higher rates when rainfall is heavy and disease pressure is high.	5 d	Toxic to fish and aquatic invertebrates.
Group M2				
sulfur	Crusade DF[O], Kumulus DF, Kumulus DF Fungicide-Acaricide, Sulfur-DF, Golden Micronized Sulfur[O], Micro Sulf, Microthiol Disperss[O], Sulfur 6 L, Thiolux[O]	Apply at bloom or early petal fall. Repeat as necessary, usually 10-14 days or after a period of wet weather.	10-14 d	Toxic to fish and aquatic organisms; sulfur may burn foliage when temperature is excessively high; sulfur may cause severe fruit and foliage injury to certain crops such as D'Anjou and Comic pears and apricots; do not apply within 2 weeks of an oil spray. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
Group M2; Group 3				
sulfur; tebuconazole	Unicorn	Begin application at white bud on cherry, or pink bud on peach and nectarine, and green tip on plums and prunes. Apply again at 50% bloom and petal fall if conditions continue to be favorable for disease development.	7 d	Toxic to mammals, fish and aquatic invertebrates. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
Group M3				
ziram	Ziram 76DF	Apply at pre-bloom through cover sprays as needed.	NL	Toxic to fish and aquatic invertebrates.

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Group M4				
captan	Captan 38.75%, Captan 50 Wettable Powder, Captan 50W (Drexel), Captan 80 WDG Fungicide, Captan 80-WDG, Captan 80WDG, Captan 80WDG Fungicide, Captan Gold 4L, Captan Gold 80WDG	**Apricot:** Apply in red bud, bloom, and 75% petal fall prays. **Cherry:** Apply in pre bloom, bloom, petal fall, shuck, cover and preharvest sprays. **Nectarine:** Apply in full pink, bloom, petal fall, shuck, cover and preharvest sprays. Applications at 3 to 4 day intervals may be necessary during bloom to control blossom blight. Repeat application at 7 to 14 day intervals as needed to maintain control. Continue applications throughout harvest if conditions favor brown rot. **Peach:** Apply in full pink, bloom, petal fall, shuck stages and in cover and preharvest sprays. When conditions are favorable, make applications at 3 to 4 day intervals during bloom to control blossom blight. Then repeat application at 7 to 14 day intervals as needed to maintain control. Continue applications through harvest if conditions favor brown rot. **Plum & Prune:** Apply at green bud, popcorn, bloom and petal fall stages. Repeat in cover sprays as conditions warrant. **Almond:** Apply at popcorn, bloom and petal fall, post petal fall, and full cover sprays.	7-20 d	Toxic to fish.
Group M4; Group 17				
captan; fenhexamid	Captevate 68 WDG	**Cherry:** Apply at early bloom, late bloom, and 2 weeks after petal fall.	NL	Toxic to fish and aquatic invertebrates.
Group M5				
chlorothalonil	Bravo Weather Stik, Bravo ZN, Echo 720, Chloronil 720, Chlorothalonil 720 SC, Daconil Ultrex, Echo 90DF, Equus 500 ZN-Fungicide, Equus 720SST, Equus-DF Fungicide, Initiate ZN	Make one application at popcorn (pink, red or early white bud) and a second application at full bloom. If weather conditions favor disease development, make an additional application at petal fall.	10 d	Toxic to aquatic invertebrates and wildlife.
Group P5				
extract of reynoutria sachalinensis	Regalia[O]	Begin application in 50-100 gallons of water per acre at early bloom, and repeat through petal fall on a 7-day interval or as needed.	7 d	See [E]Environmental Hazards information at the bottom of the chart.

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[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.1, continued. Fungicides recommended for control of **BROWN ROT BLOSSOM BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments (for [P]PHI and REI information, check the label)
Other				
Bacillus amyloliquefaciens strain D747	Double Nickel 55[O]	Start applying at early bloom stage and repeat every 7 das through petal fall.	7 d	See [E]Environmental Hazards information at the bottom of the chart.
calcium polysulfides	Lime-Sulfur Solution[O]	**Tart Cherry:** Apply up to 3 sprays at 1 1/2 gallons during pre-bloom, early bloom, or full bloom. **Nectarine:** Use 2 quarts. Apply 3 to 5 times at weekly intervals until harvest. **Peach:** DO NOT apply dormant spray to peaches immediately after or during periods of 5 das or more of unseasonable high temperatures if a sufficient number of dormant cold hours have occured. Apply 3/4 to 1 1/2 gallons (one spray at each period if conditions require it) at Pre-bloom, early bloom, or full bloom. **Plum:** Apply 3 quarts at 20, 10, and 2 days before harvest. **Prune:** Apply 2 quarts in weekly applications beggnning 3 to 5 weeks before harvest	7 d	Toxic to fish; do not apply to harvested fruit. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
calcium polysulfides	Rex Lime Sulfur Solution	**Cherry (tart):** Apply up to 3 sprays at 1 1/2 to 2 gallons of product per 100 gallons of water. **Peach:** Pre-bloom, early bloom, and full bloom. Apply 1 1/2 to 2 gallons of product per 100 gallons of water, one sray at each period if conditions require it. Summer foliage: apply 1/2 to 1 gallon 3 to 5 imes at weekly intervals until harvest. Avoid spraying during hot period of the day or during hot humid conditions. Spray only to the drip point, not runoff, as excessive spray may cause injury.	7-14 d	Toxic to fish, and aquatic organisms. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
hydrogen dioxide	Oxidate, Oxidate 2.0	Begin applications at 1/4-1/2 inch green tip and continue on a five to seven day schedule through bloom	5-7 d	Toxic to birds, fish, bees and other beneficial insects.

[E]Environmental Hazards= Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark; do not contaminate water when disposing of equipment washwater or rinsate; do not apply when weather conditions favor drift or run-off from treated areas.

[F]Fungicide Resistance Action Committee (FRAC) mode-of-action classification codes. To minimize resistance development in disease populations, limit sequential applications before alternation with another fungicide group.

Effectiveness of products will vary based on their dosage and timing of application. To minimize fungus/disease resistance, rotate applications among fungicide groups and chemical types. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target fungus/disease is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.2. Fungicides recommended for control of **BROWN ROT TWIG BLIGHT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Fungicide Group[F]				
Group M4				
captan	Captan 50 Wettable Powder, Captan 80 WDG Fungicide, Captan 80-WDG, Captan 80WDG, Captan 80WDG Fungicide, Captan Gold 4L, Captan Gold 80WDG	Apricot: Apply 3 to 5 lb. per acre in 20 to 250 gal of water using ground equipment. Apply in red bud, bloom, and 7% petal fall sprays.	NL	Toxic to fish.
Group 7; Group 11				
boscalid; pyraclostrobin	Pristine Fungicide	Begin application at pink bud or prior to onset of disease development and continue on a 7 to 14 day interval.	7-14 d	See [E]Environmental Hazards information at the bottom of the chart.
Group 44				
fenhexamid	Elevate 50 WDG Fungicide	Apply at early bloom, late bloom, and 2 weeks after petal fall.	NL	Apply in minimum of 50 gallons by ground; toxic to fish and aquatic invertebrates.

[E]Environmental Hazards= Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark; do not contaminate water when disposing of equipment washwater or rinsate; do not apply when weather conditions favor drift or run-off from treated areas.

[F]Fungicide Resistance Action Committee (FRAC) mode-of-action classification codes. To minimize resistance development in disease populations, limit sequential applications before alternation with another fungicide group.

Effectiveness of products will vary based on their dosage and timing of application. To minimize fungus/disease resistance, rotate applications among fungicide groups and chemical types. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target fungus/disease is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

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[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Brown Rot

Table 1.3. Fungicides recommended for control of
BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Fungicide Group[F]				
Group 1				
thiophanate-methyl	Cercobin, Incognito 4.5 F, Incognito 8 WDG, Nufarm T-Methyl 4.5 F, Nufarm T-Methyl 70 WSB	Apricot: Apply at early bloom (red bud). Make a second application at full bloom. If needed, under severe disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. Cherry: Apply at early bloom (early popcorn). Make a second application at full bloom. If needed under severe disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. Nectarines & Peaches: Apply at early bloom (pink bud). Make a second aplication at full bloom if conditions favor disease development. If needed under sever disease pressure, apply additional sprays at 10 to 14-day intervals between full bloom and final pre-harvest sprays. Plum: Apply at early bloom (green tip). Make a second application at full bloom if conditions favor disease development. PLUS Apply at shuck split and at first cover sprays.	10-14 d	See [E]Environmental Hazards information at the bottom of the chart.
Group 3				
propiconazole	Amtide Propiconazole 41.8% EC, Bumper 41.8 EC, Bumper ES, Fitness, Propi-Star EC, Propimax EC, Shar-Shield PPZ, Tide Propiconazole 41.8% EC, Tilt, Topaz	Apply up to two applications from pre-harvest up to the day of harvest. If disease persists (high inoculum and severe disease pressure), select a different registered fungicide to apply afer the second application of this fungicide.	NL	Toxic to fish and shrimp.
fenbuconazole	Indar 2F	Plum & Prune: Begin applications 2 to 3 weeks before harvest and reapply on a 7- to 14-day spray schedule. Apricot, Nectarine, & Peach: Begin aplicaitons 2 to 3 weeks before harvest using a 7- to 10-day spray interval. Cherry: Follow blossom blight schedule and continue application at 10- to 14-day intervals. Additional foliar applications may be made after harvest.	7-14 d	

NL= No time listed

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[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.3, continued. Fungicides recommended for control of
BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Group 3, continued				
flutriafol	Topguard Fungicide Specialty Crops	Start applications at 1-5% bloom followed by an application at 50-100% bloom	7 d	Toxic to fish and shrimp.
metconazole	Quash	Make application 14 to 21 days prior to harvest.	NL	
tebuconazole	Orius 20AQ	Apply at early bloom stage. Make one repeat aplication under low disease pressure. Make two additional applications under high disease pressure (or if variety is particularly sensitive to disease) first at 75-100% bloom and then at petal fall.	7-14 d	
Group 3; Group 1				
propiconazole; thiophanate-methyl	Protocol	Apply a maximum of 2 sprays as needed during he preharvest period up to the day of harvest. If high inoculum and severe disease conditions persist, apply another registered fungicide after applying this product twice.	NL	Toxic to fish and shrimp.
Group 7				
penthiopyrad	Fontelis	Begin applications prior to disease development and continue on a 7- to 14-day interval. Use higher rate and shorter interval when disease pressure is high.	7-14 d	Toxic to mammals, fish and aquatic invertebrates.
Group 7; Group 11				
boscalid; pyraclostrobin	Pristine Fungicide	Begin application at pink bud or prior to onset of disease development and continue on a 7 to 14 day interval.	7-14 d	Toxic to mammals, fish and aquatic invertebrates
fluxapyroxad; pyraclostrobin	Merivon			
Group 9; Group 3				
cyprodinil; difenoconazole	Inspire Super	Apply as needed a maximum of two sprays during the preharvest period up to the day of harvest (minimum of a 7-day retreatment interval). If high inoculum and severe disease conditions persist, apply a registered non-Group 3 fungicide.	7 d	Do not apply to sweet cherries; toxic to fish, mammals and aquatic invertebrates.
Group 11				
azoxystrobin	Agri Star Azoxystar, Equation SC, Satori Fungicide	Apply to fruit up to te day of harvest.	7-14 d	Toxic to freshwater and estuarine/marine fish and aquatic invertebrates.

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Brown Rot

Table 1.3, continued. Fungicides recommended for control of
BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Group 11; Group 3				
azoxystrobin; difenoconazole	Quadris Top	Apply as needed a maximum of two sprays during the preharvest period up to the day of harvest (minimum of a 7-day retreatment interval). If high inoculum and severe disease conditions persist, apply a registered non-Group 11 or non-group 9 fungicide.	7 d	Toxic to fish, mammals, aquatic invertebrates, and freshwater and estuarine/marine fish.
azoxystrobin; propiconazole	Quilt Xcel	Apply as needed, a maximum of 2 sprays, during the preharvest period up to the day of harvest. Make the two applications no closer than 10 days apart.	10 d	Toxic to fish, mammals, aquatic invertebrates, and freshwater and estuarine/marine fish.
Group 12				
fludioxonil	Scholar SC	Use scholar as a post-harvest dip or spray for the control of post-harvest diseases caused by brown rot	Max. 1 post-harvest application to fruit	Toxic to fish and aquatic invertebrates.
Group 14				
DCNA dicloran	Botran 75-W Fungicide	**Apricot, Peach, & Nectarine:** Apply at 18-day intervals and 10 days before harvest. **Sweet Cherry:** Apply 10 days before harvest.	18 d	Toxic to fish.
Group M1				
copper hydroxide	Champ WG	Apply as a full cover spray at pink bud (during bloom and growing season).	7 d	Toxic to fish and aquatic invertebrates.
Group M2				
sulfur	Kumulus DF, Sulfur-DF, Cosevate DF[O], Cosevate DF Edge[O], Golden Micronized Sulfur[O], Micro Sulf, Microthiol Disperss[O], Sulfur 6 L, Thiolux[O]	Apply when fruit starts to ripen.	10-14 d	Toxic to fish and aquatic organisms; sulfur may burn foliage when temperature is excessively high; do not apply within 2 weeks of an oil spray. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.

NL= No time listed

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[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.3, continued. Fungicides recommended for control of
BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Group M4				
captan	Captan 50 Wettable Powder, Captan 50W (Drexel), Captan 80 WDG Fungicide, Captan 80-WDG, Captan 80WDG, Captan 80WDG Fungicide, Captan Gold 80WDG	**Cherry:** Apply 3 to 4 lb. per acre in 20 to 200 gal of water using ground equipment. Apply in pre bloom, bloom, and petal fall, shuck, cover and preharvest sprays.	7-20 d	Toxic to fish.
Group M4; Group 17				
captan; fenhexamid	Captevate 68 WDG	**Cherry:** Apply up to the day of harvest.	NL	Toxic to fish and aquatic invertebrates.
Group 44				
bacillus subtilis strain QST 713	Serenade ASO[O], Serenade Max[O], Serenade-ASO[O], Serenade-Max[O]	For supression, begin aplication prio to disease development when environmental conditions and plant stage are conducive to rapid disease development and repeat on a 7- to 10-day interval or as needed.	7-10 d	See [E]Environmental Hazards information at the bottom of the chart.
fenhexamid	Elevate 50 WDG Fungicide	Apply up to day of harvest.	NL	Apply in minimum of 50 gallons by ground; toxic to fish and aquatic invertebrates.
Group P5				
extract of Reynoutria sachalinensis	Regalia[O]	Begin applications prior to disease development when environmental conditions and plan stage are conducive to rapid disease development, and repeat on a 7- 10 day interval or as needed.	7-10 d	See [E]Environmental Hazards information at the bottom of the chart.

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.3, continued. Fungicides recommended for control of **BROWN ROT FRUIT ROT IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Other				
calcium polysulfides	Rex Lime Sulfur Solution, Lime Sulfur Solution[O]	**Cherry (tart):** Apply 1/2 gallon per 100 gallons of water. Apply 3 to 5 sprays at weekly intervals just before harvest. **Nectarine:** Use 1/2 gallon of product per 100 gallons of water. Apply at 10 to 14 day intervals until about 1 month of harvest. **Peach:** Apply 1/2 to 1 gallon 3 to 5 times at weekly intervals until harvest. Avoid spraying during hot period of the day or during hot humid conditions. Spray only to the drip point, not runoff, as excessive spray may cause injury. **Plum:** Apply 3/4 gallon of product per 100 gallons of water at 20, 10 and 2 days before harvest. **Prune:** Apply 1/2 gallon of product per 100 gallons of water in weekly applications beginning 3 to 5 weeks before harvest.	7-14 d	Toxic to fish and aquatic organisms. Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
hydrogen dioxide	Oxidate, Oxidate 2.0	Spray diseased trees for threed consecutive days and continue treaments on five to seven day intervals.	5-7 d	Toxic to birds, fish, bees and other beneficial insects.

[E]Environmental Hazards= Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark; do not contaminate water when disposing of equipment washwater or rinsate; do not apply when weather conditions favor drift or run-off from treated areas.

[F]Fungicide Resistance Action Committee (FRAC) mode-of-action classification codes. To minimize resistance development in disease populations, limit sequential applications before alternation with another fungicide group.

Effectiveness of products will vary based on their dosage and timing of application. To minimize fungus/disease resistance, rotate applications among fungicide groups and chemical types. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target fungus/disease is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

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[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.4. Fungicides recommended for control of
BROWN ROT BLOSSOM BLIGHT IN HOME FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Fungicide Group[F]				
Group 3				
myclobutanil	Fertilome F-Stop Lawn & Garden Fungicide	Uniformly apply to all plant parts to the point of runoff.	7-10 d	Toxic to fish.
Group M2				
sulfur	Hi-yield Dusting Wettable Sulfur, Wettable or Dusting Sulfur, Bonide Tomato & Vegetable 3 in 1	**Cherry:** Apply in pink, bloom, petal fall, shuck, cover and post-harvest sprays. **Peach, Plum, Prune:** Apply in pink, bloom, shuck, cover and pre-harvest sprays.	NL peach: 10-14 d	Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
Group M4				
captan	Bonide Captan, Hi-yield Captan 50W	Apply in prebloom, bloom, petal fall, shuck, cover and preharvest sprays.	3-14 d	Toxic to fish.
Other				
rosemary, clove, peppermint, malic acid	Dr. Earth Final Stop Disease Control[O]	Apply early in the morning or late in the afternoon to avoid leaf burn.	NL	
cedarwood oil	Wondercide All purpose Pest Control[O]	Apply as a prtoecive spray early in the season before the diseases are noticed.	7-10 d	

[E]Environmental Hazards= Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark; do not contaminate water when disposing of equipment washwater or rinsate; do not apply when weather conditions favor drift or run-off from treated areas.

[F]Fungicide Resistance Action Committee (FRAC) mode-of-action classification codes. To minimize resistance development in disease populations, limit sequential applications before alternation with another fungicide group.

Effectiveness of products will vary based on their dosage and timing of application. To minimize fungus/disease resistance, rotate applications among fungicide groups and chemical types. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target fungus/disease is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Table 1.5. Fungicides recommended for control of
BROWN ROT TWIG BLIGHT & FRUIT ROT IN HOME FRUIT production in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments[E] (for [P]PHI and REI information, check the label)
Fungicide Group[F]				
Group 3				
myclobutanil	Fertilome F-Stop Lawn & Garden Fungicide	Uniformly apply to all plant parts to the point of runoff.	7-10 d	Toxic to fish.
Group M2				
sulfur	Hi-yield Dusting Wettable Sulfur, Wettable or Dusting Sulfur	Cherry: Apply in pink, bloom, petal fall, shuck, cover and post-harvest sprays. Peach, Plum, Prune: Apply in pink, bloom, shuck, cover and pre-harvest sprays.	NL peach: 10-14 d	Do not use products containing sulfur on apricots as they will cause severe phytotoxicity.
Group M4				
captan	Bonide Captan, Hi-yield Captan 50W	Apply in prebloom, bloom, petal fall, shuck, cover and preharvest sprays.	3-14 d	Toxic to fish.
Other				
rosemary, clove, peppermint, malic acid	Dr. Earth Final Stop Disease Control[O]	Apply early in the morning or late in the afternoon to avoid leaf burn.	NL	NA
cedarwood oil	Wondercide All purpose Pest Control[O]	Apply as a prtoecive spray early in the season before the diseases are noticed.	7-10 d	NA

[E]Environmental Hazards= Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark; do not contaminate water when disposing of equipment washwater or rinsate; do not apply when weather conditions favor drift or run-off from treated areas.

[F]Fungicide Resistance Action Committee (FRAC) mode-of-action classification codes. To minimize resistance development in disease populations, limit sequential applications before alternation with another fungicide group.

Effectiveness of products will vary based on their dosage and timing of application. To minimize fungus/disease resistance, rotate applications among fungicide groups and chemical types. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target fungus/disease is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

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[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protecion Interval= Interval required between applications (in days). Days vary depending on crop. Max. amount per year or season is for the acive ingredient in the product.

Fig. 1.1. A blossom infected with brown rot (BR); note brown spores spreading among petals.

Fig. 1.2. Blossoms infected by the BR fungus.

Fig. 1.3. Blossom blight and stem canker from BR with gummy exudate, spores, and brown, depressed lesion.

Fig. 1.4. BR has infected this blossom and twig causing gumming at the bottom of the cankered area and gray spores on the blossom.

Fig. 1.5. BR infected blossoms and twigs with stem die-back.

Fig. 1.6. BR fungus from the blossom has moved to the stem where a canker (brown depressed lesion) has formed.

Fig. 1.7. Symptoms of BR have spread from the blossoms and twigs to the leaves.

Fig. 1.8. Sporulation of BR may occur in concentric circles as seen on this cherry.

Fig. 1.9. BR sporulation on lower fruit with concentric circles.

Fig. 1.10. BR spores on peach fruit; note the brown to gray color of the spores.

Fig. 1.11. Ripened fruit are more likely to show symptoms of BR infection.

Fig. 1.12. 'Bali' cherry shows BR symptoms of sporulation.

Fig. 1.13. BR can easily infect injured fruit, such as rain split cherries.

Fig. 1.14. BR may first appear as brown lesions with skin that easily slips.

Fig. 1.15. Symptoms of BR on fruit: gray spores and a large brown lesion.

Fig. 1.16. BR of stone fruits; note the brown to gray color of spores.

Fig. 1.17. Thick wall of brown to gray BR spores on peach fruit.

Fig. 1.18. BR on peach with thick walled spores that are gray to brown in color.

Fig. 1.19. BR on peach; note the thick sporulation and wrinkled skin.

Fig. 1.20. Healthy and BR infected fruit of sand cherry.

Fig. 1.21. BR on peach; note infected fruit in different stages of infection and wrinkled drooping leaves surrounding infection.

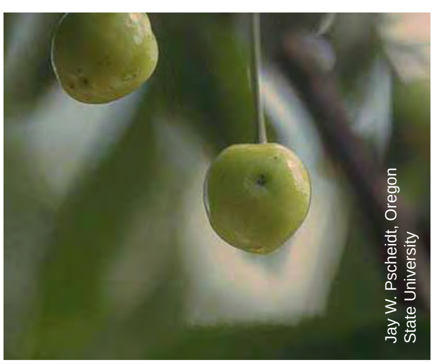


Fig. 1.22. Initial symptoms of BR may appear as small superficial spots that are brown in color.

Fig. 1.23. Mummified peach fruit; note dead leaves on BR-infected branch.

Fig. 1.24. BR-mummified peach fruit are wrinkled, rock-hard, and often dark brown to gray in color.

Fig. 1.25. Infected fruit will shrivel and dry into "mummies" which overwinter and spread BR the following season.

Fig. 1.26. Plum mummies infected with BR cling to the tree and produce new spores to spread the infection.

Fig. 1.27. BR mummified fruit can survive the winter. Spores can infect blossoms the following spring; note the necrotic blossoms.

Fig. 1.28. Fruit mummies may cling to the tree well into the next growing season.

Fig. 1.29. Sunken and necrotic spots with red halos on BR infected sweet cherries.

Fig. 1.30. BR mummy that has fallen to the ground and formed apothecia.

Fig. 1.31. A BR infected peach may fall to the orchard floor where it can overwinter and spread infection the following season.

CHAPTER 2 PLUM POX VIRUS

Quick Facts

- Plum Pox Virus (PPV) is the most devastating disease of stone fruits worldwide.
- PPV is found across Europe, the Middle East as well as India and Chile. It was introduced a few times into North America, but was successfully eradicated.
- PPV is not currently found in Utah, but is a concern because of the severe damage it can cause to Prunus crops.
- PPV infects cultivated, ornamental, and wild Prunus, or stone fruit, species.
- Prevention is the best management option for PPV through exclusion; however, if it is detected, then eradication and quarantine are crucial steps.

Background

Plum Pox Virus (PPV), also known as Sharka, is caused by a virus from the genus *Potyvirus*. PPV commonly infects economically important *Prunus* species such as plum, peach, nectarine, apricot, almond, and sweet and tart cherry. Ornamental and wild *Prunus* species are also susceptible. PPV has not been found in Utah. However, it is a concern because of the stone fruit industries in Utah and the serious threat it poses to fruit production.

PPV was first reported in Bulgaria in 1915 and 1918 on plum trees. The virus spread slowly to other countries throughout Eastern Europe until about 1950 when the disease began to spread more rapidly to countries including Germany (1956), Poland and Russia (1961), England (1970), and France (1970). By the early 1980's, PPV had spread to Spain and Portugal. PPV is one of the most devastating diseases of stone fruits in Europe, with over 100 million trees infected.

The first detection of PPV in the western hemisphere was in 1992 in Chile. It was detected in North America for the first time in 1999 in peaches growing in Adams County, Pennsylvania. PPV was discovered in eastern Ontario and Nova Scotia (2000) and then in Niagara County, New York and Michigan (2006). A strong policy of detection and eradication in the United States has been pursued by the USDA. In October of 2009, Pennsylvania was declared free of PPV thanks to the quarantine, aggressive eradication program and cooperation of many groups including fruit growers and homeowners.

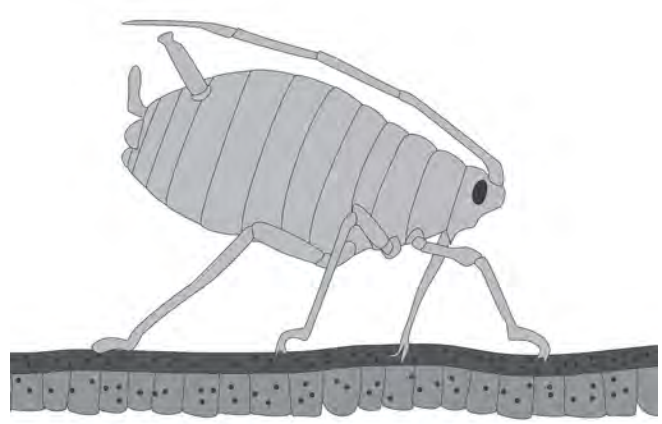
Virus Identification and Life History

There are several PPV strains that vary in their host range and symptom severity.

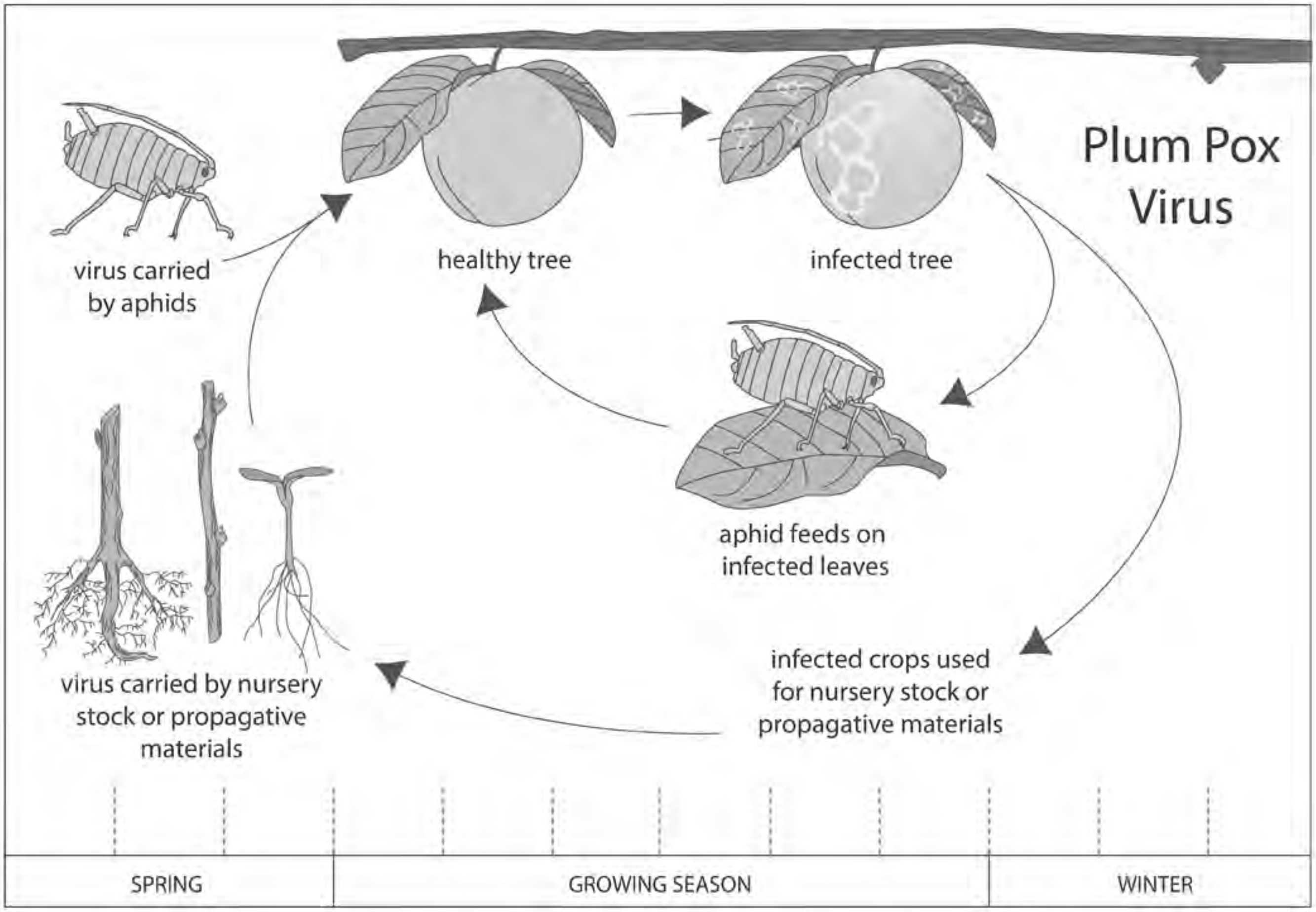
The spread of PPV most commonly occurs over short distances within an orchard or from nearby sources, such as other orchards, forests, and residential host trees. The virus is spread by aphids **(Figs. 2.1-2.2)** as they feed on PPV infected plants and then transmit the virus to uninfected plants when they disperse to continue feeding.

Research has shown that at least 20 different aphid species can transmit PPV; however only four to eight of these species are considered important vectors, including *Aphis craccivora, A. gossypii, A. spiraecola, Brachycaudus helichrysi, B. persicae, Hyalopterus pruni, Myzus persicae,* and *Phorodon humuli* (Levy et al. 2000). One of the most effective aphid vectors of PPV is *Myzus persicae*, the green peach aphid. The green peach aphid colonizes peaches as well as other stone fruits. The spread of PPV through aphids is non-persistent, meaning, the virus only remains on the stylet (sucking mouthpart of the aphid) for a few minutes to a few hours *(Fig. 2.3)*. The amount of spread of PPV depends on how soon the aphid probes a new plant after feeding on an infected plant.

Transmission of PPV over greater distances is typically through human movement of nursery stock or propagative materials (e.g., budwood, rootstock, or seedlings). Aphids vector the virus from infected nursery stock to nearby uninfected trees. Transmission through seed is possible, but uncommon. Spread through infected roots when they contact and graft together with roots of a neighboring tree can also occur.



Plum Pox Virus



Disease cycle of plum pox virus in Utah.

Research has demonstrated that many weeds and cultivated annual plants can be artificially inoculated with PPV; however, there are currently no known reports of PPV infections in wild *Prunus* species in the U.S. (Llácer, 2006).

Plant Hosts and Injury Symptoms

Plants susceptible to PPV include cultivated and wild stone fruit species. In Europe, privet (*Ligustrum vulgare*), walnut (*Juglans regia*), and euonymus (*Euonymus europea*) were confirmed as additional hosts of PPV.

Symptoms of PPV vary in severity and expression depending on the virus strain, host cultivar, environmental factors, and timing of infection. Symptoms can be highly apparent, subtle, or undetectable.

In states were Plum pox virus has been identified, symptoms were generally evident on the leaves and fruits of infested trees. Leaf symptoms include light green to yellow rings or yellowing veins. During the cooler temperatures of the spring and fall, foliar symptoms may be more apparent and severe. During the hot summer months, symptoms may fade. Plum leaves may show severe symptoms of necrotic and chlorotic ring blotches, or patterns *(Fig. 2.4)*. Peaches may show symptoms of crinkled, puckered or curling leaves along with necrotic and chlorotic rings, patches or lines *(Figs. 2.5-2.6)*. Rings and blotches from PPV are typically subtler on apricot leaves *(Fig. 2.7)*.

Plant Hosts of PPV

Fruits & Ornamentals	Wild Prunus
• apricot	• blackthorn
• peach	• American plum
• nectarine	• Western sand cherry
• plum & prune	• Mahaleb/St. Lucie cherry
• Japanese plum	• Japanese apricot
• Damson plum	• sand cherry
• Myrobalan plum	• hortulan plum
• flowering almond & cherry	• David peach
• sweet cherry	• Chinese wild peach
• tart cherry	• Nanking cherry
• almond	• Canada plum
	• beach plum
	• English cherry-laurel

Peach cultivars with large, showy flowers infected with PPV may show color-breaking (variegated petal color) *(Figs. 2.8-2.9)*.

Plum fruits infected with PPV often exhibit dark rings or spots and reddish discoloration of the flesh *(Fig. 2.10)*. Plum fruit may be deformed and exhibit premature fruit drop. Infected peach fruits can develop lightly pigmented rings or line patterns resulting from the merging of several rings *(Figs. 2.11-2.12)*. Infected apricot fruits are often misshapen and become necrotic or brown, and may also have rings on the surface of the seed *(Figs. 2.13-2.15)*.

Trees that are newly infected with PPV are rarely symptomatic. Symptoms are often delayed for three or more years after infection, and may occur sporadically. Asymptomatic trees infected with PPV are a major threat to nearby orchards. A common symptom of PPV infection is a reduction in fruit load.

Symptoms of other diseases and insect-related problems may be confused with symptoms of PPV. Symptoms of rust spot on peach and nectarine (not known in Utah) as well as damage from thrips, San Jose scale, and white apple leafhopper may all be confused with symptoms of PPV. Laboratory tests are necessary to confirm infection with PPV. Suspect plant samples may be sent to the Utah Plant Pest Diagnostics Lab at Utah State University in Logan, Utah for testing (see pg. i for contact information).

Plant Symptoms of PPV

- yellow veined leaves
- light green/yellow rings on leaves
- chlorotic/necrotic ring patterns/blotches on plum fruit
- crinkled, puckered or curled peach leaves
- subtler spots and rings on apricot leaves
- color-breaking on peaches with large show flowers
- light colored rings/line patterns on peach fruit
- misshapen and necrotic (brown) apricot fruit
- surface rings on apricot fruit
- deformed plum fruit
- dark rings or spots and reddish discolored flesh on plum fruit
- premature fruit drop of plum fruit

Monitoring

For effective detection of PPV, orchard scouts and growers should become familiar with symptoms and signs of the virus. PPV poses a major threat to Utah fruit production; vigilant and frequent scouting is critical to prevent this devastating pathogen from becoming established in the State.

Management

Ongoing surveillance of susceptible crops is crucial for the management of PPV. It is important to properly monitor plant health and positively identify trees suspected to be infected. Once a tree is infected with PPV, it will never be free of the disease. This makes it vital to foster good practices in exclusion and, once PPV is detected, eradication, and strict quarantine.

Cultural Control

The primary source of management for PPV is through exclusion. Once PPV becomes established, it is very difficult to eradicate or control. Thus, nursery propagators and commercial growers should ensure that all purchased planting stock is certified disease-free. Dissemination of virus-infected materials can be avoided by carefully selecting and limiting the exchange of budwood and rootstocks to eliminate the movement of PPV to new regions or orchards.

Mechanical & Physical Control

Eradication is the second most important management tool in controlling PPV. It is critically important to eliminate PPV infected trees in a timely manner. There are no cures or treatments for PPV once it has infected a host. Once a tree has been confirmed to be infected with PPV, it should be removed as quickly as possible. Suckers coming up from tree stumps need to be controlled because they can carry the virus as well. Proper eradication used as a management tool for PPV infected trees will help to limit the spread of the virus to neighboring trees and orchards.

Biological Control

There are no methods of biological control for the management of PPV.

Chemical Control

Although the application of insecticides may help to reduce the overall population of aphid vectors during a growing season, this is not a feasible management tactic for PPV. A single aphid can transmit PPV to a new host within seconds to minutes, and total control of aphid vectors is impossible to achieve. Keep aphid populations low with recommended insecticide management strategies to slow the spread of PPV if it is detected.

If PPV is suspected to be present, it is important to send potentially infected plant samples to the Utah Plant Pest Diagnostics Lab in Logan, Utah (see pg. i for contact information). Plant sample tests at the lab will determine if PPV is present so that further management and eradication steps can be initiated.

For Additional Information, Search the Internet for:

Plum Pox Virus Symptoms, Cornell University

Tree Fruit Production Plum Pox Virus, Penn State Extension

History, Biology and Management of the Plum Pox Virus, Michigan State University

Crop Advisory Team Alert, Plum Pox Virus, Michigan State University

Western IPM Center, State-by-State: IPM in Utah

Plum Pox Aphis Plant Protection and Quarantine Fact Sheet

Sharka of Stone Fruit and Ornamental Prunus Species, Ontario Ministry of Agriculture, Food and Rural Affairs

Plum Pox Potyvirus Disease of Stone Fruits, APS.org

References

Levy, L., V. Damsteegt, R. Scorza and M. Kolber 2000. Plum Pox Potyvirus Disease of Stone Fruits. APS*net* Features. Online. doi: 10.1094/APSnetFeature-2000-0300

Llácer, G. (2006), Hosts and symptoms of *Plum pox virus*: Herbaceous hosts. EPPO Bulletin, 36: 227–228. doi: 10.1111/j.1365-2338.2006.00978.x

Scorza, R., A. Callahan, C. Dardick, M. Ravelonandro, J. Polak, T. Malinowski, I. Zagrai, M. Cambra, I. Kamenev, 2013. Genetic Engineering of *Plum pox virus* resistance: 'HoneySweet' plum—from Concept to Product. DOI 10.1007/s11240-013-0339-6

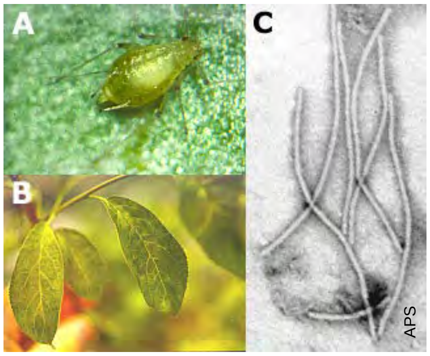


Fig. 2.1. A) Plum Pox Virus (PPV) aphid vector; B) PPV symptoms on plum leaves; C) microscopic particles of the PPV virus.

Fig. 2.2. *Myzus persicae*, or green peach aphid, is an important vector of PPV.

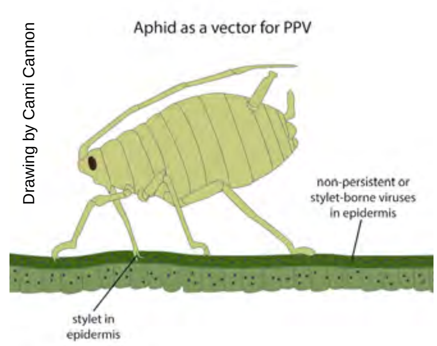


Fig. 2.3. PPV is spread through aphids that carry the virus with them after feeding (a few minutes to a few hours).

Fig. 2.4. Light green to yellow rings and yellow veins on European plum leaves infected with PPV.

Fig. 2.5. Peach leaves show symptoms of PPV infection; note the light green/ yellow rings.

Fig. 2.6. Peach leaves show symptoms of PPV; note the line patterns resulting from the merging of several rings.

Fig. 2.7. Apricot leaves show symptoms of PPV infection; note that symptoms are less extreme than in plum and peach leaves.

Fig. 2.8. Peach cultivars with showy blossoms that are infected with PPV exhibit color breaking.

Fig. 2.9. Peach cultivars with showy blossoms that are infected with PPV exhibit color breaking.

Fig. 2.10. PPV infected plums show dark rings/spots on fruit skin, deformed fruit, and discolored fruit flesh.

Fig. 2.11. Peach fruit infected with PPV show symptoms of yellow rings on a yellow-fleshed peach cultivar.

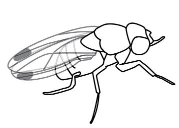
Fig. 2.12. Peach fruit infected with PPV show symptoms of line patterns from coalescing rings.

Fig. 2.13. Apricot fruit infected with PPV show symptoms of misshapen and discolored fruit.

Fig. 2.14. Apricot fruit infected with PPV show symptoms of necrotic (brown) patches or rings.

Fig. 2.15. PPV-infected apricot seeds show discolored rings on the seed surface.

CHAPTER 3



SPOTTED WING DROSOPHILA

Quick Facts

- Spotted wing drosophila (SWD) is a small vinegar fly that infests ripening, ripe, and overripe fruits.
- SWD is native to Southeast Asia; it was first detected in the U.S. in 2008, and in Utah in 2010.
- Preferred hosts include stone fruits (especially cherry and peach), berries, and soft-skinned vegetables.
- Monitoring SWD and timely harvest of fruit are important IPM practices.
- SWD management tactics include timely applications of insecticides, and protecting pre- to post-ripe fruit stages.

Background

The spotted wing drosophila (SWD), *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), is an invasive vinegar fly native to Japan and parts of Thailand, India, China, Korea, Myanmar, and Russia. SWD was first detected in the U.S. in California in 2008. In Utah, it was first discovered in a raspberry and blackberry field in Kaysville (Davis County). It is currently an economic pest of soft fruits and vegetables throughout much of the U.S. SWD is named for a dark spot on each wing of the male fly.

Other species of vinegar flies only attack fruit that is overripe or rotten, but SWD females lay eggs in unripe, ripe, and overripe fruit. Because it will lay eggs in fruit still maturing on the plant, larvae can be present in fruit that is harvested for market. The larva is the main damaging life stage; the female fly punctures fruit when laying eggs which can introduce secondary pathogen infections.

Because SWD is widely distributed throughout the U.S., it is not considered a quarantine pest. Of the countries that receive U.S. fruit exports, Australia and New Zealand are the only ones with quarantine restrictions for SWD.

Identification and Life History

ADULT: REPRODUCTIVE, DISPERSAL, DAMAGING, AND OVERWINTERING STAGE

- About 0.1 in (2-3 mm) long.
- Pale brown body with unbroken bands on the backside of the abdomen.
- Red eyes and featherlike antennae.
- Males have a single black spot on the leading edge of each wing and two dark bands ("sex combs") on each foreleg **(Figs. 3.1-3.2)**.
- "Sex combs" can be important for identification when wing spots are faint or missing.
- Females can be distinguished from similar flies by their large, saw-like ovipositor (egg-laying device) located on the back of their body **(Figs. 3.3-3.5)**.
- Ovipositor may be difficult to see unless extended.
- Magnification with a hand lens or dissecting microscope is helpful for identifying specimens.

EGG

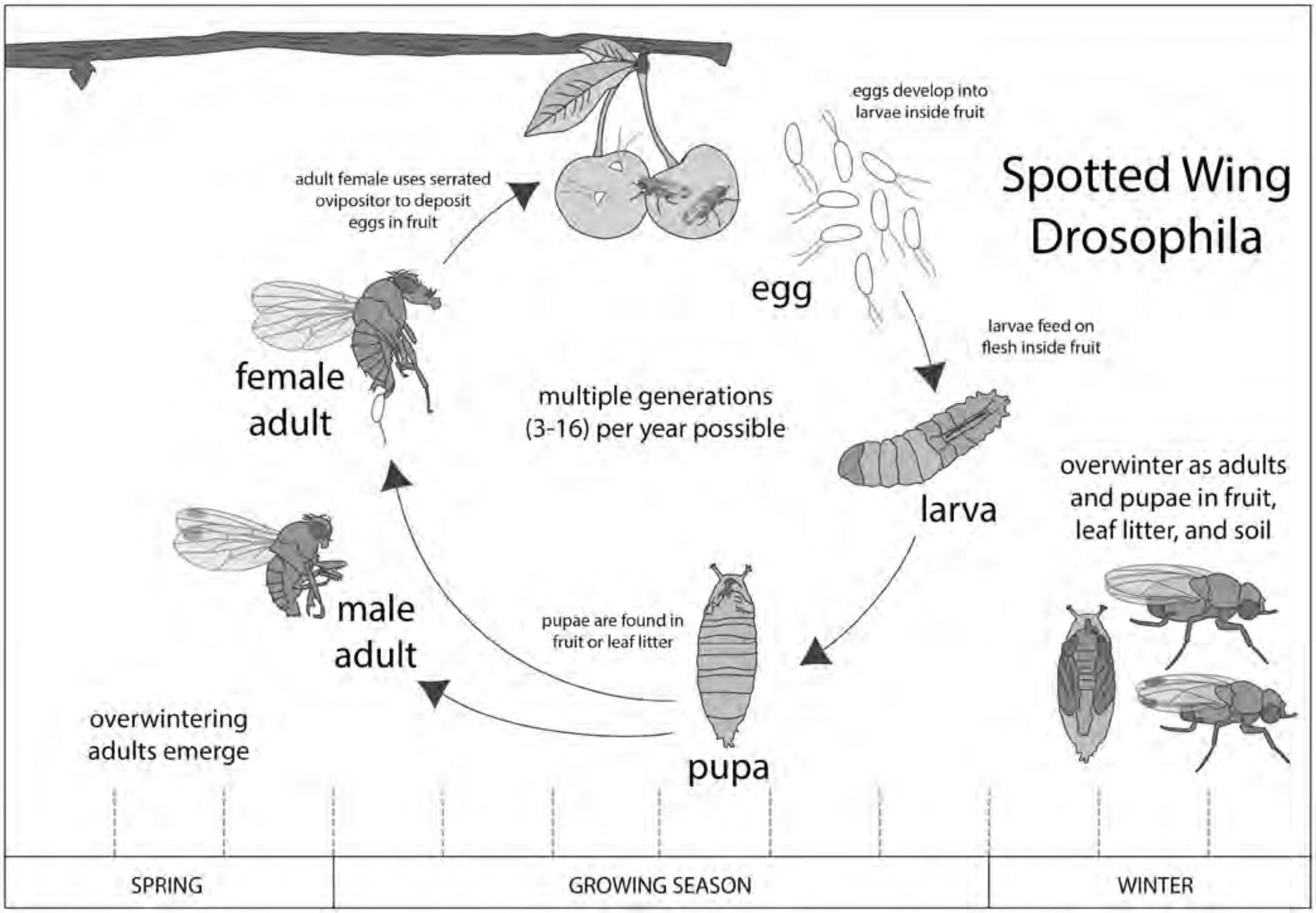
- About 0.02 inches (0.6 mm) long and 0.007 inches (0.18 mm) wide.
- White to creamy translucent; cylindrical in shape.
- Two thin respiratory filaments occur on one end *(Figs. 3.6-3.8)*.
- Filaments may protrude from fruits with eggs *(Figs. 3.9-3.10)*.

LARVA: DAMAGING STAGE

- About 0.003-0.01 in (0.067-3.5 mm) long.
- Cream-colored maggots with black mouthparts *(Figs. 3.11-3.13)*.
- Typically creates a breathing hole through the fruit skin as it matures *(Fig. 3.14)*.
- Mature larvae can be distinguished from other fruit fly larvae (cherry fruit fly) by a smaller body, tapered at both ends, and shallow fruit feeding.

PUPA: POSSIBLE OVERWINTERING STAGE

- About 0.1 in (2-3 mm) long.
- Brown, cylindrical capsules with two extensions on one end *(Figs. 3.15-3.17)*.



Life history of spotted wing drosophila in Utah. Degree-day models estimate 3-16 generations may be completed per year.

Adults and pupae are common overwintering life stages; however, adults are the only life stage that has been detected in Utah to-date. Adult flies increase activity in the spring as temperatures warm, and are most active from 68°F to 77°F (20°C-25°C). SWD does not prefer hot temperatures; activity and egg laying decreases above 86°F (30°C), and egg laying stops above 91°F (33°C). Degree-day (DD) models estimate that adult emergence begins at 270 DD, mid to late April in Utah; however, low populations are difficult to detect, and few SWD adults have been detected in traps before August. In locations outside of Utah with higher SWD populations, adult emergence peaks in June and July during sweet cherry harvest, and again in September during grape harvest.

Egg-laying begins in the spring when average temperatures exceed 50°F (10°C), and continues until average temperatures decline below 42°F (5.5°C) in the autumn. Females pierce the skin of fruits with their toothed ovipositor, or egg-laying device. Females typically lay 1-3 eggs per fruit and 7-16 eggs per day. A female may lay over 350 eggs in her lifetime. Eggs typically hatch quickly, in 12-72 hours. Larvae feed inside the fruit for 3-12 days before pupating. Larvae can pupate within or on the outside of fruit, or they may drop to the soil. Pupae are usually found in fruit, or in the leaf litter or soil below infested fruit. Pupation requires from 3-15 days.

Eggs and larvae have not been detected in Utah due to very low populations; however, because adults have been detected in the same locations in subsequent years, this suggests that SWD is reproducing and completing full generations in Utah. In Utah, trap captures of adults peak from late September to November. The adult lifespan can vary from 8 days to 9 weeks depending on environmental conditions and time of year. Both male and female adults can overwinter. When average minimum temperatures in the fall drop to 41°F (5°C), SWD adults seek protected sites for the winter, such as under leaf litter and rocks. Degree-day models estimate that SWD may complete 3-16 generations per year in Utah; however, low populations to-date have precluded researchers from determining how many generations are actually completed.

Plant Hosts and Injury Symptoms

SWD hosts include tree fruits, berries, some soft-skinned vegetable fruits, and many ornamental and wild fruits (see Plant Hosts of SWD). SWD prefer fruits with soft skin; favorites include cherry, peach, blueberry, raspberry, blackberry, and grape. Firmer-skinned fruits, such as apple, tomato, and grape, become more attractive to SWD when they are over-ripe or damaged **(Figs. 3.18-3.19)**. Fruits are most vulnerable to attack by SWD as they near maturity. On tough-skinned fruits, female SWD will glue eggs to the surface with a sticky excretion. Although damaged, spoiled or fermented fruit attracts adults, egg-laying is low in damaged fruit and almost no egg-laying occurs in spoiled fruit.

Plant Hosts of SWD

Tree Fruits	Berry Fruits	Vegetable Fruits	Ornamental & Wild Fruits
• apple • apricot • cherry • nectarine • peach • plum • pluot • persimmon	• blackberry • raspberry • strawberry • blueberry • grape	• tomato • melon	• Himalayan blackberry • buckthorn • chokecherry • dogwood • elderberry • honeysuckle • laurel • mulberry • bittersweet nightshade • snowberry • flowering cherry

With the potential for numerous generations each year, infestation levels of SWD can quickly increase to concerning levels. Fruits that are particularly at high risk for infestation include unharvested pollinizer, organic, wild, and ornamental fruits. Because SWD is a late season pest, fruits that are harvested early in the season may be less susceptible to SWD infestations.

Females cause injury to fruit via oviposition. Egg-laying scars are typically pin-prick holes in the fruit skin. Primary damage is caused by larval feeding and tunneling in the fruit flesh. Oviposition and larval damage cause soft tissue in the fruit and an increased chance of mold, wrinkling, and decay.

The area of oviposition or pin-pricks may become sunken *(Fig. 3.20)* and when closely examined, eggs within fruit may have two hair-like filaments protruding through the fruit skin *(Figs. 3.9-3.10)*. Fruit that has been infested may also exude a sappy juice when squeezed.

After 5-7 days of larval feeding, the fruit skin begins to show damage symptoms. Larval feeding will cause the fruit to become soft, wrinkled, and spotted which may lead to fruit decay *(Figs. 3.21-3.23)*. As the larvae increase in size, they cut breathing holes through the skin of the fruit *(Fig. 3.14)*. Several methods to monitor fruit for infestation by SWD are discussed in the monitoring section.

Plant Injury Symptoms of SWD

- two hair-like filaments protruding from SWD eggs within fruit
- spots or scars on the fruit surface
- egg-laying scars form pin-prick holes in the fruit skin; fruit liquids may exude from holes
- softened, collapsed, and bruised fruit
- small white larvae and/or pupae in or on fruit

Monitoring

With multiple generations in a short period of time, monitoring and properly identifying SWD are crucial to prevention of crop loss. Effective monitoring techniques can determine if SWD is present. Detection of SWD presence is critical to development of effective management strategies. Begin monitoring well before the earliest fruit begins to ripen. Fruit becomes most vulnerable to egg-laying as it nears maturity. Refer to the Utah IPM Pest Advisories (www.utahpests.usu.edu/ipm/), or contact your local county extension office to find out when SWD egg-laying is predicted to begin.

Traps

Traps are a common and useful tool for monitoring SWD. Set out traps before fruit begin to ripen and before flies begin to lay eggs. The current degree-day model predicts that SWD will begin laying eggs in May in northern Utah. Traps perform best when placed in cool and shady areas of the field or orchard.

Commercial monitoring traps are available for purchase (see Sources of Monitoring Supplies at the end of this chapter), or they can be made with readily available items. A clear plastic cup filled with a bait mixture (see Trap Bait below) may be used. Use a wire hanger threaded through holes punched in the cup sides to hang the trap in a tree or from a stake *(Fig. 3.24)*. Drill, punch, or melt holes into the sides of the cup that are big enough for SWD to enter, but small enough (1/4 in or 6.35 mm or 3/16 in drill bit size) to exclude larger insects. Leave a portion of the circumference around the cup without holes to allow for easy pouring of the mixture and trapped insects when replacing the bait **(Figs. 3.24-3.25)**. Holes can be covered with a mesh nylon fabric to allow entry of SWD, but exclude larger insects.

Optimal trap numbers vary depending on the crop type and size of field. For commercial plantings of a single crop type of 10 acres or greater, use at least one trap per 5 acres. For smaller commercial plantings of ≤ ½ acre, use 1-2 traps per crop type (e.g., raspberry, cherry, and tomato). For residential or home garden sites, use 1-2 traps per site. Place traps in shady areas at 1-2 ft. height.

Liquid or drowning baits should be replaced at least weekly. Do not place holes in the cup lid to avoid dilution of the liquid bait from rain or irrigation water. A simple trap can be constructed from a jar or cup filled with vinegar and a paper funnel *(Fig. 3.26)*; however, a more durable container (e.g., a Nalgene bottle) will produce a more reliable and longer-lasting trap that is less prone to spill or crack. Continue to monitor and check traps through harvest of susceptible fruits, or continue post-harvest if “clean-up” treatments may be considered.

TRAP BAIT

The most common liquid baits used in SWD traps are apple cider vinegar (ACV) or sugar-water-yeast mixtures (*2 tsp active dry baker’s yeast, 4 tsp white sugar, 12 oz (1½ C) warm water—good for 2-3 traps*). Both baits are effective; their preference has varied among studies and locations. Entomologists in many regions of the U.S. have found yeast mixtures to be superior (in their luring capabilities) to ACV alone. Some studies have found that yeast mixtures catch more flies under hot summer conditions while ACV attracts more flies in spring and fall when temperatures are cooler.

Yeast mixtures are cost effective, but produce a foul odor and a thick, gooey liquid in the trap that makes it difficult to see the specimens (specimens may need to be rinsed several times). ACV is generally more user-friendly. Other vinegars may attract SWD; however, apple cider vinegar is the most attractive.

Adding a small drop of unscented dish soap to liquid bait mixtures acts as a surfactant (to break the surface tension) to improve the trapping quality of the bait. It may also be helpful to add a sticky card *(Fig. 3.25)* to the trap (on a paperclip poked through the lid) in order to ensure flies do not escape the trap. Use of sticky cards in traps increases the time required to recover and count the SWD.

In some cases, it may be preferable to use a synthetic, commercially available dry lure with your chosen trap to make monitoring simple, quick, and clean (currently produced by Trece and Scentry - see Sources of Monitoring Supplies at the end of the chapter). A drowning solution (water or ACV) is placed in the cup and the lure is hung from the trap lid (see figure below). Studies in Washington have shown that Scentry lures may catch more SWD early in the season (July and August) but that Trece lures in combination with ACV as the drowning solution may perform best late in the season (September and October). Both Scentry and Trece lures provided higher rates of SWD capture than traps baited with only ACV and are useful as an early warning in susceptible crops (both captured SWD earlier in the season than ACV alone). Commercially available lures last 1-2 months in the field (1 month in hot climates) but drowning solutions should be checked and replaced with fresh solution weekly.

Dry traps constructed from yellow sticky cards are another option **(Figs. 3.25 and 3.32).** Dry traps need to be baited with a lure (e.g., AlphaScents); however, experiences in Utah found that yellow traps attracted a large number of non-target flies that hampered identification of SWD.

CHECKING TRAPS

Check the traps weekly. Carefully decant the liquid bait and captured flies from the trap into a storage container (sealable food storage container or heavy-duty plastic bag). Label the container with trap location and date. Refill the trap with fresh bait solution. Do not combine new with old bait, or dump old bait on the ground near monitoring sites as this may compete for SWD adults with the bait inside the traps.

Transport the trap bait containers indoors where it is easier to identify SWD characteristics (refer to Identification and Life History above). Keep comprehensive records of monitoring activities and numbers of SWD identified in each trap at each weekly check.

Indoors, pour the bait solution through a fine mesh strainer *(Fig. 3.28)*. Plastic wrap with pin-pricked holes placed over a bowl can be used as an inexpensive alternative to a strainer *(Fig. 3.29)*. Carefully wash insect specimens from the strainer with clean water into a white tray to provide good contrast and visibility of the insects *(Fig. 3.30)*. Another option for washing insect specimens is to "dip" the strainer containing the flies into another water-filled container. A hand lens or magnifying glass of about 30X magnification will facilitate identification of key SWD characters (see adult identification above) *(Fig. 3.31)*.

Proper identification of SWD is important when checking traps *(Fig. 3.32)*. Other flies, including look-alike species, may be present and will need to be distinguished from SWD. Some species of fruit flies will have dark patches on their wings, but will not have the distinctive dark dot that is present on both wings of SWD males. See the identification section for more characteristics specific to SWD. If identification help is needed, samples can be sent to the Utah Plant Pest Diagnostics Lab with the Utah State University IPM Program (see contact information on pg. i). If SWD is detected, refer to the management section below to take step to prevent crop injury.

Monitoring Fruit

Visual inspection of ripening fruit for signs of SWD can be effective to detect infestations before they become severe *(Fig. 3.18-3.19)*. See Plant Injury Symptoms above for a description of common SWD signs.

EXTRACTION SOLUTION

When fruit is suspected of infestation, check crushed fruit for larvae. Crush fruit in an extraction solution within a bag or a pan. Alternatively, open fruit by hand and look for larvae inside. Extraction solutions are made with salt or sugar: 1) mix 1 cup plain salt in 1 gallon of warm water, or 2) mix 2 ½ cups of brown sugar in 1 gallon of water. Prepare the solution in advance, and ensure the salt or sugar are thoroughly dissolved. A well-mixed solution will facilitate the floating of larvae to the surface for easier viewing.

PAN EXTRACTION

Use a large clear durable plastic bag to crush fruit suspected of SWD larvae. Fruit can be crushed with a rolling pin or by hand (on the outsides of the bag). Use a shallow light colored pan and pour a layer of crushed fruit into the pan. Pour either the salt or sugar extraction solution over the crushed fruit. Within about 5 minutes, larvae (if present) will begin to exit the fruit and float to the top of the solution seeking oxygen. Wait 15 minutes to allow all larvae to exit the fruit. Some larvae may adhere to fruit pulp; stir the pulp to release the larvae. Look for movement of the larvae on the water surface (a hand lens is recommended). Check the solution between 15-20 minutes after immersion. Larvae will die and sink to the bottom after approximately 30 min. Sugar solutions have been observed to keep larvae alive longer than salt solutions. SWD larvae may be confused with fruitworms, thrips, aphid skins, other plant parts, and other debris. Thus, a hand lens or microscope is recommended to properly identify SWD.

BAG EXTRACTION

Use a large clear durable plastic bag to crush fruit with a rolling pin or by hand. Pour either the salt or sugar solution over the crushed fruit while still in the bag. Seal the bag and gently shake it to allow the solution to distribute through the fruit. Most fruit will sink to the bottom while larvae float to the top (if present). Wait 15 minutes before inspecting the solution for floating larvae. Hold the clear bag up to the light to check carefully for larvae. Use of a hand lens is recommended.

BOILING FRUIT

Fruit can be boiled to release SWD larvae, if present. Place fruit suspected of infestation in a large pot of water, and bring to a boil for 1 minute. Fruit placed in water can also be boiled in a microwave oven (be sure to use a microwave-safe bowl). After boiling, crush the fruit with the back of a spoon over a sieve (4 mesh per inch). Rinse crushed fruit with cold water over a dark-colored tray to collect the juice and larvae. A dark tray will provide color contrast with the small white larvae.

Management

Cultural Control

If SWD larvae are detected in fruit, harvest all of the fruit immediately or apply an insecticide to prevent the damage from increasing before harvest. If fruit are left untreated or unharvested, the infestation levels may increase rapidly and become more extreme. Be sure to remove and destroy any infested fruit throughout the monitoring process. Continue to monitor with traps throughout the management activities to determine effectiveness of the program.

SANITATION

If SWD infestations are low, some of the fruit may be salvaged by immediately harvesting infested fruits, placing them in strong plastic sealable bags, and disposing of the bags in the trash. Composting or burying fruit is not effective in killing SWD.

Keep the orchard clean by eliminating fallen and infested fruit remaining on the trees or plants. Sanitation will reduce SWD populations that may infect fruit ripening later in the season or the following year. As described above, dispose of infested fruit in a strong plastic sealable bag in the trash. Some studies done in Oregon have shown that solarizing fruit under clear plastic in the sunshine has been quite successful in killing SWD in fruit.

Monitor fruit regularly for any physical damage as SWD can be attracted to damaged fruit. When possible, protect fruit from sun or rain damage to reduce splitting and poor quality. Monitor areas surrounding the crop with traps, and manage other plants in the area that may be potential hosts.

After harvest, chill fruit immediately to 34°F to 38°F (1°C to 3°C), or to just above the fruit freezing point, for at least 12 hours and up to three days. This will stop SWD development and kill many of the eggs and older larvae. Maintain consistent temperature throughout the chilling period for the greatest mortality of SWD. If eggs are present, the fruit shelf life will be compromised because the fruit skin surface has been damaged. Thus, post-harvest chill should be combined with immediate marketing of the fruit (McDermott et al., 2014 & Cole et al., 2014).

IRRIGATION AND CANOPY

SWD prefer humid shady sites. Minimize overhead irrigation and repair leaks in the irrigation system. Maintain good air flow and open tree canopies to reduce humidity and shade in the crop canopy.

NETTING

Fine netting placed over branches as a sleeve or draped over the whole plant of small fruit trees or bushes may keep SWD adults from attacking fruit. Proper timing of netting placement is critical to avoid trapping SWD inside the netting where they will infest the fruit. Netting should be applied after flowering to allow for pollination, but before fruit begins to ripen and SWD activity is detected in traps. Mesh size should be about 0.98 mm mesh (used for screening out no-see-um flies). Secure the netting to exclude adult flies. Netting may be especially useful if the crop site has a history of SWD infestation, or if you want to ensure prevention of SWD infestation. Netting is most suitable for small-scale fruit production sites.

EARLY OR TIMELY HARVEST

Early and timely harvest of fruit can help reduce the exposure to SWD infestations. SWD are especially attracted to ripe, ripening and over-ripe fruit; thus, timely harvest reduces the exposure of susceptible fruits to SWD. Harvest fruit as early as possible and continue to pick fruit as it ripens. Select early maturing cultivars to avoid exposure to late-season SWD when populations tend to increase.

TRAPPING

Trapping is not an effective method to reduce SWD populations; however, it is important for determining presence and activity of SWD, assessing if treatment is needed, and timing insecticide applications if they are to be used. See Traps section above for more information on monitoring with traps.

Biological Control

Surprisingly little is known about the most effective natural enemies of SWD. Native natural enemies require time to adjust to a new insect host or prey (Chabert et al. 2012). Thus, a non-native invasive species like SWD may attract few parasitoids and predators for a number of years after it invades a new location. There is promising research on potential biological control agents from Asia and other regions.

French and Spanish populations of *Pachycrepoideus vindemmiae* (Hymenoptera: Pteromalidae), a pupal parasitoid, have shown effectiveness against SWD under laboratory conditions **(Figs. 3.33-3.34)**. Although *P. vindemmiae* is a generalist parasitoid, it parasitized up to 80% of SWD in raspberry fruits in the lab (Asplen, 2015).

In addition to parasitoids, predators are being studied for their ability to control SWD populations. Although no known predators have been shown to individually control SWD, *Orius laevigaus*, *O. majusculus* (*Orius* are also known as minute pirate bugs), *Anthocoris nemoralis*, and *Atheta coriaria* are all commercially available predators that have provided control of SWD in different environments *(Fig. 3.35)* (Cuthbertson et al. 2014). Anecdotal observations also suggest that potentially important biological control agents of SWD include parasitic wasps, lacewing larvae, and predaceous bugs (e.g. big-eyed bugs and minute pirate bugs).

Insect-killing pathogens (viruses, fungi, bacteria, and nematodes) are under investigation for their ability to control SWD. Nematodes that have been found to parasitize other species of drosophila fruit flies include *Howardula aoronympium*, *Steinernema feltiae* and *Heterorhabditis baceriophora* (Jaenike 1992 & Dobes et al. 2012).

Two bacteria, with broad host ranges that have been used to control fruit flies are *Beauveria* (white muscardine fungus) and *Metarhizium* (green muscardine fungus) (Toledo et al. 2000). Both of these fungi kill the insect host within a few days after contact by germinating and penetrating the body cuticle. Laboratory studies of the fungus *Isaria fumosorosea* have also been observed to cause mortality in SWD when directly sprayed onto flies (IOBC-NRS, 2013) *(Fig. 3.36)*. Tthe Drosophila C Virus infects drosophilid flies, and has been shown to reduce fly fecundity and lifespan (Unckless 2011).

Reliance on biological control of SWD is challenging because of the economic loss that can occur even at low levels of infestation. Additionally, the rapid reproduction of SWD can cause population size to increase rapidly. Generalist natural enemies do not feed exclusively on SWD, and so their impact on SWD populations may be low. However, a combination of multiple biological control agents may help to reduce SWD infestations; research continues to search for and test promising natural enemies of SWD.

Chemical Control

Effective monitoring and rapid identification of SWD life stages are critical to quick response to threats from SWD infestations. If SWD is identified, insecticide applications may be necessary to reduce the population size. Monitoring throughout the season will help to accurately time insecticide applications, and assess effectiveness of previous treatments.

Most insecticides should be applied to killed adult flies before they lay eggs in the fruit. Systemic insecticides (e.g., neonicotinoids and diamides) may kill eggs and larvae inside of the fruit (Beers et al. 2011). The level of control needed will depend on the size of the SWD population, timeliness of application, coverage of fruit, and product effectiveness. Because of their short generation time and multiple generations per season, SWD are prone to develop insecticide resistance; thus it is critical to rotate chemical classes between SWD generations.

If monitoring results indicate a need for insecticidal sprays, apply the sprays to fruit just as it is turning from yellow to pink in color. In cherries, this generally occurs 2-3 weeks before harvest. Reapply products based on their protection interval to maintain control through harvest or based on trap captures and fruit monitoring. Follow the mandated pre-harvest interval (PHI) on the product label. PHI is the required waiting time between the final application and the start of harvest. If SWD are present, consider the use of post-harvest clean up sprays to reduce the population size for later maturing and next season's crops.

Recommended Insecticides

Table 3.1. Insecticides recommended for control of SPOTTED WING DROSOPHILA IN COMMERCIAL FRUIT production in Utah

Table 3.2. Insecticides recommended for control of SPOTTED WING DROSOPHILA IN HOME FRUIT production in Utah

Sources of Monitoring Supplies

AgBio
Westminster, CO
303-469-9221
agbio-inc.com

Scentry
Billings, MT
800-735-5323
scentry.com

Great Lakes IPM
Vestaburg, MI
800-235-0285
greatlakesipm.com

Gemplers
Mt. Horeb, WI
800-382-8473
gemplers.com

Trésé
Salinas, CA
408-758-0205
trece.com

Alpha Scents
West Linn, OR
503-342-8611
alphascents.com

For Additional Information, Search the Internet for:

MyPest Page Degree-Day/Phenology Models, uspest.org

Labeled Insecticides for Control of Spotted Wing Drosophila in New York Tree Fruit, Cornell University

How Do I manage Spotted Wing Drosophila in my Garden, Cornell University

Spotted Wing Drosophila Part 1: Overview and Identification, Penn State Extension

Spotted Wing Drosophila Part 3: Monitoring, Penn State Extension

Spotted Wing Drosophila Part 4: Management, Penn State Extension

Recommendations for Managing SWD in Oregon Sweet Cherry (traps and insecticides), Oregon State University

Spotted Wing Drosophila, Washington State University

Spotted Wing Drosophila, Oregon State University

Noncrop Host Plants of Spotted Wing Drosophila in North America, MSU

A Detailed Guide for Testing Fruit for the Presence of Spotted Wing Drosophila (SWD) Larvae, Oregon State University

Spotted Wing Drosophila Management Recommendations for Michigan Raspberry and Blackberry Growers

Spotted Wing Drosophila, USU Extension

Monitoring for Spotted Wing Drosophila in Utah, USU Extension

Sampling Berries for Spotted Wing Drosophila Larvae, MSU

Comparing Larvae of Western Cherry Fruit Fly and Spotted Wing Drosophila, Oregon State University

Monitoring Trap for Spotted Wing Drosophila (SWD), Oregon State University

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Beers, E.H., R.A. Van Steenwyk, P.W. Shearer, W.W. Coates, J.A. Grant. 2011. Developing Drosophila suzukii Management Programs for Sweet Cherry in the Western United States. Article first published online: 14 SEP 2011. DOI: 10.1002/ps.2279.

Chabert, S., R. Allemand, M. Poyet, P. Eslin, P. Gibert. 2012. Ability of European Parasitoids (Hymenoptera) to Control a New Invasive Asiatic Pest, Drosophila suzukii. Biological Control. 63(1): 40-47. DOI:10.1016/j.biocontrol.2012.05.005.

Cini, A., C. Ioriatti, and G. Anfora. 2012. A review of the invasion of Drosophila suzukii in Europe and a draft research agenda for integrated pest management. Bulletin of Insectology. 65: 149–160.

Cole, J., P. Lucas, R. Bessin. 2014. Spotted Wing Drosophila Management. University of Kentucky College of Agriculture, Food and Environment.

Cuthbertson, A.G.S., L.F. Blackburn, N. Audsley. 2014. Efficacy of Commercially Available Invertebrate Predators against *Drosophila suzukii*. Insects 2014, 5, 952-960; doi: 10.3390/insects5040952

Dobes, P., Z. Wang, R. Markus, U. Theopold, P. Hyrsl. 2012. An improved method for nematode infection assays in Drosophila larvae. Fly. 6: 75-79.

Jaenike, J. 1992. Mycophagous Drosophila and their nematode parasites. Am. Nat. 139: 893-906.

McDermott, L., C. Heidenreich, J. Carroll, M. Helms, A. Agnello, G. Loeb. 2014. How Do I Manage Spotted Wing Drosophila (SWD) in my Garden? Cornell University.

Toledo, J., P. Liedo, S. Flores, S.E. Campos, A. Villaseñor, P. Montoya. 2006. Use of Beauveria bassiana and Metarhizium anisopliae for fruit fly control: a novel approach. Proc. 7th Int. Symp. Fruit Flies Econ. Importance. 10-15 September 2006. Salvador, Brazil. pp. 127-132.

Unckless, R. 2011. A DNA virus of Drosophila. PLoS ONE 6(10): e26564. doi:10.1371/journal.pone0026564

IOBC-NRS, International Organization for Biological Control Nearctic Regional Section. 2013. IOBC-NRS Newsletter. Winter 2013. Vol. 35, No. 1, pp. 6.

Pest Management Tables for Commercial and Home Use

Table 3.1. Insecticides recommended for control of **SPOTTED WING DROSOPHILA IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Organophosphates (1B)					
malathion	Fyfanon ULV AG, Malathion 8 Aquamul	Make first application as soon as flies appear.	1 d grape: 3 d	7 d grape: 14 d	Toxic to aquatic organisms, fish, invertebrates and bees. **Fyfanon:** Apply by aircraft only.
naled	Dibrom 8 Emulsive[R]		For grape only: 10 d	For grape only: 7 d	
phosmet	Imidan 70-W Insecticide		7 d grape: 7-14 d	NL grape: 10-14	
Pyrethroids, Pyrethrins (3A)					
fenpropathrin	Danitol 2.4 EC Spray[R]	Begin applications when pest activity is first noted; repeat as needed, and according to specified protection interval to maintain control.	3-14 d caneberry: 3 d grape: 21 d strawberry: 2 d	10 d caneberry: NL grape: 7 d strawberry: NL	Toxic to fish, aquatic organisms, wildlife, and bees.
pyrethrins	Pyganic EC 1.4 II[O], Pyganic EC 5.0 II[O], Tersus		0 d	3 d	
Benzoylureas (15)					
novaluron	Rimon 0.83 EC	Apply when adults appear.	8 d caneberry: 1 d	7 d caneberry: 7 d	Toxic to freshwater and estuarine/marine invertebrates, bees and other pollinators.
METI Acaricides and Insecticides (21A)					
tolfenpyrad; tolfenpyrad	Bexar	Apply when pest populations are beginning to build.	14 d	NL	Toxic to fish, aquatic invertebrates, and bees.
Diamides (28)					
cyantraniliprole	Exirel	Apply at the specified rates when insect populations reach locally determined action thresholds.	3 d	7 d	Toxic to aquatic invertebrates, oysters, and bees.
Other; Pyrethroids, Pyrethrins (3A)					
piperonyl butoxide; pyrethrins	Evergreen EC 60-6	Apply only as specified on the label.	0 d	7 d	Toxic to aquatic organisms, fish, invertebrates, and bees.
Unknown (UN)					
azadirachtin	Molt-X	Spray when pests first appear.	0 d	7-10 d	Toxic to fish and aquatic invertebrates.

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Spotted Wing Drosophila

Spotted Wing Drosophila

Table 3.2. Insecticides recommended for control of
SPOTTED WING DROSOPHILA IN HOME FRUIT production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Pyrethroids, Pyrethrins (3A); Unknown (UN)					
pyrethrins; sulfur	Bonide Tomato & Vegetable Ready To Use, Ortho Rose & Flower Care, Ortho Elementals 3-In-1 Flower Fruit & Vegetable Care, Bayer Advanced Natria Fruit & Vegetable RTU, Ready-To-Use Worry Free Brand 3 In 1 Garden Spray, Earth-Tone 3 N 1 Disease Control, Bonide Citrus Fruit & Nut Orchard Spray Concentrate	Apply as soon as insect problems are observed.	1-7	7-14 d	Toxic to wildlife and bees.
Neonicotinoids (4A)					
acetamiprid	Ortho Bug B Gon Systemic Insect Killer Concentrate, Ortho Flower Fruit & Vegetable Insect Killer	Apply when insects first appear.	3-14 d	7 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees. Efficacy is good.
Spinosyns (5)					
spinosad	Bonide Captain Jack's Deadbug Brew Flower & Vegetable Garden Dust, Bonide Captain Jack's Deadbug Brew, Ferti-Lome Borer Bagworm Leafminer & Tent Caterpiller Spray, Monterey Garden Insect Spray[O], Protector Pro[O], Spinosad 0.5% SC	Apply when listed pests are present. Repeat applications may be made as indicated on the label.	3-7 d	5-10 d	Toxic to bees and aquatic invertebrates. Efficacy is very good.
Other					
caster oil, citric acid, corn oil	Srills Fruit Fly Bully	Kills fruit flies on contact.	NL	NL	NA
cedar oil, ehtyl lactate (corn oil by product)	Wondercide Outdoor Natural Pest Control	To treat an active problem, you must apply twice within 7-10 days to ensure you break the egg cycle.	NL	7-10 d	NA
neem oil	Green Light Neem Concentrate[O], Bonide Neem Oil Fungicide-Miticide-Insecticide, Triple Action Neem Oil[O], Monterey Neem Oil RTU (Ready-To-Use)[O], Bayer Advanced Natria Neem Oil Ready-To-Use	Apply at first sign of insects.	0 d	7-14 d	Toxic to bees. Efficacy is poor.

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

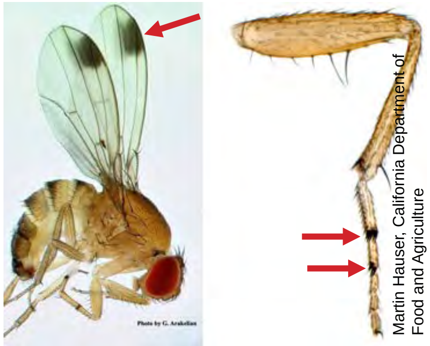


Fig. 3.1. Male spotted wing drosophila (SWD); note spots on wings, and “sex combs” on banded forelegs.

Fig. 3.2. Adult male SWD; note the spot on each wing.

Fig. 3.3. Adult female SWD; note the lack of spots on wings and generally bigger body than the male adult.

Fig. 3.4. Female SWD ovipositor (egg laying device on tip of abdomen); note dark serrated teeth for cutting into fruit.

Fig. 3.5. Female SWD uses ovipositor to insert egg into fruit.

Fig. 3.6. SWD egg; note the two filaments or breathing tubes on one end.

Fig. 3.7. Female SWD with egg protruding from ovipositor; note the serrated ovipositor and two filaments on the egg.

Fig. 3.8. Close-up of female SWD ovipositor and egg.

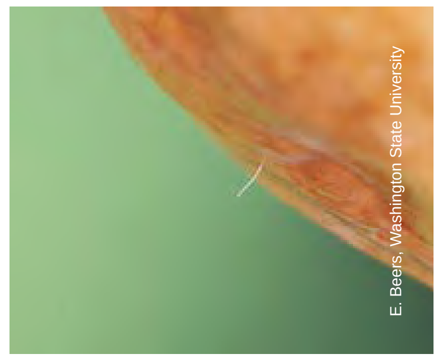


Fig. 3.9. SWD egg filaments protruding from fruit.

Fig. 3.10. SWD egg filaments protruding from blackberry fruit.

Fig. 3.11. SWD larva in cherry fruit.

Fig. 3.13. Larva of SWD on cherry fruit showing internal structures.

Fig. 3.14. Larva of SWD on cherry fruit; note breathing holes cut through the skin.

Fig. 3.15. Pupa of SWD; note the two extensions on the anterior end.

Fig. 3.16. Pupa of SWD protruding from a cherry fruit with breathing tubes extended.

Fig. 3.17. Adult flies visible inside pupae of SWD.

Fig 3.18. SWD adult on wine grapes.

Fig. 3.19. SWD adults on a cracked tomato fruit.


Martin Hauser, California Department of Food and Agriculture

Fig. 3.20. Sweet cherry damage from SWD egg-laying scars and larval feeding.

Fig. 3.21. Damage from SWD larvae; note the elliptical depressions in the fruit skin.

Fig. 3.22. Damage to raspberry fruit 1-2 days after SWD eggs were laid.

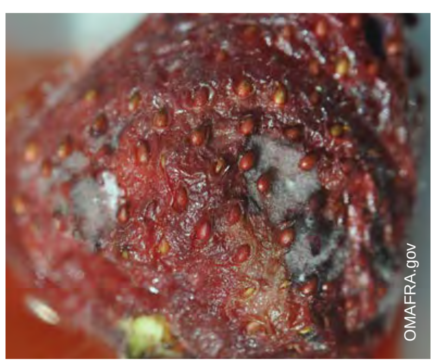


Fig. 3.23. Three days after sSWD egg-laying, the strawberry fruit has deteriorated and mold has grown.

E. Beers, August 2010

Fig. 3.24. Homemade SWD monitoring trap.

Fig. 3.25. Homemade trap with a sticky card for added trapping quality of SWD.

Fig. 3.26. A simple funnel trap filled with vinegar to bait and trap SWD adults.

Fig. 3.27. A commercial fruit fly trap that can be used for monitoring SWD.

Fig. 3.28. Fine mesh strainer used to separate SWD specimens from trap bait.

Fig. 3.29. Plastic wrap with holes used to separate SWD specimens from trap bait.

Fig. 3.30. SWD adults on the left, collected and strained from a trap.

Fig. 3.31. Use a hand lens, magnifying glass, or microscope to identify specimens of SWD.

Fig. 3.32. Flies caught on a yellow sticky trap (left), and a close up of SWD males in red circles (right).

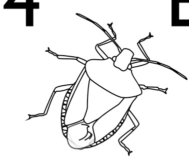
Fig. 3.33. A female parasitoid wasp, *Pachycrepoideus vindemmiae*, shown attacking a SWD pupa.

Fig. 3.34. *P. vindemmiae* (female); a parasitoid wasp native to the Northwest that may adapt to parasitizing SWD in the field.

Fig. 3.35. The predatory bug *Anthocoris nemoralis* feeding on an adult SWD.

Fig. 3.36. An adult SWD male infected with the fungal pathogen *I. fumosorosea*.

CHAPTER 4 BROWN MARMORATED STINK BUG



Quick Facts

- Brown marmorated stink bug (BSMB) is native to Asia (China, Japan, Taiwan, and Korea).
- In the U.S., BMSB was first introduced into Pennsylvania in the late 1990s, and now occurs in most states.
- BMSB is a tree-loving bug, but attacks many types of plants; feeding causes misshapen fruit, discolored spots on leaves and fruit, and wounds and oozing sap on tree trunks and branches.
- BMSB can be a major nuisance pest when adults invade buildings and other structures during the fall and winter.
- BMSB can be difficult to control with insecticides; however, natural enemies may be effective along with an integrated pest management approach.

Background

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stal) (Hemiptera: Pentatomidae), is a major pest of important agricultural crops such as tree fruits, small fruits, legumes, vegetables and ornamentals. Originally from Asia (China, Japan, Korea and Taiwan), BMSB was first found in the U.S. in Allentown, PA around 1996, but was initially misidentified as a local species. In 2001, after increasing homeowner complaints, BMSB was positively identified as a new invasive species. The range of BMSB has since expanded throughout much of the U.S., including Hawaii, California, Oregon, and Washington, and has become an economic agricultural pest in many parts of the country.

BMSB was first detected in Utah in 2012, and is now considered to be established in Weber, Davis, Salt Lake, and Utah counties (as of 2015). Reproducing populations have been found on ornamental plants, particularly catalpa trees, and massing adults can be seen on buildings.

In China, BMSB prefers to feed on the rubber bark tree (*Eucommia*), a small tree that is cultivated for its medicinal properties and threatened in the wild. BMSB feeds on many fruit and ornamental trees such as pear, peach, apple, plum and mulberry. In Korea, BMSB can be a pest on soybean, sweet persimmon, yuzu, and citrus. Its primary plant hosts in Japan include cedar and cypress. BMSB is not a significant pest in its native habitats because natural enemies keep its populations low, but when environmental conditions are ideal, BMSB outbreaks may occur.

In the U.S., BMSB has an abundant food supply and limited natural enemies. Due to its broad plant host range, potential for severe crop injury, and adult behavior of congregating for winter shelter on buildings, BMSB has become a major economic concern and nuisance pest in many regions of the U.S.

Pest Identification and Life History

Accurate identification is critical, as there are several look-alike species, including other stink bugs *(Figs. 4.1-4.7)*.

ADULT: REPRODUCTIVE, DISPERSAL, DAMAGING, AND OVERWINTERING STAGE

- About 5/8 in (17 mm) long and ½ in (13 mm) wide *(Figs. 4.1, 4.3, 4.5)*.
- Shield-shaped body.
- Marmorated means "marbled", referring to the brown mottled pattern on the back- and under-side of adult bodies.
- Antennae, legs, and posterior edge of the back have distinct light and dark banding patterns.
- "Shoulders" are rounded and smooth, as opposed to other stink bug species that have notched or pointed shoulders.

EGG

- Typically laid on the underside of leaves.
- Barrel-shaped, 1/16 in (1.6 mm) wide.
- Translucent to white in color.
- Mature eggs develop dark triangular-shaped spots *(Fig. 4.8)*.

NYMPH: DISPERSAL, DAMAGING, AND OVERWINTERING STAGE

- Five instars or immature stages (nymphs).
- Range from 1/10-1/2 in (2.5-12 mm) long.

- First instar nymphs are bright orange or red *(Fig. 4.9)*, and will remain near the egg mass and feed on eggshells for nutrients *(Fig. 4.10)*.
- As nymphs mature, they darken in color, develop wing pads (immature wings), and begin to look similar to adults in color and size *(Fig. 4.11)*.

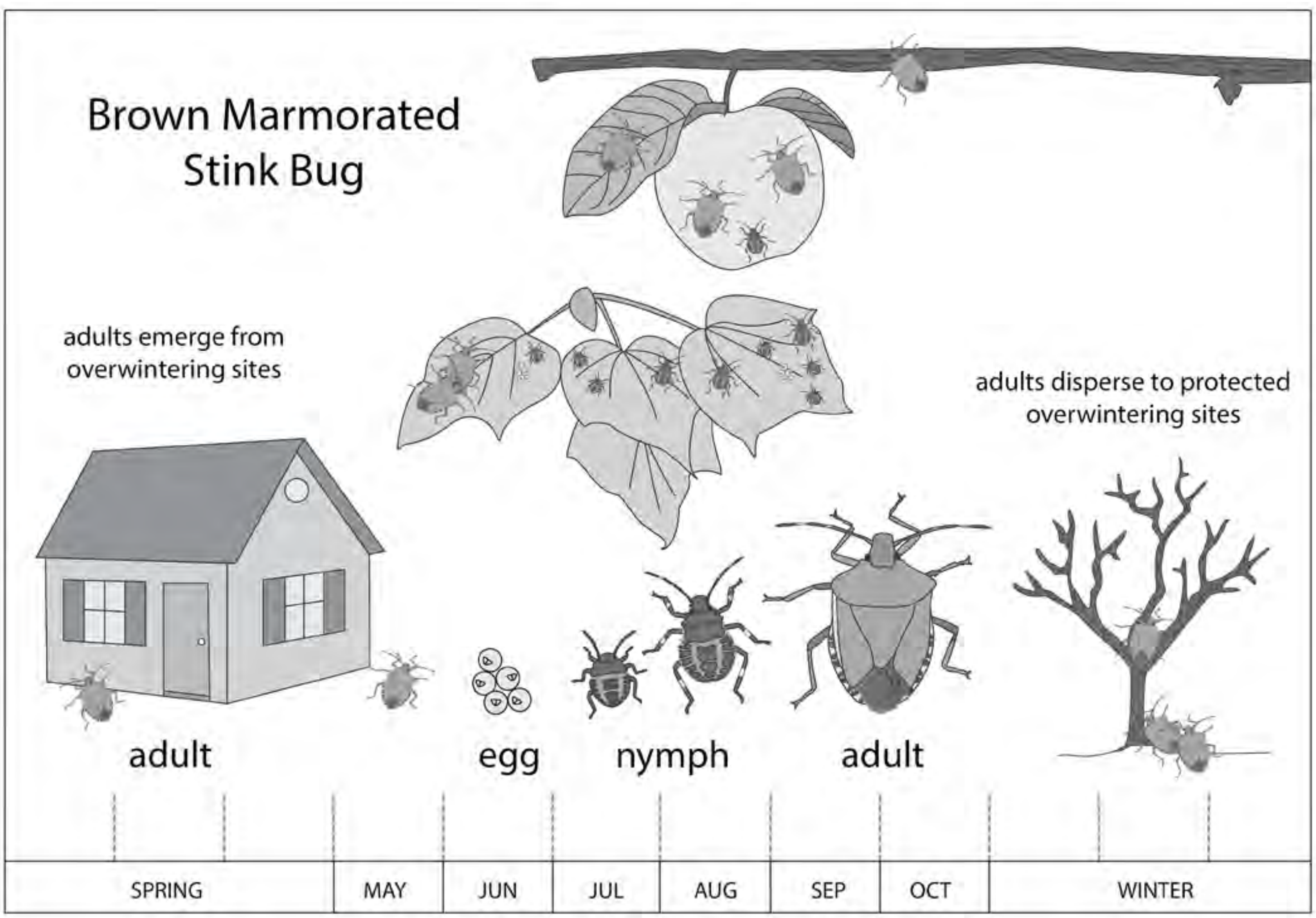
Adults become active in the spring (after temperatures and daylight hours have increased), and feed on any green, growing plant for about two weeks before mating. In Utah, BMSB adults have been observed on honeysuckle, butterfly bush, Siberian pea shrub, and Japanese downy maple in the spring and catalpa in the summer. Eggs are laid in masses of approximately 20-30, and are typically laid on the underside of leaves. A female may lay as many as 400 eggs in her lifetime. In northern Utah, BMSB egg masses have been detected from late May to late August.

There appears to be only one generation per year in Utah, but multiple generations are possible. In other states, eggs have been observed through September. There are five instars or immature stages (nymphs). The development time for each instar or nymph is about 1 week, depending on temperature. In October to November, adults (and sometimes nymphs) move to protected sites where they mass together for the winter, including under the bark of standing trees, downed and dead trees, and inside buildings, especially in attics and walls. Adult aggregations may be seen on the outside of buildings, and in window seals, air vents, window cooling units, and cracks and crevices in concrete or buildings *(Fig. 4.12)*.

Plant Hosts and Injury Symptoms

BMSB is a tree-loving bug, but has a very broad plant host range. Adults and nymphs will feed on vegetative and reproductive plant structures, including stems, leaves, fruits, seeds, pods, buds, and flowers. Plants that bear fruiting bodies (fruits, vegetables, and ornamentals) are especially vulnerable to this pest. BSMB prefers stone and pome fruits, caneberries, strawberries, and recently has been found to feed on citrus fruits. Vegetables are also highly susceptible to BMSB feeding; especially solanaceous fruits, legumes, cucumber, and sweet corn *(Figs. 4.13-4.14)*. In Utah to-date, BMSB has been found only on ornamental woody plants: catalpa, maple, butterfly bush, honeysuckle, and Siberian pea shrub.

True bugs, including BMSB and other stink bugs, have piercing-sucking mouthparts *(Fig. 4.15)*. They use their



Life history of brown marmorated stink bug (BMSB) in Utah. There is one generation per year; however, adults can fly to orchards and multiple life stages can be present throughout much of the growing season. BMSB is a major nuisance pest and has a wide range of host plants.

mouthparts to puncture plant cells to obtain nutrients in the sap. Common feeding damage symptoms include dimples, pits, and discoloration of fruits, flowers, buds, and leaves *(Figs. 4.13-4.20)*, softening of fruits, corky spots under the fruit skin, and "cat facing" *(Fig. 4.16)*. Damage is often patchy. BMSB will migrate among preferred host plants in a localized area, and can cause substantial economic loss to crops.

Tree trunks and plant stems are less preferred food sources; however, when fed upon, BMSB will cause scars, bumps, and sap to ooze from feeding wounds. Damaged limbs and stems may be weakened, and at greater risk for breakage.

BMSB is also a nuisance pest due to its tendency to congregate in high numbers on and inside buildings from late summer through early spring. They can invade homes, schools, work places, barns, and other structures, and will emit a cilantro-like odor when disturbed or crushed. Adults seek shelter in narrow spaces such as cracks, under or behind baseboards, around window and door trim, and around lights in ceilings or exhaust fans. Infestations in these areas may attract more BMSB as they emit aggregation pheromones. As BMSB die, they may attract dermestid beetles (also known as carpet beetles) coming to feed on the dead carcasses. BMSB prefer to shelter in locations high above the ground and that have stable cool temperatures.

Plant Hosts of BMSB		
Fruits & Nuts	**Vegetables**	**Ornamentals**
apple	lima bean	sunflower
peach	snap pea	hibiscus
pear	pepper	snapdragon-box elder
apricot	tomato	birch
nectarine	soybean	elm
mulberry	pods of legumes	oak
fig	eggplant	tree of heaven
citrus fruits	cucumber	**maple***
cherry	corn	**Catalpa***
raspberry	pumpkin	**butterfly bush***
grape		**honeysuckle***
strawberry		**Siberian pea shrub***
pecan		crabapple
hazelnut		dogwood
black walnut		English holly
		Southern magnolia
		redbud
		Chinese pistache

*In Utah, BMSB have been found on plants in bold letters.

Although they can be a major nuisance, BMSB do not bite, sting, suck blood, or spread mammalian diseases, and they do not bore into or eat wooden structures. They are not directly harmful to people, pets or buildings, and do not reproduce or cause damage inside structures.

Plant Injury Symptoms of BMSB
• discolored spots on fruits, flowers, buds, and leaves
• dimples and pits in fruits, flowers, buds, and leaves
• fruit that is soft to the touch
• skin of fruit may easily peel away
• corky spots under fruit skin or "cat-facing" on firm fruits
• patchy discoloration
• withered leaves and stems
• bumps and scars on stems and trunks
• weakened stems that cannot support plant weight
• scars and oozing sap on tree trunks
• white pimple-like salivary residue on plant tissues

Monitoring

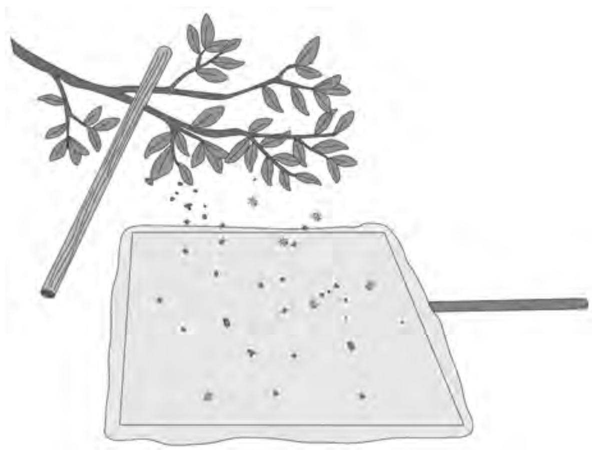
There are a number of effective monitoring techniques for BMSB, including visual surveys, beating sheets, and traps. Monitoring should be conducted at regular intervals from spring through fall to determine its presence, abundance, and plant damage.

Visual Surveys

Visual surveys can provide a measure of abundance and seasonal activity. Visual surveys should be conducted during peak activity times for BMSB. In Utah, BMSB is more active during the afternoon hours in the cooler spring and fall months, whereas it is most active during the early morning and evening hours in the hotter summer months. Plants should be visually inspected for a 3-5 minute period. BMSB is known to prefer the edges of plantings, meaning it invades crops from the outside and congregates along the borders. Thus, monitoring and trapping should be focused around the edge rows and perimeters of orchards, field crops, and gardens.

Beating Sheets

Beating sheets or trays are an effective method to dislodge BMSB adults and nymphs directly from plants *(Fig. 4.23)*, and are highly effective when bug populations are low. Beating trays can be purchased online or constructed from a canvas sheet spread over a square frame (approx. 24 × 24 inches), and paired with a beating stick. Higher branches (BMSB have been shown to prefer top portions of the canopy) of suspect plants (trees, shrubs, etc.) are gently beaten directly above the sheet. Due to BMSB's nature of releasing the plant when threatened, the stink bug falls onto the sheet and can be collected. This method is recommended for determining the presence or absence of BMSB. This strategy is effective for monitoring all life stages of BMSB. When early instars are detected, the plant can be visually inspected for egg masses.



Traps

Traps are the most common method for detecting BMSB, but may not be highly effective in areas with low BMSB populations. Traps typically consist of a dark pyramid base and a capture container on the top. Typically, a two-part pheromone lure (an aggregation pheromone plus MDT, a chemical attractant) and an insecticide strip to kill collected specimens are placed in the container *(Fig. 4.21)*. The aggregation pheromone combined with MDT provides an attractive season-long lure for BMSB. Traps and lures are available from numerous suppliers (see sources of monitoring supplies list at the end of the chapter). Traps should be checked frequently, about once a week, and lures replaced every 4 weeks. Traps are most attractive to adults and late-instar nymphs. Using traps to determine BMSB abundance can help in making management decisions. Studies have shown that intervention by the grower should be made when 10 adult BMSB per trap are present. This intervention may need to be an insecticidal spray; however, using these numbers (rather than spraying weekly) can reduce sprays by about 40% and still protect the fruit as if you had been spraying weekly (Northeast IPM, 2016).

In addition to detecting the presence of BMSB, the aggregation pheromone and MDT can be used to manage BMSB by using these two stimuli in higher doses to bait perimeter or border row trees. BMSB will aggregate in the baited trees reducing their dispersal within the orchard block. Insecticide sprays or other control techniques can be focused the bait trees, reducing the area treated with insecticide. This "trap-and-kill" method can reduce the amount of insecticide applied by over 70% (Northeast IPM, 2016).

Trap crops have shown promise for monitoring and management of BMSB. Trap crops are discussed in detail in the management section of this chapter.

BLACK LIGHT TRAPPING

BMSB are highly mobile, may fly up to 3 miles (5 km) in a 24-hour period, and are attracted to a wide range of host plants. These characteristics make them difficult to monitor, especially when population densities are low, such as during the initial stages of establishment and spread. Research conducted on farms in New Jersey using a network of black light traps *(Fig. 4.22)*; found the traps to be a highly effective method of monitoring BMSB and their spread at the landscape level (Nielsen et al. 2013). Black light traps were shown to attract BMSB early in the season and when populations are low, improving predictions of pest pressure and management decisions.

BMSB are night-flying insects, and are attracted to black light traps because they mistake them for the light of the moon. Black lights are particularly effective in attracting BMSB when they are dispersing among host plants and during mating. Black light traps are non-specific, and will attract other nocturnal insects. Phases of the moon, cloud cover, and weather can cause variations in attractiveness of black light traps (Nelsen et al. 2014).

Management

BMSB populations have been increasing every year in the U.S. since first detection in the late 1990s. Adults are highly mobile (average dispersal is 0.35 miles or 0.6 km per day; individuals have been tracked up to 3 miles per day), and easily spread by hitchhiking (e.g. on shipping containers, vehicles, and infested nursery material). Effective BMSB management, therefore, requires an integrated pest management, or IPM, approach that integrates multiple options – cultural, mechanical, biological, and chemical.

Cultural Control

Trap crops can lure BMSB away from economically important crops. Effective trap crops in a southern U.S. study included triticale, sorghum, millet, buckwheat, and sunflower (Mizell et al. 2008). Researchers found it is important to use a mixture of at least two species within a border planting, and maintain an adequate amount of attractive food for BMBS to outcompete the cash crop. Trap crops may also lure BMSB to a specific location where they can be trapped and killed, such as with an insecticide, or gathered in a collection device.

Mechanical & Physical Control

IN CROPS

Traps are generally used for monitoring; however, properly placed light and pheromone traps may be used for attract-and-kill control methods. Cardboard boxes packed with straw or paper, or slit traps made of layered wood, may attract overwintering adults. Trapped BMSB can then be collected and destroyed.

Some physical barriers can be effective in deterring BMSB, and are typically more feasible in small crop acreage situations. Examples include floating row cover, sticky bands around trunks and stems made from adhesives such as Tangle-Trap®, and covering fruits with breathable bags or plants with netting.

IN BUILDINGS BEFORE BUGS HAVE ENTERED

Mechanical exclusion is one of the best methods to reduce BMSB adult aggregations in homes and other buildings. Exclusion can be accomplished by sealing cracks around windows, doors, siding, utility pipes, chimneys, and underneath fascia (covering for the ends of roof rafters) and other openings with high quality silicone or silicone-latex caulk. Repair or replace damaged screening on doors and windows. Screen exterior vents and remove window-mounted air conditioners in the winter to reduce access points for BMSB adults.

IN BUILDINGS AFTER BUGS HAVE ENETERED

In homes, BMSB have become a nuisance and can affect the anxiety level and mood of the residents within infested homes. In some areas, BMSB presence in homes can also affect the property value. BMSB can be found in unexpected or surprising places such as bedclothes, kitchen drawers, behind photos on walls, or crawling on many surfaces within the home. During the winter months, BMSB become an increasing issue inside buildings and their activity tends to increase as day length increases. This may cause them to begin flying around the interior of the house causing alarm for people living inside.

There are many commercial products on the market for trapping BMSB indoors. Some products use aggregation pheromones marketed to lure BMSB to the traps; however, BMSB does not respond to these pheromone stimuli when they are overwintering. BMSB *do* respond to light during this time.

Aigner and Kuhar (2014) studied trapping of BMSB indoors. The most effective method was a simple pan filled with soapy water with a light shining on it *(Figs. 4.24-4.25)*. During the night, adults were attracted to the light and drowned in the soapy water. BMSB can also be removed by sweeping with a broom or with a vacuum when indoors or clustering on exterior surfaces.

Biological Control

Insect natural enemies (insect-attacking predators, parasitoids, and pathogens) that will kill BMSB may also attack many other species of insects. In the U.S. to-date, natural enemies have not been effective in limiting population growth of BMSB. Research on biological control is still in its early stages; however, there is an emphasis to develop effective agents and tactics for their use. In China, biological control rates average 50%, and keep BMSB populations low (Wiman, 2013). In the U.S., biological control levels are low (4%), and do not yet provide the control needed for BMSB.

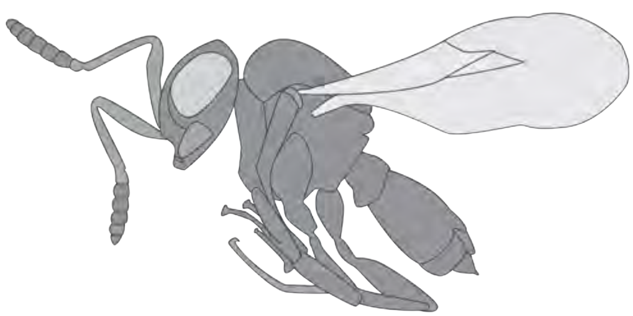
PREDATORS

Generalist predators of BMSB have not been well studied. They include predators that attack stink bug eggs (ants, earwigs, soldier beetles, big eyed bugs, insidious flower bugs, spiders, spined soldier bugs, thrips, lady beetles, lacewings, grasshoppers, katydids, and crickets), and those that attack stink bug nymphs and adults (assassin bugs, predatory stink bugs, spiders, praying mantids, and birds such as starlings, chickens, and geese) *(Figs. 4.26-4.27)*. These predators also attack native stink bugs, and will follow stink bug prey from crop to crop. In a Maryland soybean field infested with BMSB, rates of egg predation by spiders and big-eyed bugs approached 50% (Leskey et al. 2012a).

PARASITOIDS

Stink bug parasitoids include species that attack eggs (scelionid and chalcidoid wasps) and adults (tachinid flies and rarely braconid wasps). There are currently no known parasitoids of BMSB nymphs.

BMSB parasitoids reported from Asia include many species of *Trissolcus* wasps in the Family Scelionidae (*T. itoi*, *T. mitsukurii*, and *T. plautiae* in Japan; *T. halyomorphae* in China; and *Trissolcus spp.* in Korea) as well as *Gryon japonicum* wasps in the Family Chalcidoidea (Korea), and flies in the Family Tachinidae (*Bogosia spp.* in Japan). Multiple *Trissolcus* species and populations collected in Asia are under evaluation for their efficiency in killing BMSB in the U.S. Currently, the research has been confined to quarantine facilities to ensure that non-target stink bugs and other insects are not negatively impacted. However, recent discoveries of naturally occurring *Trissolcus japonicas (Fig. 4.28-4.29)* attacking BMSB eggs in Washington State and several eastern U.S. locations will likely accelerate the research and release of promising parasitoids.



Trissolcus halymorphae Yang *(Fig. 4.30-4.31)* (Order Hymenoptera: Family Scelionidae) is a specialist (meaning it typically feeds on pentatomids specifically) egg parasitoid, and the principal natural enemy of BMSB in China, with average parasitism rates of 50% in its native range. Other genera of pentatomid egg parasitoid specialists in the scelionid family include *Telenomus*, *Gryon*, and *Psix*. The most common parasitoid observed in organic vegetable fields in the U.S. is *Telenomus podisi (Fig. 4.32)*.

Anastatus spp. (chalcidoid wasps) are known in China to parasitize eggs of stink bugs and other types of insects, but have been ineffective in reducing BMSB injury to crops in laboratory studies (Hou et al. 2009). Two *Anastatus* species have been observed in high numbers emerging from BMSB eggs found in non-agricultural wooded areas: *A. reduvii (Figs. 4.33)* and *A. mirabilis*.

Tachinid flies can parasitize BMSB adults. A tachinid fly found in the eastern U.S., *Euclytia flava*, *(Fig. 4.34)* is attracted to the aggregation pheromone of BMSB (Aldrich et al. 2007). In this case, pheromones used in traps to monitor BMSB may increase biological control when both tachinids and BMSB are drawn to the same areas. Although tachinids may be successful in placing their eggs inside BMSB adults, indigenous North American tachinids may not be physically adapted to develop and emerge from BMSB after egg placement. Research in this area is ongoing. Another tachinid reported to attack BMSB in Korea is P*entatomophaga latifascia*; however, its biology is not well known and successful emergence from BMSB has been low.

PATHOGENS

All stages of BMSB are potentially vulnerable to attack by insect pathogens *(Fig. 4.35)*. The fungus *Metarhizium* (also known as green muscardine) has been used with moderate success against stink bugs. The fungus genus *Ophiocordyceps* includes about 140 species that kill insects, and have been reported to be effective against BMSB. See the Biopesticide section below for more information on pathogens of BMSB.

Chemical Control

BMSB is a challenging insect to kill. Adults have a tough exoskeleton and can easily reinvade previously treated fields, both nymphs and adults damage crops, and over time, BMSB may develop resistance to insecticides. For these reasons, insecticidal control of BMSB often requires multiple applications of insecticides. To evaluate the residual effects of insecticides (when BMSB lands on recently treated plant surfaces), a laboratory study exposed BMSB adults to 18-hour-old dried insecticide residues (Leskey et al. 2012b). Of 37 insecticides tested against BMSB adults, residues of about one-third of the products were ineffective. Materials that caused the highest immediate mortality with little recovery included methomyl (1A), acephate (1B), chlorpyrifos (1B), dimethoate (1B), malathion (1B), methidathion (1B), endosulfan (2A), bifenthrin (3A), fenpropathrin (3A), and permethrin (3A). Insecticides in the pyrethroid class exhibited good knockdown action against BMSB, but many bugs recovered within 7 days of exposure to residues.

Targeted insecticide applications, such as spraying only the borders of orchards and fields, have been shown to be effective while reducing insecticide use by 85% (Leskey et al. 2012a). BMSB has a tendency to cluster along edges of orchards and crop fields; thus, most of the damage observed in apples, sweet corn, and soybeans is in the outer rows (Leskey et al. 2012ac). BMSB may also be lured to specific locations to be treated with insecticides (attract-and-kill). Insecticide applications were reduced by baiting border-row orchard trees with aggregation pheromones and targeting insecticide applications to these trees (Leskey et al. 2012c). When BMSB adults are found in the orchards or fields as well as on the edges or perimeter rows, alternate row middle (ARM) sprays are recommended. However, when nymphs are found, whole orchard spray applications are recommended.

Utilizing knowledge of BMSB behavior to modify insecticide use can decrease the amount of material required. Adult BMSB tend to fly to the base of tree trunks, and then crawl up the trunk into the canopy. Nymphs do not have wings, and therefore climb trunks into fruit tree canopies. Banding tree trunks with insecticides or sticky barriers can reduce the amount of insecticides necessary to suppress BMSB in tree crops.

Completely sealing the exterior of a home or building to prevent entry of BMSB (adults and nymphs) when populations are large can be difficult to achieve. In these cases, insecticides may provide minor relief. A local pest control company or a licensed individual should perform the applications. Accurate timing of sprays is critical for success, such as when the stink bugs first begin to aggregate in the fall. BMSB control with insecticides is difficult; the chemicals break down in sunlight reducing effects to several days to a week. Consider any negative effects of applying insecticides to a home or workplace before applications are made.

BIOPESTICIDES

Biopesticides are biologically derived materials and living organisms that may have lethal and/or sub-lethal effects on pests. In some cases, biopesticides are as or more effective than conventional pesticides; therefore, they can be a good fit to reduce negative environmental impacts, including effects on non-target organisms such as beneficial insects.

Botanically derived biopesticides that are effective against BMSB include formulations of neem (azadirachtin), which acts as an anti-feedant and may reduce female reproduction; and pyrethrin, which can provide contact mortality and act as a repellent. Neem and pyrethrin can be combined; a common technique used in organic treatments.

Chitin synthesis inhibitors are a type of insect growth regulator, and are more selective than many insecticides. In other words, these products have lower toxicity to mammals and predatory insects. Chitin synthesis inhibitors such as novaluron and diflubenzuron are lethal to nymphal stages of BMSB, but are ineffective against eggs and adults. Treatment of nymphs should occur during June and July while they are still developing for best effects.

Fungi that attack insects, called entomopathogenic fungi, can be effective against BMSB. Lab tests have shown that several isolates of *Beauveria bassiana*, including the commercial formulation Botanigard, killed 100% of the BMSB (Gouli et al. 2012). Other effective fungi include *Ophiocordyceps nutans*, and *Metarhizium anisopliae* from Japan (commercial formulation MET52), which specifically attack BMSB and induce nearly 85% mortality of BMSB (Gouli et al. 2012).

Recommended Insecticides

Evaluation of insecticide effectiveness has shown that BMSB can be more difficult to kill than other stink bug species. In laboratory and field studies, the following active ingredients were found to cause high mortality of BMSB: methomyl (1A), acephate (1B), chlorpyrifos (1B), dimethoate (1B), malathion (1B), methidathion (1B), endosulfan (2A), bifenthrin (3A), fenpropathrin (3A), and permethrin (3A) (Leskey et al. 2012b). For treatment of building exteriors and non-edible ornamentals, a number of synthetic pyrethroid insecticide active ingredients are registered, such as bifenthrin (Brigade), cyfluthrin (Tombstone), and deltamethrin (Delta Gold). For vegetable and fruit crops, acetamiprid (Assail, Ortho*), dinotefuran (Green Light*, Scorpion), lambda-cyhalothrin (Lambdastar, Warrior), and zeta-cypermethrin (Mustang) are available (New Jersey Agricultural Experiment Station 2011). On a small scale or for those using organic management, insecticidal soap* may be effective on young nymphs or to temporarily knockdown adults congregating on outdoor surfaces.

**Homeowner formulations available.*

Table 4.1. Insecticides recommended for control of BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT production in Utah.

Table 4.2. Insecticides recommended for control of BROWN MARMORATED STINK BUG ON BUILDINGS INDOOR/OUTDOOR COMMERCIAL USE in Utah.

Table 4.3. Insecticides recommended for control of BROWN MARMORATED STINK BUG IN HOME FRUIT production use in Utah.

Table 4.4. Insecticides recommended for control of BROWN MARMORATED STINK BUG ON BUILIDNGS INDOOR/OUTDOOR HOME use in Utah.

Sources of Monitoring Supplies

AgBio
Westminster, CO
303-469-9221
agbio-inc.com

Scentry
Billings, MT
800-735-5323
scentry.com

Great Lakes IPM
Vestaburg, MI
800-235-0285
greatlakesipm.com

Gemplers
Mt. Horeb, WI
800-382-8473
gemplers.com

Trésé
Salinas, CA
408-758-0205
trece.com

Alpha Scents
West Linn, OR
503-342-8611
alphascents.com

For Additional Information, Search the Internet for:

Stop BMSB Video Series, StopBMSB.org

Indoor Traps for BMSB, Nik Wiman, Oregon State University

Stink Bugs Beware! Homemade stink bug traps squash store-bought models, Virginia Tech researchers find

Stop BMSB: Biology, Ecology, and Management of Brown Marmorated Stink Bug in Specialty Crops

Indoor Traps for BMSB, Oregon State University

Insect Advice from Extension: Brown Marmorated Stink Bug, Penn State Extension

How to Control the Brown Marmorated Stink Bug, Rutgers Extension

A New Vegetable Crop Pest: The Brown Marmorated Stink Bug, Ohio State University

Stink Bugs Studied at Shephard University, Herald-Mail Media

Native Natural Enemies of BMSB, Stop BMSB

Natural Born Stink Bug Killer Found in Washington State, Entomology Today

Asian Wasp, Enemy of Stink Bugs, Found in the United States, Stop BMSB

Natural Enemies of the Brown Marmorated Stink Bug, K. Hoelmer & K. Tatman, USDA ARS

Utah Pests Fact Sheet: Brown Marmorated Stink Bug

Stop BMSB

New Species of Hymenoptera: Scelionidae, Parasitizing Eggs of Brown Marmorated Stink Bug

Penn State Extension, Dinotefuran Emergency Exemption for BMSB Control

Penn State Extension, Management Options for BMSB in PA Fruit Orchards, 2012 Perspective

Cornell University Jentsch Lab, BMSB Update: Bifenthrin Use recommendations

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Pest Management Tables for Commercial and Home Use

Table 4.1. Insecticides recommended for control of **BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Carbamates (1A)					
methomyl	Lannate LV[R], Lannate SP[R], Nudrin LV[R], Nudrin SP[R]	Begin application when insect populations reach economic threshold levels.	4-14 d	7 d	Toxic to fish, aquatic invertebrates, birds, mammals, bees, and beneficial insects, mites, and spiders. **Lannate SP:** high adult and nymphal mortality **Lannate LV:** high adult and nymphal mortality
Organophosphates (1B)					
azinphosmethyl	Guthion[R]	Base timing and frequency of applications upon economic thresholds.	14-21 d	7 d	Toxic to fish, aquatic invertebrates, birds, mammals, and bees.
chlorpyrifos	Lorsban 75 WG, Lorsban Advanced[R]		14 d (Lorsban Advanced For grape only: 35 d)	10 d (Lorsban Advanced For grape only: max. 1 appl per season)	
Pyrethroids, Pyrethrins (3A)					
beta-cyfluthrin	Baythroid[R]	Contact activity and short residuals. Begin applications when adults are first detected, and before populations enter a phase of rapid increase.	7 d	14 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees; odor may be a problem in public places. **Baythroid:** low to high mortality **Bifenture 2EC & 10DF:** high adult and nymphal mortality **Asana:** low mortality **Danitol:** high adult and nymphal mortality **Lambda-cy:** moderate adult mortality **Warrior II:** moderate adult and high nymphal mortality
bifenthrin	Athena[R], Bifenture EC[R], Bifenture LFC[R], Brigade 2EC[R], Brigade WSB[R], Discipline 2EC[R], Fanfare 2EC[R], Fanfare ES[R], Sniper[R], Tailgunner[R], Tundra EC[R]		14 d (Brigade & Fanfare: strawberry: 0 d)	30 d (Brigade & Fanfare: strawberry: 7-14 d)	
cyfluthrin	Renounce 20WP[R], Tombstone[R], Tombstone Helios[R]		7 d	14 d	
deltamethrin	Delta Gold[R]		21 d	7 d	
esfenvalerate	Asana XL[R], S-Fenvalostar[R], Zyrate[R]		14-21 d	7-14 d	
fenpropathrin	Danitol 2.4 EC Spray[R]		3-14 d grape: 21 d caneberry: 3 d strawberry: 2 d	10 d grape: 7 d caneberry: 14 d strawberry: 30 d	
gamma-cyhalothrin	Declare[R], Proaxis[R]		14-21 d	5 d	

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Table 4.1, continued. Insecticides recommended for control of **BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Pyrethroids, Pyrethrins (3A), continued					
lambda-cyhalothrin	Grizzly Too[R], Grizzly Z[R], Kendo[R], Lambda T[R], Lambda-cy[R], Lambda-Cy EC[R], Lambdastar[R], Lambdastar 1CS[R], Lambdastar Plus[R], Lamcap[R], Nufarm Lambda-Cyhalothrin 1 EC[R], Paradigm[R], Province[R], Silencer[R], Warrior II with Zeon[R], Warrior with Zeon[R], Willowood Lambda-Cy 1EC[R]	Contact activity and short residuals. Begin applications when adults are first detected, and before populations enter a phase of rapid increase.	14-40 d	5-10 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees; odor may be a problem in public places. **Baythroid:** low to high mortality **Bifenture 2EC & 10DF:** high adult and nymphal mortality **Asana:** low mortality **Danitol:** high adult and nymphal mortality **Lambda-cy:** moderate adult mortality **Warrior II:** moderate adult and high nymphal mortality
pyrethrins	Pyganic EC 1.4 II[O], Pyganic EC 5.0 II[O], Tersus		0 d	3 d	
zeta-cypermethrin	Mustang Maxx[R], Mustang[R]		14 d	7 d	
Pyrethroids (3A); Neonicoinoids (4A)					
bifenthrin; imidacloprid	Brigadier[R], Skyraider[R], Swagger[R], Tempest[R]	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	14 d	30 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees; odor may be a problem in public places. **Brigadier:** high mortality **Leverage 360:** high adult and nypmhal mortality **Lambda-cy + Assail 30SG:** high mortality **Endigo ZC:** moderate to high mortality **Perm-up 3.2EC + Assail 30SG:** high mortality
imidacloprid; cyfluthrin	Leverage 2.7[R], Leverage 360[R]		7 d	14 d	
imidacloprid; lambda-cyhalothrin	Kilter[R]		14-21 d	7-10 d	
lambda-cyhalothrin; acetamiprid	Lambda-cy[R] + Assail 30SG		14-40 d	5-14 d	
lambda-cyhalothrin; thiamethoxam	Endigo ZC[R]		14-35 d	7-10 d	
permethrin; acetamiprid	Perm-up 3.2EC[R] + Assail 30SG		7 d	10-14 d	
Neonicitinoids (4A)					
acetamiprid	Assail 30SG, Assail 70WP	Apply before insect populations reach damaging threshold.	7 d	10-14 d	Toxic to fish, aquatic invertebrates, and bees. **Assail 30SG:** moderate adult and nymphal mortality **Assail 70WP:** moderate to high adult and nymphal mortality

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Table 4.1, continued. Insecticides recommended for control of **BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Neonicitinoids (4A), continued					
clothianidin	Belay	Apply before insect populations reach damaging threshold.	7-21 d	10-14 d	Toxic to fish, aquatic invertebrates, and bees. **clothianidin & imidacloprid:** Restricted to post-bloom applications only; petals must have dropped. **Scorpion 3.24:** high adult and nymphal mortality **Provado:** low mortality **Admire Pro:** high adult and nymphal mortality **Malice:** for suppresion only **Calypso:** moderate adult mortality **Actara:** high adult and nymphal mortality
dinotefuran	Scorpion 3.24, Scorpion 35SL		For grape only: 1 d	For grape only: 7 d	
imidacloprid	Admire Pro, Advise 2FL, Advise Four, Amtide Imidacloprid 2F, Amtide Imidacloprid 4F, Couraze 2F, Couraze 4, Couraze 4F, Macho 2.0 FL, Malice 75 WSP, Mana Alias 4F, Montana 2F, Montana 4F, Nuprid 1.6 F, Nuprid 2SC, Nuprid 4F Max, Pasada 1.6F, Prey 1.6, Provado 1.6F, Sherpa, Wrangler		0-21 d	7-10 d	
thiacloprid	Calypso		30 d	7 d	
thiamethoxam	Actara		14 d caneberry: 3 d	7 d caneberry: 7 d	
Avermectins, Milbemycins (6); Pyrethroids, Pyrethrins (3A)					
abamectin; bifenthrin	Athena[R]	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	28 d strawberry: 3 d	30 d strawberry: 7-21 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, wildlife, and bees.
avermectin B1; zeta-cypermethrin	Gladiator[R]		21-28 d	21 d	
Benzoylureas (15)					
novaluron	Rimon 0.83EC	Apply when adults are first detected. For adult control, tank mix with an adulticide.	8-14 d	7-10 d	Toxic to freshwater and estuarine/marine invertebrates.
METI Acaricides and Insecticides (21A)					
tolfenpyrad; tolfenpyrad	Bexar	Apply when pest populations are beginning to build.	14 d	10 d	Supression only. Toxic to fish, aquatic invertebrates, and bees.

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[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 4.1, continued. Insecticides recommended for control of **BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Diamides (28)					
flubendiamide	Belt SC	Treatment shoud be made when insect populations begin to build and before a damaging population becomes established.	7-14 d	7 d	Toxic to aquatic invertebrates, oysters, and bees. **Belt SC:** low mortality
Diamides (28); Pyrethroids, Pyrethrins (3A)					
chlorantraniliprole; lambda-cyhalothrin	Voliam Xpress[R]	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	14-21 d	7-10 d	Toxic to fish, aquatic organisms, aquatic invertebrates, oysters, shrimp, wildlife, and bees. **Voliam Xpress:** low adult mortality
Diamides (28); Neonicotinoids (4A)					
chlorantraniliprole; thiamethoxam	Voliam Flexi	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels. Apply higher rates within the listed rate range for heavy infestations.	7-14 d	7 d	Toxic to wildlife, aquatic invertebrates, oysters, shrimp, and bees. High adult mortality.
Unknown (UN); Pyrethroids, Pyrethrins (3A)					
azadirachtin; pyrethrins	Azera[O]	Spraying should begin when listed insects first appear. Do not wait until plants are heavily infested.	0 d	3 d	Toxic to fish, aquatic invertebrates, and bees.
Unknown (UN)					
azadirachtin	Aza-Direct[O], Molt-X	Spray as soon as possible when pests are expected or when pests first appear.	0 d	7-10 d	Toxic to fish and aquatic invertebrates. **Molt-x:** Spray nymphs early

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[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 4.1, continued. Insecticides recommended for control of **BROWN MARMORATED STINK BUG IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Other; Pyrethrins, Pyrethroids (3A)					
piperonyl butoxide; pyrethrins	Evergreen EC 60-6	Apply before pests reach damaging levels.	NL	3-7 d	Toxic to aquatic organisms, fish, aquatic invertebrates, and bees.
Other; Neonicitinoids (4A)					
kaolin clay + thiamethoxam	Surround WP[O] + Actara	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	14 d	7 d	Toxic to aquatic invertebrates, bees and other insect pollinators. Thorough coverage is important to obtain optimum control; white coating on the fruit may require removal after harvest to make fruit marketable.
Other					
Beauveria bassiana Strain GHA	Botanigard ES, Mycotrol O[O]	Begin treatment of crops at the first appearance of the insect pest. Typically, it takes 7-10 days after the first spray to see control.	0 d	NL	May be toxic to fish, aquatic organisms, and potentially pathogenic to honey bees.
Burkholderia spp. Strain A396	Venerate XC[O]	Proper timing of application targeting newly hatched larvae, nymphs or immature pests is important for optimal results.	0 d	3-10 d	May be toxic to fish, aquatic organisms, and potentially pathogenic to honey bees.
kaolin clay	Surround WP[O]	Start before infestation and continue at 7-14 day intervals.	0 d	7-14 d	Thorough coverage is important to obtain optimum control; white coating on the fruit may require removal after harvest to make fruit marketable. **Surround WP:** Do not widen respray interval past 14 days, for suppresion only

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

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Brown Marmorated Stink Bug

4.2. Insecticides recommended for control of BROWN MARMORATED STINK BUG ON BUILDINGS INDOOR/OUTDOOR COMMERCIAL USE in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]				
Organophosphates (1B)				
chlorpyrifos	Vulcan[R]	Apply where congregations of stink bugs are observed. To help prevent infestation of non-residential buildings, treat a band of soil 6 to 10 feet wide around and adjacent to buildings where pests are active and may find entrance.	NL	Outdoor use only. Toxic to fish, aquatic invertebrates, birds, mammals, and bees.
Pyrethroids, Pyrethrins (3A)				
bifenthrin	Bisect L, Menace 7.9% Flowable	Apply where congregations of stink bugs are observed. Apply to band of soil and vegetation 6 to 10 feet wide around and adjacent to the structure.	NL	Toxic to fish, aquatic invertebrates, and bees. **Bisect:** indoor and outdoor use **Menace:** outdoor use only **Declare & Proaxis:** outdoor use only **Tombstone:** outdoor use only
Unknown (UN)				
azadirachtin	Aza-Direct[O]	Spray as soon as possible when pests are expected or when pests first appear.	7-10 d	Outdoor use only. Toxic to fish and aquatic invertebrates.

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Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[PI]Protection Interval= Interval required between applications (in days).

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[R]Restricted use products= require an applicators license to purchase.

4.3. Insecticides recommended for control of BROWN MARMORATED STINK BUG IN HOME FRUIT production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Pyrethroids, Pyrethrins (3A)					
bifenthrin	Ortho Bug B Gon Concentrate, Ortho Bug B Gon Ready-to-Spray	Begin applications when adults are first detected, and before populations enter a phase of rapid increase.	14 d	7 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees.
gamma-cyhalothrin	Spectracide Triazicide Insect Killer for Lawns & Landscapes		14-21 d	NL	
pyrethrins	Bug Buster-O[O], Bon-Neem II, Worry Free Ready to Spray, Monterey Fruit Tree Spray Plus[O]		0-1 d	7 d	
Neonicitinoids (4A)					
acetamiprid	Ortho Flower, Fruit & Vegetable Insect Killer, Ortho Tree & Shrub Fruit Tree Spray	Apply as soon as insect problems are noticed.	7 d	10-14 d	Toxic to wildlife, fish, aquatic invertebrates, and bees.
Other					
kaolin clay	Surround WP[O]	Suppresion only. Start before infestation and continue at 7-14 day intervals.	0 d	7-14 d	Thorough coverage is important to obtain optimum control; white coating on the fruit may require removal after harvest to make fruit marketable. **Surround WP:** Do not widen respray interval past 14 days

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

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[PI]Protection Interval= Interval required between applications (in days).

4.4. Insecticides recommended for control of BROWN MARMORATED STINK BUG ON BUILDINGS INDOOR/OUTDOOR HOME use in Utah

Common Name	Example Brands	Timing of Application	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]				
Pyrethroids, Pyrethrins (3A)				
bifentrhin	Ortho Bug B Gon Insect Killer For Lawns & Gardens, Ortho Home Defense MAX Insect Killer For Indoor & Perimeter	Begin applications when adults are first detected, and before populations enter a phase of rapid increase.	7 d	Toxic to fish, aquatic invertebrates, and bees. **Bug B Gon, Bayer Vegetable & Garden:** outdoor use only **Ortho Ant & Roach:** indoor use **Ortho Home defense max, Spectracide Home Barrier, Spectracide Flying & Crawling Insecte Killer, Spectracide Stink Bug Killer, Monterey Stink Bug Spray, Monterey Houseplant:** outdoor and indoor use
gamma-cyhalothrin	Spectracide Bug Stop Home Barrier, Spectracide Bug Stop Flying & Crawling Insect Killer		NL	
cyfluthrin	Bayer Vegetable & Garden Insect Spray		7 d	
cypermethrin	Ortho Ant & Roach Killer I		NL	
deltamethrin	Spectracide Stink Bug Killer		NL	
permethrin	Monterey Stink Bug Spray, Monterey Houseplant Insect Spray		NL	
Neonicitinoids (4A)				
imidacloprid	Ortho Dual-Action Bed Bug Killer	Spray as spot or crack & crevice application where insects are harboring, moving, or breeding. Treat feeding or hiding areas such as baseboards, carpet, floor, rugs, under refrigerators, cabinets, sinks, and stoves. Also treat interior entry points such as doors, around windows, and water pipes.	NL	Indoor use only.

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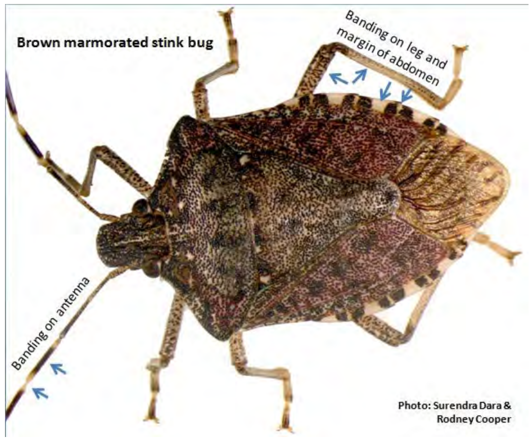
NL= No time listed

[PI]Protection Interval= Interval required between applications (in days).



Surendra Dara, UCCE and Rodney Cooper, USDA-ARS

Fig. 4.1. Adult brown marmorated stink bug (BMSB); note the two white bands on antennae, single white band on hind legs and white banding pattern on margin of abdomen (back side).

Common Brown Stink Bug

Fig. 4.2. The adult of the common brown stink bug is less mottled and more yellowish in color than the BMSB, and does not have distinct white bands on its anttennae.

Fig. 4.4. The underside of the adult common brown stink bug is yellow-green in color.

Brown Marmorated Stink Bug

Fig. 4.3. Adult BMSB has smooth "shoulders", two distinct white bands on its antennae, and white banding on back legs and margin of abdomen.

Fig. 4.5. The underside of the BMSB looks brown/gray in color.

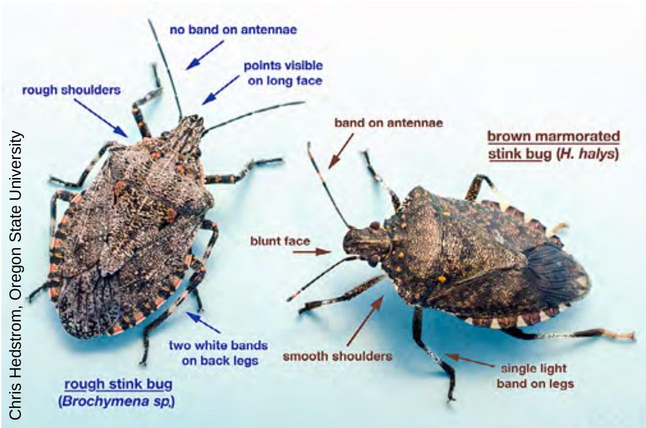


Fig. 4.6. The rough stink bug does not have bands on its antennae, has two white bands on its back legs, has rough shoulders, and a long pointed face.

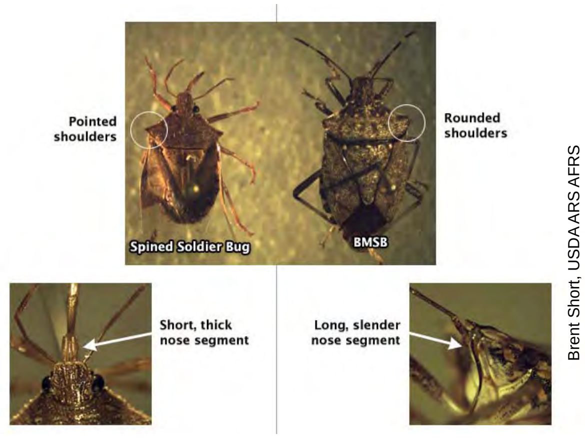


Fig. 4.7. The spined soldier bug has pointed shoulders and a short, thick nose segment.

Fig. 4.8. BMSB eggs on the underside of a leaf develop black triangles upon maturing.

Fig. 4.9. First instar nymphs of BMSB; note their orange to red color.

Fig. 4.10. BMSB eggs and newly hatched nymphs; note open lids of eggs where nymphs have emerged.

Fig. 4.11. Fourth instar nymph of BMSB; note colors becoming more like those of an adult.

Fig. 4.12. BMSB massing on the shutter of a house seeking winter shelter.

Fig. 4.13. BMSB damage to a ripe tomato.

Fig. 4.14. Late-season injury from BMSB to an ear of corn.

Fig. 4.15. BMSB using piercing-sucking mouth parts to feed on an apple.

Fig. 4.16. BMSB Feeding damage or "cat-facing" (corking and tissue necrosis) on an apple.

Fig. 4.17. Fruit skin discoloration caused by BMSB.

Fig. 4.18. BMSB feeding on ripe peaches.

Fig. 4.19. Necrotic spots on an apple, and necrosis of surrounding leaves from BMSB damage.

Fig. 4.20. Apples stored at cold temperatures can show BMSB damage that was not visible at harvest.

Fig. 4.21. A pyramid trap with a capture container at the top for collecting BMSB.

Fig. 4.22. Black light trap for catching and monitoring BMSB.

Fig. 4.23. Beating tray used to monitor for BMSB adults in the spring.

Fig. 4.24. A simple attract-and-kill solution for BMSB indoors: a pan with soapy water and a light to shine on it.

Fig. 4.25. BMSB caught over a 12 hour period in a pan like the one shown at left.

Fig. 4.26. The European praying mantis (predator) eating a BMSB adult.

Fig. 4.27. A bluebird with a BMSB adult in its mouth taking its prey back to the nest.

Fig. 4.28. *Trissolcus japonicas*, a natural enemy and parasitoid wasp of BMSB eggs.

Fig. 4.29. *Trissolcus japonicas* parasitoid adult emerging from a BMSB egg after killing it.

Fig. 4.30. A female *Trissolcus halymorphae*, parasitoid wasp of BMSB eggs.

Fig. 4.31. *Trissolcus halymorphae* (egg parasitoid), ovipositing into BMSB eggs.

Fig. 4.32. *Telenomus podisi*, a parasitoid wasp of BMSB eggs.

Fig. 4.33. *Anastatus reduvii*, a parasitoid wasp of BMSB eggs.

Fig. 4.34. *Euclytia flava*, a tachinid fly that parasitizes adults of BMSB.

Fig. 4.35. An adult BMSB infected with the fungal pathogen *Metarhizium robertsii*.

CHAPTER 5 PLUM CURCULIO

Quick Facts

- Plum curculio (PC) is a small brown weevil (beetle with a snout) that infests pome and stone tree fruits, including cultivated, ornamental and wild species.
- PC is native to eastern North America; it was first detected west of the Rocky Mountains in Box Elder County, UT in the early 1980s where it remains the only western population.
- Adult PC damage fruit by chewing feeding holes and crescent-shaped egg-laying scars, and larvae tunnel in the fruit flesh.
- Effective PC management can be accomplished with proper monitoring techniques, good sanitation practices, and insecticide applications that target adult egg-laying timed at approx. petal fall.

Background

Plum curculio (PC), *Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae) is a small brown weevil native to eastern North America where it is a major pest of pome and stone fruits. It thrives in environments where orchards are grown next to hardwood forests. It evolved feeding on wild fruits, but readily adapted to cultivated orchard and ornamental tree fruits planted by humans. Native hosts of plum curculio include wild plum, crab apple, cherry, and related fruits.

PC was detected in Box Elder County, Utah in the early 1980s, and is the only known infestation in western North America. In Utah, it can be found in commercial and home garden fruit trees; however, concerted monitoring and management efforts have reduced its populations. In western North America (U.S. and Canada), PC is a quarantine pest with restrictions on export of fruit grown in infested counties. Thus, it is a threat to Utah's fruit industry and requires ongoing monitoring and management to keep Utah's export fruit markets open.

Identification and Life History

ADULT: REPRODUCTIVE, DISPERSAL, DAMAGING, AND OVERWINTERING STAGE

- About ¼ in (4-6 mm) long snout beetle, or weevil.
- Chewing mouthparts are at the end of a slightly curved snout.
- A brownish-black body with light gray and brown markings, and four dark humps along a rough back *(Fig. 5.1-6.3)*.
- Adults are nocturnal in their activity; females seek out host fruit on which to feed and lay eggs.

EGG

- Small white and oval in shape; about 0.01 by 0.2 in (0.35 by 0.6 mm) in size *(Fig. 5.3)*.
- Inserted into crescent-shaped holes chewed into host fruit by the female.

LARVA: DAMAGING STAGE

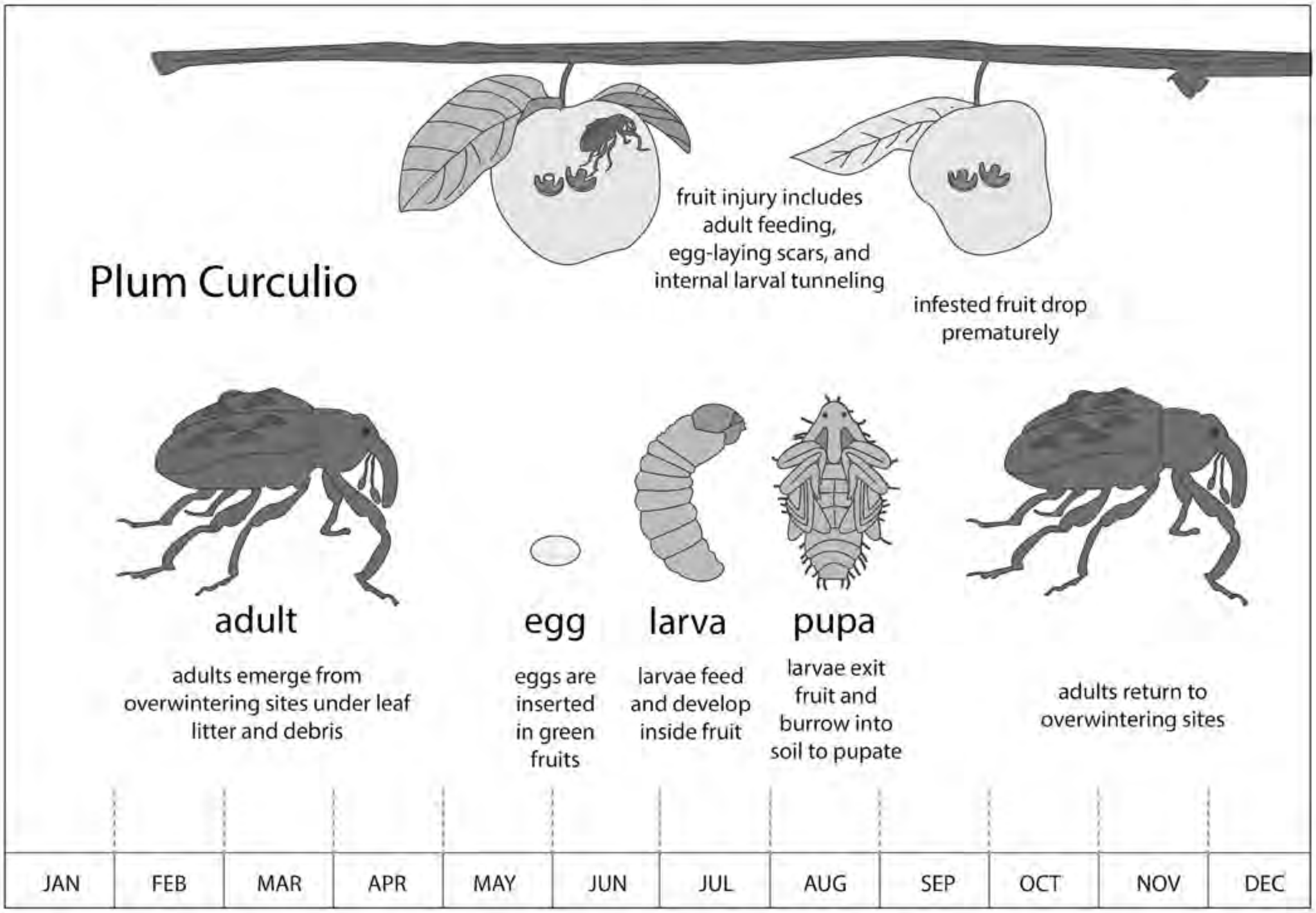
- Legless white to grayish-white grub with curved body, and a small brown head *(Fig. 5.4)*.
- The newly hatched larva is about 0.03 in (1 mm) long; when full grown it reaches 0.2-0.35 in (6-9 mm) in length.
- The larva tunnels into the flesh of host fruits.

PUPA

- White in color, about 0.2-0.3 in (4.5-7 mm) long *(Fig. 5.5)*.
- Pupate in the soil at 1-3 in (2.5-7.6 cm) deep.

PC overwinters as an adult in protected areas, preferentially by burrowing under leaf litter in wooded areas, ditch banks, fence rows, and compost piles in and near host orchards. In spring, adults become active when mean ambient temperatures exceed 50°F (10°C) for at least three days, and begin moving into orchards when maximum temperatures exceed 70°F (21°C).

PC adults primarily move by walking when temperatures are below 70°F (21°C), but may fly into host trees at warmer temperatures. In the early season, PC feed on fruit tree buds, foliage and young fruits. Plum curculio



Life history of plum curculio in Utah. The majority of its active life is spent feeding on fruit as an adult or larva. Adults overwinter in protected sites in and near orchards. There is one generation per year in Utah.

feeding looks similar to injuries caused by "cat-facing" insects or cold damage.

Beginning about petal fall in apple (when petals readily dislodge) and shuck-split in peach (when the developing fruit splits open the flower shuck), female PC lay eggs in young fruits by chewing a crescent-shaped slit, and inserting an egg under the 'flap of skin'. A degree-day models provides additional information for timing of first egg-laying (see Monitoring section below). Egg-laying activity peaks on warm and humid evenings. Eggs will hatch in 2-12 days (5 days on average), depending on temperatures. The hatched larva then chews into the fruit flesh, requiring 8-22 days to complete its development.

Once full-grown, the larva exits the fruit to enter the soil where it constructs a small cavity 1-3 in (2.5-7.6 cm) deep in which it forms a pupa. The pupa will complete its development in 12-16 days. The spring-to-summer generation requires 5-8 weeks depending on environmental conditions. In Utah, PC completes only one generation per year. Adults that emerge from pupae during the summer will feed on host fruits causing later season damage, and then move to overwintering sites as the days shorten.

Plant Hosts and Injury Symptoms

High PC populations can cause severe early-season fruit damage to commercial pome and stone tree fruits. Wild and ornamental fruits growing near orchards help sustain PC populations *(Fig. 5.6)*.

Adults chew small, round holes into fruits *(Figs. 5.7-5.9)*. Early-season feeding from overwintered adults may cause fruit to be deformed at harvest *(Fig. 5.10)*. In addition to fruit, PC will feed on host fruit tree leaves, buds, flowers, and stems *(Fig. 5.11)*. Feeding and egg-laying damage on peach fruits may appear as shiny areas of disturbed fuzz *(Fig 5.12)*.

Egg-laying scars have a characteristic crescent shape cut by the adult female to protect the egg from being crushed as the fruit expands in size *(Figs. 5.13-5.14)*. The female uses chewing mouthparts to form a small cavity, then places her posterior end into the depression and deposits an egg. The female then cuts a crescent shaped slit beneath the egg, leaving a flap of skin and flesh to cover the egg. The slits are about ¼ in (4-6 mm) long, and will darken to form a scar on the fruit surface.

A larva will hatch from the egg and tunnel within the fruit flesh making it unfit for consumption. Stone fruits with PC larvae inside may rot during ripening *(Figs. 5.15-5.17)*. Damaged fruits often abscise and drop to the ground prematurely. PC larvae will rarely be found in pome fruit at harvest, as they have already exited to enter the soil for pupation.

Plant Hosts of PC	
Pome & Stone Fruits	**Ornamental & Wild Fruits**
• apple • pear • peach • nectarine • plum • apricot • sweet cherry • tart cherry • quince	• Saskatoon or western serviceberry • wild plum • hawthorn • crabapple • sand cherry • black cherry • common deerberry • currant • gooseberry • laurel cherry • mayhaw

Infested fruits that remain on the tree are usually deformed; however, larvae in these fruits have usually died before completion of development. PC damage to fruits may allow for the invasion of fungal pathogens, such as brown rot, increasing the severity of crop loss.

After completing development within the fruit, PC larvae chew a hole and exit the fruit. Frass (PC excrement) or webbing may be evident on stone fruits, but is usually absent on pome fruits.

Plant Injury Symptoms of PC
• round feeding holes from adults • deformed fruit at harvest from surface feeding of overwintered beetles • tan, discolored, or scarred crescent shapes on fruit skin from egg-laying injury • internal fruit injury from burrowing larvae • premature fruit drop • introduction of fruit-rotting pathogens • PC frass or webbing in stone fruits

Monitoring

Begin monitoring for PC in the spring during bloom of host fruit trees. PC begin moving into orchards from external overwintering sites during orchard bloom. Crucial monitoring periods occur when ambient temperatures reach or exceed 70⁰F (21-22⁰C) at shuck-split in stone fruits and petal-fall in pome fruits. In orchards with a history of PC injury, monitor 2-3 times per week during critical periods.

Visual

Use a beating tray (see Brown Marmorated Stink Bug Monitoring section for a description) or small tarp beneath a tree branch, and beat or shake the branch vigorously *(Fig. 4.18)*. The beating or shaking action will dislodge PC adults onto the sampling surface so that they can be observed and counted. Early morning when temperatures are cool and adults are less active (less likely to fly away) is the best time of day for beating and shaking samples.

Another visual method is to check fruit for characteristic adult feeding holes and crescent-shaped scars caused by PC oviposition (egg-laying). Inspect 100 fruit per block along the orchard edges. PC adults tend to congregate near edges, especially in the spring as they disperse into orchards from external overwintering sites. Early detection of fruit injury is critical to implement timely control measures. Thus, monitor in representative locations throughout orchards to detect adults or injury before economic crop loss occurs.

Traps

Beginning at early bloom, place pyramid traps baited with benzaldehyde lures *(Fig. 5.19)* in the outer rows of orchard trees adjacent to woodlots or fence lines (Whalon et al. 2007). Initially, check traps weekly, and when adult captures become frequent or by petal fall, check traps at least two times per week. Adjust visual sampling for fruit injury as dictated by PC adult captures in beating tray samples and/or traps. A trap threshold of 0.1 adults per trap per day or 1%, fruit injury in visual inspections suggests that an insecticide application is recommended.

Timing of Plum Curculio Activity

See accompanying table for general timing guidelines for plum curculio activity. Additionally, degree-day (DD) can be used to determine when egg-laying will end. Begin accumulating degree days at petal fall of the earliest blooming varieties (when 75% of petals have fallen from the north side of the tree). Use a DD baseline of 50°F. When 308 DD have accumulated after petal fall, plum curculio activity is no longer a threat. This is when adults will have finished moving into orchards for the season and egg-laying has subsided. Refer to https://climate.usurf.usu.edu/traps/ to calculate DDs for fruit-growing locations in Utah.

Timing of Plum Curculio Activity in Orchards*		
Stage	**Timing**	**Where to Look**
Adults	Spring when temperatures exceed 60°F (5.5°C)	In orchards next to woodlots and hedgerows. Adult feeding injury is typically the first sign of adult presence.
	Late July to early fall when temperatures drop below 60°F (5.5°C)	Adults move out of orchards for winter hibernation (diapause).
Eggs	Beginning at approx. petal fall and continuing for approx. 30 days, or 308 DD after petal fall	Eggs are laid in young fruits within crescent shaped oviposition wounds.
Larvae	Early June through mid-July	Within injured fruit attached and dropped from the tree.
Pupae	Mid-July through mid-August	In soil within approx. 2 in (25 mm) of surface.

*Adapted from Lienk 1980, and Breth and Shaw 2014.

Management

The most common management tactic for PC, when present, is the application of one to three insecticide treatments per season (the number required depends on population severity and application timing). Insecticide programs that are already in place for pests such as codling moth and San Jose scale may provide control of plum curculio. Despite a heavy reliance on insecticides for PC control, supplementation with non-chemical tactics will improve PC suppression and may reduce the number of insecticide sprays needed.

Cultural Control

Good sanitation practices will help reduce PC populations in a local area. Host trees, including cultivated, wild, and ornamental hosts, contribute to PC population size. Remove alternate host trees and shrubs near commercial orchards.

Remove or destroy fallen fruit during the summer in an infested orchard. Fruit on the ground can be chopped with a flail mower, or collected and fed to animals or disposed in the trash.

Mechanical & Physical Control

Shake or beat tree limbs and trunks with a padded stick or mechanical shaker to dislodge PC adults onto tarps where they can be collected and destroyed (see Visual Monitoring section above). Mechanical control is labor intensive, and best suited to small-scale and organic orchards.

Biological Control

Entomopathogenic nematodes (EPNs) have been shown to suppress ground-dwelling stages of plum curculio. In a study done by Shapiro-Ilan et al. (2013), lures were used to attract adult PC to selected sentinel trees in the perimeter of apple orchards in Massachusetts and West Virginia. Only the sentinel trees were sprayed with insecticides to control adults. After these trees dropped their fruit, EPNs were applied to the soil. The insecticidal sprays applied to the sentinel trees killed adult PC, protecting the interior of the orchard, while the EPNs suppressed ground dwelling stages of PC, preventing subsequent generations from developing and reproducing. This method provided an economically feasible control method by decreasing the amount of pesticides used, while maintaining control of PC. In this study, *Steinernema riobrave* (EPN) exhibited high levels of efficacy in suppressing PC populations while *S. feltiae* (EPN) caused mortality in PC, but at a lower rate than *S. riobrave*.

Studies in Utah found a native population of *Heterorhabditis bacteriophora* (EPN) in PC-infested soils of Brigham City, UT (Kim and Alston 2008). Although the nematodes attacked PC larvae and pupae, and reduced PC populations readily in the laboratory, satisfactory field control was not achieved by relying on nematodes alone. Entomopathogenic nematodes are a good fit in an integrated pest management (IPM) program that combines multiple tactics to lower pest populations, as shown by the study mentioned above.

Chemical Control

Chemical control of plum curculio may be necessary depending on the severity of damage in previous years. Insecticides to control PC are typically applied at petal fall, and repeated at 7-10 days. A third application, 7-10 days after the second application, may be needed depending on previous timing and severity of PC. In some years and locations, the timing for plum curculio control may coincide with that of codling moth and/or San Jose scale.

When using the degree-day model described above, if 308 DD (base 50°F) post-petal fall is reached before spray residues have diminished, additional sprays are not needed. If 308 DD has not been reached within 10-

14 days after a spray was applied at petal fall, repeat the spray to keep fruit protected. Adults will be active in orchards through 308 DD post-petal fall, and spray residues older than 10-14 days will be ineffective.

Conventional insecticides such as organophosphates (1B; chlorpyrifos, malathion, and phosmet) and pyrethroids (3A; cyfluthrin, bifenthrin, permethrin, and others) are lethal contact poisons to PC adults in the tree canopy. Avaunt (indoxacarb, 22A) must be ingested by PC for optimum activity. Neonicotinoids (4A; acetamiprid, clothianidin, imidacloprid, and thiamethoxam) are taken up systemically by the tree, and kill PC eggs and larvae within the fruit. Imidacloprid and clothianidin have been implicated in causing harm to bees and other pollinators that feed on nectar and pollen from flowers on treated plants; therefore, applications of these products should be restricted to post-bloom only and when bees are not active in orchards, including on ground cover and weeds. Some organophosphates and neonicotinoids can be used as rescue treatments due to their curative action that kills PC eggs and larvae that are already in the fruit.

Use caution when applying the insecticide carbaryl (e.g., Sevin), including mixtures with carbaryl as this chemical has fruit-thinning action and can cause heavy fruit-drop if used within 30 days of bloom.

Kaolin clay (Surround WP) is an insecticide option amenable to organic production. It works through a physical mode of action, repelling adults from feeding and egg-laying on fruits. Kaolin clay is applied as a white-colored powder to the fruit and foliage. Good coverage must be maintained for effective PC control.

Esteem (pyriproxyfen, 7C), an insect growth regulator, and Delegate (spinetoram, 5), a bacterial insecticide, are labeled as PC suppressants only; however, they can contribute to an overall IPM program when combined with other insecticides and/or non-chemical management tactics. Esteem applied within two weeks after harvest in sweet cherry (a suitable timing for San Jose scale management) can reduce fecundity (reproductive capacity) of overwintering female PC.

Recommended insecticides

Table 5.1. Insecticides recommended for control of PLUM CURCULIO LARVAE IN COMMERCIAL FRUIT production in Utah.

Table 5.2. Insecticides recommended for control of PLUM CURCULIO IN HOME FRUIT production in Utah.

For Additional Information, Search the Internet for:

How to Monitor for Fruit Pests: Using a Beating Tray, Utah State University Extension, (Video)

Apple Pest Management, Plum Curculio, University of Minnesota Extension

Stone Fruit Pest Management, Plum Curculio, University of Minnesota Extension

Tree Fruit IPM Advisory, Plum Curculio, Utah State University Extension

Invasive Insect Field Guide for Utah, Utah State University Extension

Plum Curculio Management in Stone and Pome Fruits, Michigan State Extension

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Pest Management Tables for Commercial and Home Use

Table 5.1. Insecticides recommended for control of **PLUM CURCULIO IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Carbamates (1A)					
carbaryl	Carbaryl 4L, Sevin 4F, Sevin SL Carbaryl, Sevin XL[R] Plus	Begin application when insect populations reach recognized economic threshold levels.	3 d	7-14 d	Toxic to aquatic invertebrates, and bees. On apples avoid use during the period from full bloom until 30 days after full bloom unless fruit thinning is desired.
Organophosphates (1B)					
chlorpyrifos	Lorsban 75 WG	Consult with your state agricultural experiment station, certified pest control advisor or extension specialist for specific application timings in your area.	14 d	NL	Toxic to fish, aquatic invertebrates, and bees. Do not apply phosmet to sweet cherries; causes burning of foliage.
malathion	Cheminova Malathion 57%, Fyfanon, Helena, Malathion 57 EC, Malathion 8 Aquamul		1-7 d	7-11 d	
phosmet	Imidan 70-W		7-14 d	NL	
Pyrethroids, Pyrethrins (3A)					
beta-cyfluthrin	Baythroid XL[R]	Apply when insects appear.	7 d	14 d	Toxic to fish, aquatic invertebrates, and bees. Do not apply after petal fall in apples.
bifenthrin	Bifenture EC[R], Brigade 2EC[R], Brigade WSBR, Discipline 2EC[R], Fanfare 2EC[R], Fanfare ES[R], Sniper[R], Tundra EC[R]		14 d	30 d	
cyfluthrin	Renounce 20WP[R], Tombstone[R], Tombstone Helios[R]		7 d	14 d	
deltamethrin	Delta Gold[R]		21 d	7 d	
esfenvalerate	Asana XL[R], S-Fenvalostar[R], Zyrate[R]		14-28 d	7-14 d	
fenpropathrin	Danitol 2.4 EC[R]		3-14 d grape: 21 d caneberries: 3 d	10 d grape: 7 d caneberries: 14 d	
gamma-cyhalothrin	Declare[R], Proaxis[R]		14-21 d	5 d	
lambda-cyhalothrin	Grizzly Too[R], Grizzly Z[R], Kendo[R], Lambda T[R], Lambda-Cy EC[R], Lambdastar[R], Lambdastar 1CS[R], Lambdastar Plus[R], Lamcap[R], Nufarm Lambda-Cyhalothrin 1 EC[R], Paradigm[R], Province[R], Silencer[R], Warrior II with Zeon[R], Warrior with Zeon[R], Willowood Lambda-Cy 1EC[R]		14-21 d	5-7 d	

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Plum Curculio

Table 5.1, continued. Insecticides recommended for control of **PLUM CURCULIO IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Pyrethroids, Pyrethrins (3A), continued					
permethrin	Ambush 25W[R], Ambush[R], Arctic 3.2 EC[R], Astro, Perm-Up 3.2 EC[R], Permastar AG[R], Permethrin[R], Permethrin 3.2 EC[R], Pounce 25WP[R]	Apply when insects appear.	3-14 d	10-14 d	Toxic to fish, aquatic invertebrates, and bees. Do not apply after petal fall in apples.
zeta-cypermethrin	Mustang[R], Mustang Maxx[R]		14 d	7 d	
Pyrethroids, Pyrethrins (3A); Neonicoinoids (4A)					
beta-cyfluthrin; imidacloprid	Leverage 360[R]	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	7 d	14 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees. Odor may be a problem in public places. Endigo: For suppression only.
bifenthrin; imidacloprid	Brigadier[R], Skyraider[R], Swagger[R], Tempest[R]		14 d	30 d	
imidacloprid; lambdacyhalothrin	Kilter[R]		14-21 d	7-10 d	
lambda-cyhalothrin; thiamethoxam	Endigo ZC[R]		14-35 d	7-10 d	
Neonicitinoids (4A)					
acetamiprid	Assail 30 SG, Assail 70WP	Apply at early petal fall followed by one or two cover sprays during the egg-laying period.	7 d	10-12 d	Toxic to wildlife, aquatic invertebrates, and bees. Acetamiprid & Imidacloprid: For suppression only. clothianidin & imidacloprid: Restricted to post-bloom applications only; petals must have dropped.
clothianidin	Arena 50 WDG, Belay	Apply when threshold populations are observed. Do not wait until insect populations have been established.	7-21 d	10 d	
imidacloprid	Admire Pro, Advise 2 FL, Advise Four, Amtide Imidacloprid 2F, Amtide Imidacloprid 4F, Couraze 2F, Couraze 4, Courze 4F, Macho 2.0 FL, Malice 75 WSP, Mana Alias 4F, Montana 2F, Montana 4F, Nuprid 1.6 F, Nuprid 2SC, Nuprid 4F Max, Pasada 1.6 F, Prey 1.6, Sherpa, Wrangler	Make application immediately following petal fall.	0-7 d	7-10 d	
thiamethoxam	Actara		14-35 d	7-10 d	
Spinosyns (5)					
spinetoram	Delegate WG	Consult with your state agricultural experiment station, certified pest control advisor or extension specialist for specific application timings in your area.	1-14 d	7 d	Toxic to bees and aquatic invertebrates. Supression only.
Avermectins, Milbemycins (6); Pyrethroids, Pyrethrins (3A)					

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 5.1, continued. Insecticides recommended for control of **PLUM CURCULIO IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
abamectin; bifenthrin	Athena[R]	Apply as required by scouting. Timing and frequency of applications should be based upon insect populations reaching locally determined economic threshold levels	28 d	30 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, terrestrial wildlife, and bees.
avermectin B1; zeta-cypermethrin	Gladiator[R]		21-28 d	21 d	
Avermectins, Milbemycins (6); Neonicotinoids (4A)					
abamectin; thiamethoxam	Agri-flex[R]	Apply immediately following petal fall.	35 d	21 d	Toxic to fish, wildlife, aquatic invertebrates, and bees.
METI Acaricides & Insecticides (21A)					
tolfenpyrad	Bexar	Apply when pest populations begin to build.	14 d	10 d	Toxic to fish, aquatic invertebrates, and bees.
Oxadiazines (22A)					
indoxacarb	Avaunt	Apply at listed rates when insect populations reach locally determined economic thresholds.	14 d	7 d	Toxic to mammals, birds, fish, aquatic invertebrates, and bees.
Diamides (28)					
chlorantraniliprole	Altacor	Make first application prior to egg hatch.	5 d	10 d	Toxic to aquatic invertebrates, oysters, and shrimp. Suppression only.
cyantraniliprole	Exirel		3 d	7 d	
Diamides (28); Pyrethroids, Pyrethrins (3A)					
chlorantraniliprole; lambda-cyhalothrin	Voliam Xpress[R]	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels.	14-21 d	7-10 d	Toxic to fish, aquatic organisms, wildlife, aquatic invertebrates, oysters, shrimp, and bees.
Diamides (28); Neonicotinoids (4A)					
chlorantraniliprole; thiamethoxam	Voliam Flexi	Apply before pests reach damaging levels. Scout fields and treat again if populations rebuild to potentially damaging levels. Pome fruit: Make application immediately following petal fall.	14-35 d	10 d	Toxic to wildlife, aquatic invertebrates, oysters, shrimp, and bees.
Unknown (UN)					

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Plum Curculio

Table 5.1, continued. Insecticides recommended for control of **PLUM CURCULIO IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
azadirachtin	Molt-X	Consult with your state agricultural experiment station, certified pest control advisor or extension specialist for specific application timings in your area.	0 d	10 d	Toxic to fish and aquatic invertebrates.
Other					
Beauveria bassiana Strain GHA	Botanigard ES	Begin treatment of crops at the first appearance of the insect pest. Typically, it takes 7-10 days after the first spray to see control.	0 d	NL	May be toxic to fish, aquatic organisms, and potentially pathogenic to honey bees.
Burkholderia spp. strain A396	Venerate XC[O]	Close scouting and early attention to infestations is highly recommended. Proper timing of application targeting newly hatched larvae, nymphs or immature pests is important for optimal results.	0 d	3-10 d	May be harmful to fish, aquatic organisms, and bees.
kaolin clay	Surround WP[O]	Start before infestation and continue at 7-14 day intervals.	0 d	7 d	Thorough coverage is important to obtain optimum control; white coating on the fruit may require removal after harvest to make fruit marketable.

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Plum Curculio

Table 5.2. Insecticides recommended for control of **PLUM CURCULIO IN HOME FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Organophosphates (1B)					
malathion	Spectracide Malathion Insect Spray concentrate	Begin treating when insects first appear.	3-7 d grape: 3 d	3-11 d grape: 14 d	Toxic to bees.
Pyrethroids, Pyrethrins (3A)					
gamma-cyhalothrin	Spectracide Malathion Insect Spray concentrate Triazicide Insect Killer for Lawns and Landscapes	Apply when insects appear or when damage occurs.	14-21 d	NL	Toxic to fish, aquatic organisms, and bees.
Neonicitinoids (4A)					
acetamiprid	Ortho Flower, Fruit & Vegetable Insect Killer, Ortho Rose & Flower Disease Control	Apply as soon as insect problems are noticed.	7 d	10-12 d	Toxic to bees. Post-bloom use only.

Plum Curculio

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

Fig. 5.1. Adult plum curculio (PC); note the gray and black mottled coloring, long curved snout, and humps on its back.

Fig. 5.2. Adult PC feeding on fruit.

Fig. 5.3. PC egg next to oviposition scar and adult.

Fig. 5.4. PC larva in peach fruit flesh; note the grub-like body and small brown head.

Fig. 5.5. PC pupa in its soil cavity prepared by the larva.

Fig. 5.6. PC feeding and egg laying damage on Saskatoon or Western serviceberry.

Fig. 5.7. Cherries showing PC feeding (round holes) and egg laying (crescent-shaped scars) damage.

Fig. 5.8. Nectarines showing PC feeding scars and crescent-shaped egg laying scars.

Fig. 5.9. Superficial damage on pears caused by PC feeding and egg laying.

Fig. 5.10. Scarred and misshapen apple fruit at the time of harvest, due to PC damage.

Fig. 5.11. PC feed on a variety of plant materials including leaves.

Fig. 5.12. Peach fruit showing PC damage; note the shiny areas or disturbed fuzz, and feeding scars.

Fig. 5.13. A green plum showing PC crescent-shaped egg-laying damage.

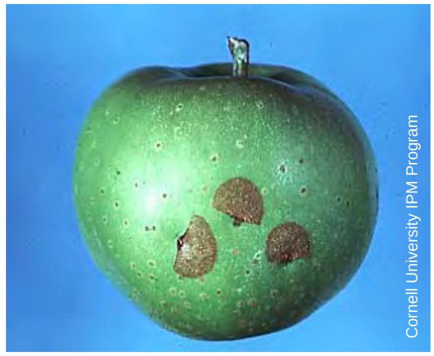


Fig. 5.14. PC oviposition scarring on an apple; note the distinct half-moon or crescent shape.

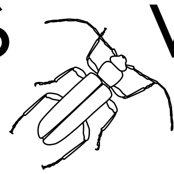
Fig. 5.15. Young peach fruit with PC larvae present; note the frass and the rotting fruit flesh.

Fig. 5.16. PC larva and frass present in a rotting cherry fruit.

Fig. 5.17. PC present in a plum; note frass inside the fruit and scarring on the fruit skin.

Fig. 5.18. A beating tray and stick are used for sampling pests present in fruit trees.

Fig. 5.19. Black pyramid trap placed at field border to monitor for PC.

CHAPTER 6  VELVET LONGHORNED BEETLE

Quick Facts

- The velvet longhorned beetle (VLB) is native to Asia and Russia.
- VLB was first found in North America in 2002; it was detected in Utah in 2010, and since has become widespread in Salt Lake and Utah counties.
- VLB will attack healthy as well as stressed and dying trees, and cut wood; in its native range, VLB prefers apple, mulberry and hardwood and conifer timber tree species.
- In Utah, multiple life stages of VLB have been found in peach and cherry, confirming that these are reproductive hosts.
- Injury signs and symptoms include round adult emergence holes (about 3/8 in or 9.5 mm in diameter) in trunks, larval tunnels beneath the bark, frass (insect excrement) at the tree base, canopy thinning, and yellowing of new leaf growth.
- Prevention, monitoring and detection are the key management recommendations for VLB in Utah.

Background

The velvet longhorned beetle (VLB), *Trichoferus campestris* (Faldermann) (Coleoptera: Cerambycinae) is a wood-boring beetle native to Asia and Russia. It was first detected in North America in 2002 in Quebec, Canada, and in Rhode Island, U.S. in 2006. In Utah, VLB was first found in South Salt Lake City in July 2010. Detection traps in orchards, ornamental landscapes, and along natural waterways indicate that VLB is widespread in Salt Lake and Utah counties *(Fig. 6.1)*.

VLB has been found inside warehouses associated with imported wooden pallets and crates in Rhode Island (2006), New Jersey (2007, 2013), Ohio (2009), and Illinois (2009). VLB was detected in Colorado in 2013 and New York in 2014. It travels to new areas by infesting wood that is used as packing material for imported commodities such as machinery, building supplies, glass, tools, and tiles.

In its native range, VLB prefers apple, mulberry, and hardwood and conifer timber hosts. In Utah, larvae, pupae, and adult life stages of VLB have been found in peach and cherry trees. It attacks healthy, stressed, and dead and dying trees. Due to its polyphagous (feeds on many different hosts) life style, VLB poses a threat to Utah's orchard, landscape, and riparian wood lands.

Identification and Life History

ADULT: REPRODUCTIVE AND DISPERSAL STAGE

- Elongated body, ½-¾ in (12-20 mm) long.
- Brown to orange coloring and long parallel wing covers (elytra).
- Legs and antennae usually lighter in color than the body *(Figs. 6.2-6.5)*.
- Fine hairs irregularly distributed along its wing covers and body, hence the name "velvet".
- Fine hairs form light colored "spots" along the body.
- Segmented antennae about ¾ the length of its body.

EGG

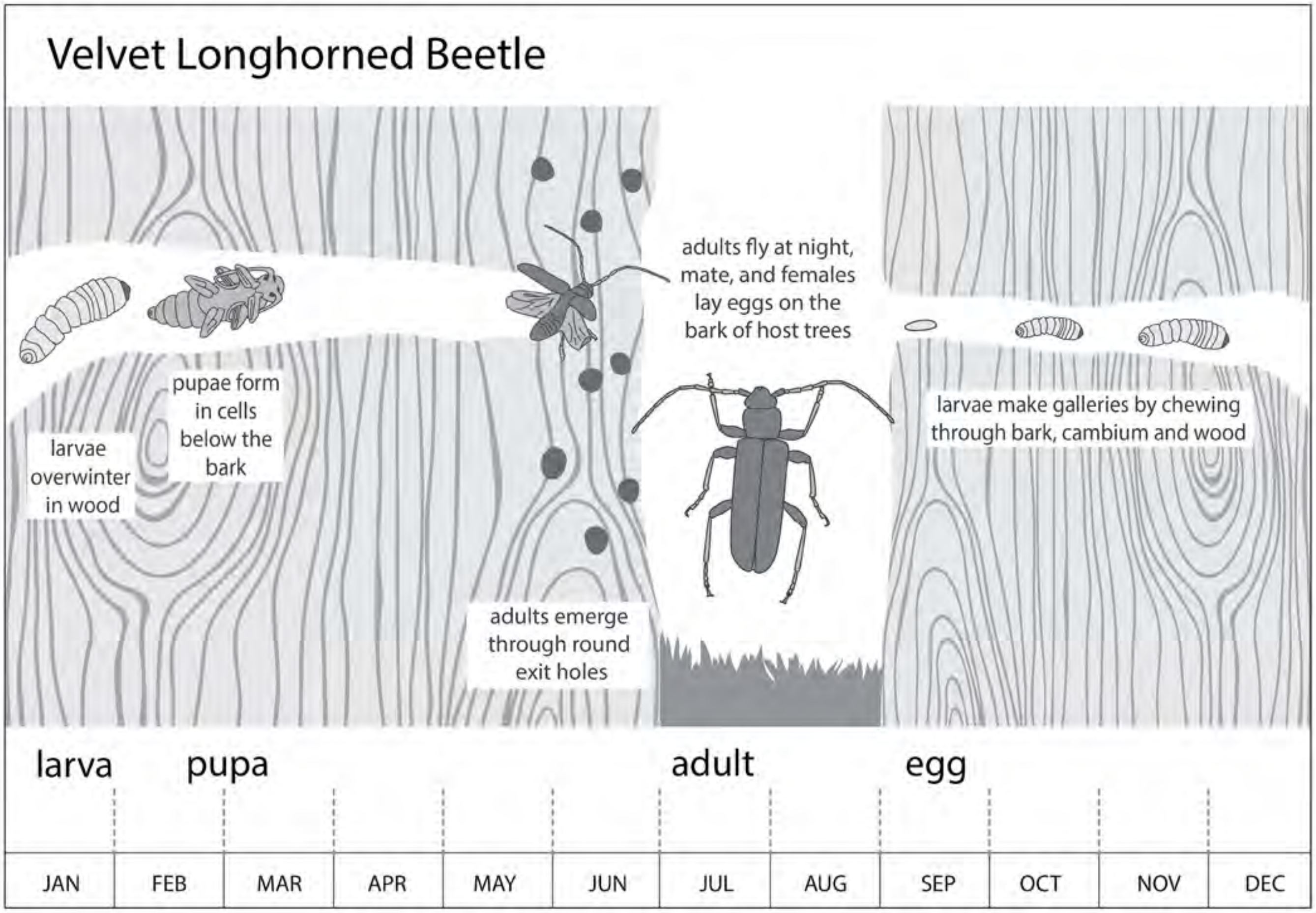
- Approximately 1/16 in. (1.5 mm) long and 0.02 in (0.5 mm) wide.
- White, and oval in shape.

LARVA: OVERWINTERING AND DAMAGING STAGE

- About ½-1 in (13-25 mm) long *(Figs. 6.6-6.7)*.
- Yellow to white in color with a brown head, segmented body, and short, poorly developed legs.

PUPA: RESTING AND FORM-CHANGING STAGE

- About ¾ in (20 mm) long and ¼ in (5 mm) wide.
- White to cream colored body.
- Long antennae that curve and are held close to the body *(Fig. 6.8)*.



Life history of velvet longhorned beetle in Utah; larvae remain in host trees for 2 or more years to complete their development.

Adults fly at night; they are attracted to lights. Adults chew exit holes in tree bark to emerge from the end of May to mid-July; peak flight and mating occurs from June to early August. Females lay their eggs on the trunks and large branches of healthy, stressed, dying, and cut trees.

Larvae hatch and burrow into the tree bark forming galleries (tunnels) in the cambium (conductive tissues) between the bark and sapwood. Older larvae tunnel into the sapwood below the cambium and may move into the heartwood, increasing in size as they mature. Larvae can tolerate dry wood; thus, their ability to bore into cut and dried wood. Larval galleries range in size from 2 to 6 in (5 to 15 cm) wide.

Larvae complete their development in two or more years overwintering in cells they form beneath the bark; Pupation occurs in the late winter to spring with a final molt to the adult stage in spring to summer.

Plant Hosts and Injury Symptoms

In its native range, VLB prefers apple, mulberry, and a number of hardwood and conifer timber tree species.

Live tree hosts in Utah potentially include many cultivated and wild species (see VLB hosts table). Many tree species may also serve as dry wood hosts for VLB.

It is unknown whether VLB prefers stressed or healthy trees, however, it does seem to be more attracted to medium to large sized trees. VLB has been found reproducing in sweet cherry and peach trees in Utah, but not in apple yet. Nursery trees in the U.S. are susceptible hosts to VLB larvae and may act as a reservoir for the pest to spread to new areas.

Tree Injury Symptoms of VLB

- thinning/wilted/yellowing tree canopy
- round exit holes on tree trunk and main branches
- frass deposits at base of tree
- peeling bark
- tunnels made by large larvae
- epicormic shoots

Tree injury symptoms include a thinning, wilted or yellowing canopy; round exit holes on the trunk and main branches *(Fig. 6.9)*; frass (insect excrement) deposits at the base of the tree; peeling bark; tunnels made by large larvae; and epicormic shoots (shoots that grow from dormant buds beneath the bark, trunk, stem, or branch of a plant). Fruit yield, tree longevity, and wood marketability can all be negatively impacted by a VLB infestation.

Plant Hosts of VLB		
Pome & Stone Fruits	**Ornamental & Wild Fruits**	**Dry Wood**
• apple (preferred) • cherry (preferred) • crabapple (preferred) • mulberry (preferred) • peach	• birch • crabapple (preferred) • fir • hickory • honey locust • mountain ash • paper mulberry • pine • rowan • spruce • willow	• alder • apple • ash • birch • black locust • dogwood • elm • fir • grape • holly • Japanese beech • maple • mulberry • oak • pine • spruce • sumac • willow

*USDA APHIS PPQ CAPS Exotic Wood Borer/Bark Beetle Host List 2014

Monitoring

The best time of year to monitor for VLB is during peak flight from late June to early August. In Utah, high numbers of the VLB have been detected in riparian habitats near golf courses and near cull piles of discarded plant materials in commercial fruit production areas.

Monitoring in Utah has been successful with Lingren funnel traps baited with an ethanol lure (see list of trap and lure sources at the end of this chapter). Other monitoring methods include visual inspection for adult exit holes and tree injury symptoms (see table of tree injury symptoms), and black light (infrared light) trapping.

Place black light traps as far away from other light sources as possible and turn them on one or two nights per week for 3-4 weeks from late June to early August. These three to four weeks of monitoring will ensure an overlap with VLB's peak flight period. It is ideal to check traps within 24 hours of run time, as any VLB caught may be consumed by other predatory insects that are also caught in the traps.

A homemade black light trap can be constructed of a mercury vapor (MV) bulb and two black light bulbs (run at the same time) with a white sheet hung vertically to collect the beetles *(Fig. 6.10)*. Light from the MV bulb is intense and attracts insects from a large area. To effectively attract large insects, such as VLB, to land on the sheet, turn the MV bulb on and off every 30-60 minutes. Commercially manufactured black light traps may also be effective in capturing VLB *(Fig. 6.11)*.

Management

Prevention is a key component in managing VLB. Early detection and proper identification accomplished through monitoring methods described above, will greatly increase the success of VLB prevention. If you suspect you have seen VLB, contact the Utah Cooperative Agricultural Pest Survey (CAPS) program, the local Utah Department of Agriculture and Food inspector, or the local USU Extension county agent (see contact information on pg. i).

Cultural Control

Cultural practices outlined by the CAPS program for preventing the spread invasive pests, like VLB, are:

1. Buy local: avoid transporting fruit, seeds, or live plants outside their area of origin and don't transport firewood. Moving plant parts that can harbor pests may contribute to the spread of invasive species.
2. Plant carefully: avoid planting invasive, non-native plants.
3. Keep it clean: when traveling, inspecting belongings and remove plants, soil, and insects from your clothing, boots, gear, pets, and vehicles.

Mechanical & Physical Control

Traps used for monitoring VLB (Lindgren funnel and black light traps) may be used for trap-and-kill control methods. An insecticide vapor strip can be placed in traps to kill trapped insects.

Biological Control

Natural enemies of longhorned beetles in North America include predators, parasitoids, and pathogens. Predators of longhorned beetles include flat bark beetles, cylindrical bark beetles, clerid beetles, click beetles, robber flies, assassin and ambush bugs, thrips, carpenter ants, birds, lizards, spiders, scorpions, toads, and small mammals. Parasitoids include braconid, ichneumonid, and chalcid wasps; and tachinid and sarcophagid flies. Nematodes and fungi have been observed as pathogens of longhorned beetle larvae (Smith 1999).

Chemical Control

There are no insecticides labeled specifically for velvet longhorned beetle; however, insecticides labeled for longhorned beetles in general should reduce numbers of larvae in infested trees. Insecticides containing the active ingredient imidacloprid (neonicotinoid class) have been used successfully on high-value trees for the control of Asian longhorned beetle, a closely related invasive wood borer. Treatments of imidacloprid can be applied through injection into the tree trunk, or via soil drench to the tree dripline or containerized plants. Apply imidacloprid to infested trees before and during the VLB adult emergence period in the late spring and summer. Repeat applications once per year for at least three years to ensure mortality of all ages of larvae and pupae in the infested trees. Be aware that imidacloprid treatments do not ensure complete control because many variables, including weather conditions, tree health, application methods, and insecticide rates affect the systemic movement and reach of imidacloprid into the wood of the tree. Large larvae feeding in deeper wood are difficult to kill with insecticides (Rose et al. 2014). Another neonicotinoid class insecticide labeled for Asian longhorned beetle treatment is dinotefuran (e.g. Safari). However, dinotefuran products are only registered for use on ornamentals, and are not allowed on fruit trees.

Recommended insecticides

Recommended insecticides are given based on products labeled for general longhorned beetle control. There are currently no products labeled specifically for velvet longhorned beetle.

Table 6.1. Insecticides recommended for control of VELVET LONGHORNED BEETLE IN COMMERCIAL FRUIT production in Utah.

Table 6.2. Insecticides recommended for control of VELVET LONGHORNED BEETLE IN HOME FRUIT production in Utah.

Sources of Traps and Lures

AgBio Westminster, CO 303-469-9221 agbio-inc.com (ethanol lure)	Alpha Scents West Linn, OR 503-342-8611 alphascents.com (ethanol lure)
Great Lakes IPM Vestaburg, MI 800-235-0285 greatlakesipm.com (lingren funnel traps)	Gemplers Mt. Horeb, WI 800-382-8473 gemplers.com (black light traps)

For Additional Information, Search the Internet for:

Exotic Pest Control, Velvet Longhorned Beetle, UDAF

Total Records of Velvet Longhorn Beetle Utah, UDAF

Velvet Longhorned Beetle, USU Extension

Velvet Longhorned Beetle, Purdue University

Maps of Vevlet Longhorned Beetle, Purdue University

Chinese Longhorned Beetle, Minnesota Department of Agriculture

The Velvet Longhorn Beetle, University of Nebraska

Trichoferus campestris, An Asian Wood-Boring Beetle Recorded in North America, BioOne

Asian Longhorned Beetle Response Guidelines

The Potential for Biological Control of Asian Longhorned Beetle in the U.S.

Chinese Longhorned Beetle Information, USDA

Blacklight Traps, Mississippi State University

Prevention is Key with Invasive Pests, Utah Pests

References

Rose, R., J. Ryan, D. Lance, P. Baldauf, J. Gittleman, C. McFarland, J. Burch, P. Douglass, D. Hoffman, R. Santos. 2014. Asian Longhorned Beetle Response Guidelines. USDA APHIS PPQ, Asian Longhorned Beetle Eradication Program.

Smith, M.T. 1999. The Potential for Biological Control of Asian Longhorned Beetle in the U.S. Midwest Biological Control News 6: 1-7

Pest Management Tables for Commercial and Home Use

Table 6.1. Insecticides recommended for control of **VELVET LONGHORNED BEETLE IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Neonicitinoids (4A)					
imidacloprid	Enforce 75WSP, Lada 2F, Malice 2F, Mallet 75 WSP, Merit 2F, Merit 75WSP	Apply as a tree trunk or soil injection (soil drench on containerized plantings), prior to and during the adult emergence period.	7-21 d	10 d	Toxic to aquatic invertebrates and bees. Restricted to post-bloom applications only; petals must have dropped. Allow enough time for the insecticide to be distributed throughout the tree. When multiple applications are being considered, fall treatments have been shown to be as effective as treatments applied only in the spring. **Not for bearing fruit trees; for ornamental and non-bearing fruit trees only.**

Velvet Longhorned Beetle

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

Table 6.2. Insecticides recommended for control of **VELVET LONGHORNED BEETLE IN HOME FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Imidacloprid (4A)					
Imidacloprid	Compare N Save Systemic Tree and Shrub Insect Drench	Can be applied anytime except when the ground is waterlogged or frozen.	NL	NL	Toxic to aquatic invertebrates. Restricted to post-bloom applications only; petals must have dropped. **Not for bearing fruit trees; for ornamental and non-bearing fruit trees only.**

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

Velvet Longhorned Beetle

NL= No time listed

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

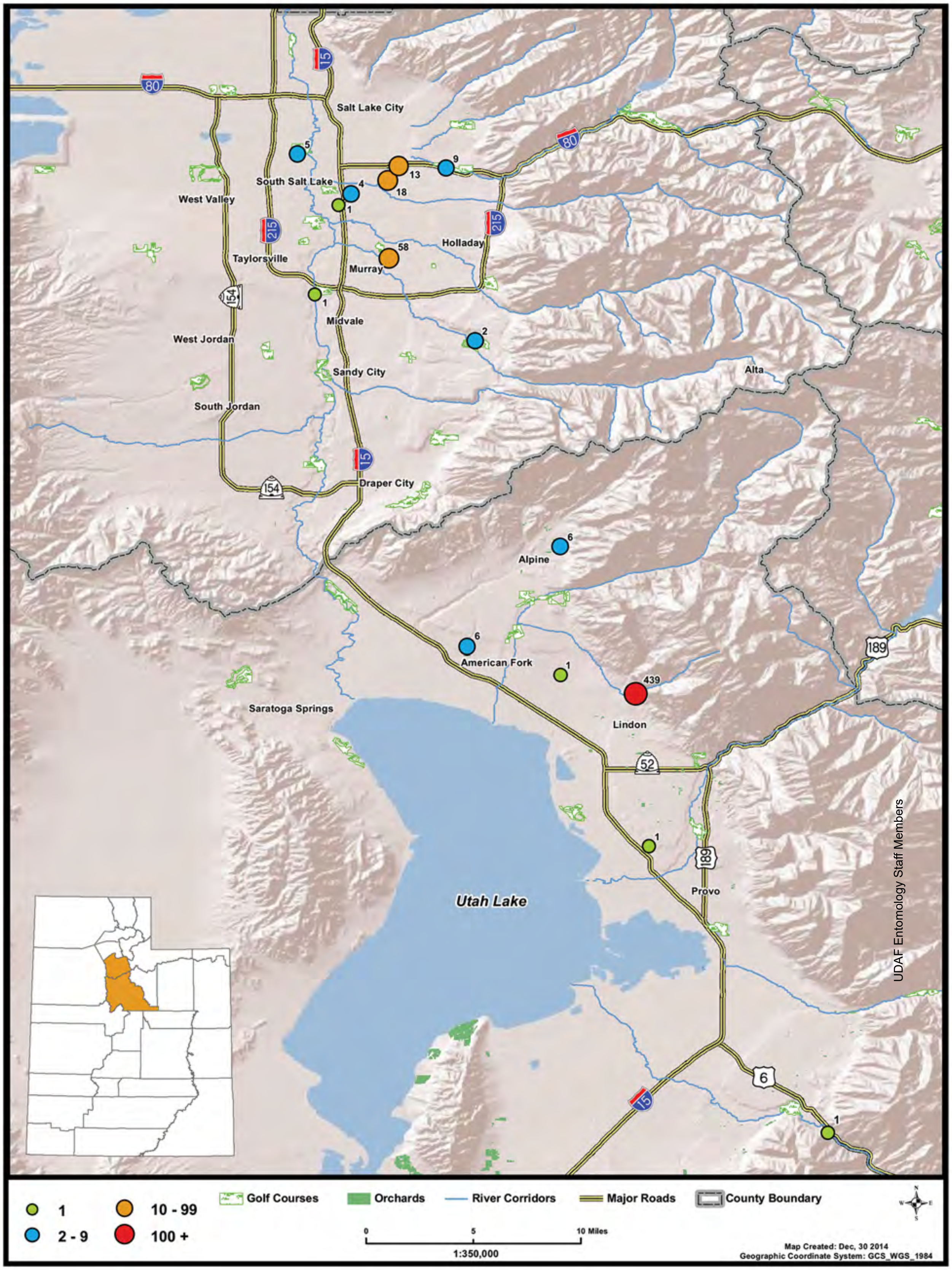


Fig. 6.1. Map of detections of velvet longhorned beetle (VLB) in Salt Lake and Utah counties in 2014.

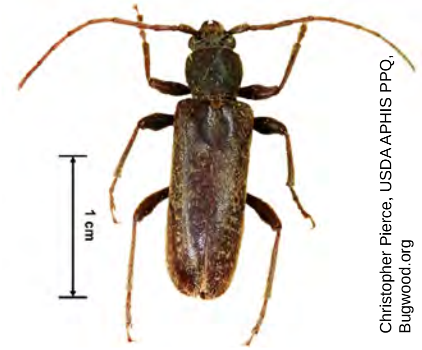


Fig. 6.2. Adult VLB; note the "velvet"-like hairs, long body, long antennae, and brown to orange coloring.

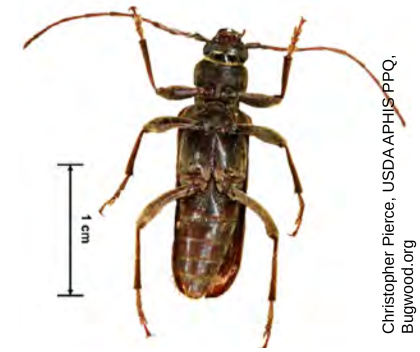


Fig. 6.3. Underside of an adult VLB.

Fig. 6.4. Close-up of the fine hairs on the VLB, hence the name "velvet".

Fig. 6.5. Newly emerged VLB adult next to pupal chamber.

Fig. 6.6. VLB larvae and pupa; note the larvae with white/cream segmented bodies and a brown head.

Fig. 6.7. VLB larva; note white/cream segmented body with a small brown head.

Velvet Longhorned Beetle

Fig. 6.8. VLB pupa; note the white to cream colored body

Fig. 6.9. VLB adult emergence holes in a host tree trunk.

A. Steiner

Fig. 6.10. Blacklights used with a sheet hung vertically to capture nocturnal insects like VLB.

Fig. 6.11. A commercially manufactured blacklight trap for capturing nocturnal insects like VLB.

CHAPTER 7 JAPANESE BEETLE

Quick Facts

- Japanese beetle (JB) is a quarantine insect pest due to its invasive nature, its extensive plant host range and plant damage inflicted by adult and immature life stages.
- JB has been established in the eastern U.S. for nearly 100 years; it was first detected in Utah (Orem) in 2006.
- An intense eradication program directed by the Utah Department of Agriculture and Food was successful in eliminating JB from Utah.
- Monitoring programs continue today to prevent re-establishment of JB in Utah.
- Turfgrass is at greatest risk for infestation by JB larvae (white grubs); adult JB attack numerous ornamental, fruit, and vegetable plants.

Background

The Japanese beetle (JB), *Popillia japonica* (Newman) (Coleoptera: Scarabaeidae) is a quarantine pest in the U.S. Originally from Japan, JB was first found in the U.S. in 1916 in a New Jersey nursery. It was likely introduced from Japan in shipments of ornamental plants. By the late 1970s, JB had spread throughout the eastern U.S., reaching as far west as Wisconsin. More recently, JB has spread to many western states. In its native environment, JB is not a serious pest due to the natural predators that keep its population in check. Without its natural enemies in the U.S., JB has become established in favorable environments with an abundant food supply and limited competition. Adult JB feeds on the foliage of many plant species, while the immature stage, larva (white grub), primarily feeds on the roots of turf grasses. The prevalence of turf grass in the U.S. has been a major factor in JB's establishment and range expansion.

Pest Identification and Life History

ADULT: REPRODUCTIVE, DISPERSAL, AND DAMAGING STAGE

- About ¼ in wide and ½ in long (6.5 × 13 mm).
- Highly characteristic in color: metallic green head and mid-section (thorax) with copper-brown wing covers *(Figs. 7.1-7.2)*.
- Five pairs of white hair tufts along the sides of the abdomen and another pair on the last abdominal segment.
- Legs have prominent spines.
- Underside of body is metallic green and copper-brown.

EGG

- About 1/16 in (1.5 mm) in diameter *(Fig. 7.3)*.
- Cylindrical when laid.
- When it is ready to hatch, the egg is nearly spherical and 1/8 in (3 mm) in diameter.

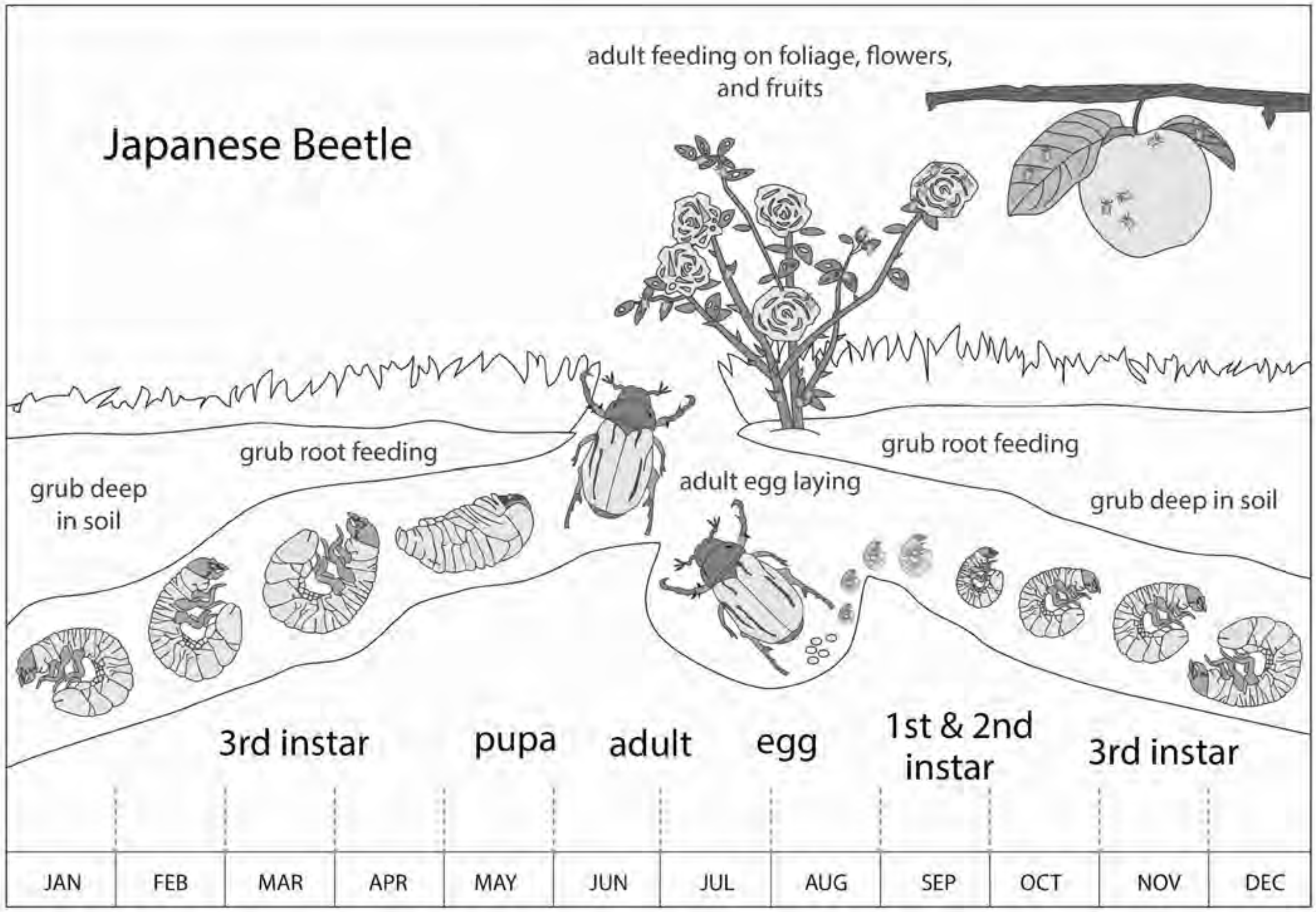
LARVA: OVERWINTERING AND DAMAGING STAGE

- Creamy white with a grayish-brown hind end *(Fig. 7.4)*.
- Head is yellow-brown with darker mandibles (chewing teeth).
- Grows from just under 1/8 in (3 mm) in length upon hatching to 1 in (25 mm) at maturity.
- Known as a white grub.
- Three pairs of underdeveloped legs (one on each of their thoracic segments).
- Long brown hairs dispersed with short, blunt spines on the body.

PUPA

- About ¼ in wide and ½ in long (6.5 × 13 mm).
- Color varies from creamy white through tan, to the metallic green of adulthood in late pupation *(Fig. 7.5)*.

Adults emerge from pupae in the soil during June and July, and feed on a wide range of crop, garden, and ornamental plants over a 6-8 week period. Adults release both sex and aggregation pheromones to congregate males and females for mating and feeding. Plant odors emitted from beetle damaged leaves also cause beetles to aggregate. Mated females will fly to turf grass and burrow 2-3 in (5-8 cm) underneath the soil to lay their eggs. Each female can lay up to 60 individual eggs. The larvae or white grubs complete five instars or molts by late September, and burrow 2-6 in (5-15 cm) deep to spend the winter. The following spring, larvae pupate and adults emerge as described. Larvae feed on plant roots in the spring, summer, and fall. Pupation takes place in an earthen cell made by the final instar of the larvae. Most of the JB life cycle is spent underground, only emerging as adults to feed, mate, and lay eggs during the summer *(Fig. 7.6)*.



Life history of Japanese beetle in Utah. There is one generation per year; the majority of its lifespan is spent as a larva (white grub) in the soil feeding on roots of turf grass and other plants. (Adapted from drawings by J. Kalisch (University of Nebraska) & Joel Floyd (APHIS)

Plant Hosts and Injury Symptoms

A main reason for the quarantine pest status of JB is the number and diversity of plants it attacks (over 300 species of ornamental and crop plants). Preferred adult hosts include rose, maple, elm, grape, apple, stone fruits (cherry, plum, peach), blackberry, raspberry, asparagus, bean, and corn. Adults chew on the leaves, flowers, fruit, and in some cases, stems of plants *(Figs. 7.7-7.14)*. They are voracious feeders. Adults skeletonize leaves, chewing away softer tissue, and leaving the veins. They also chew holes in flower buds and petals, soft fruits, and corn silks *(Figs. 7.15-7.16)*. The adult beetles congregate (mass together) and can destroy crops in just a few days before moving on. They also wreak havoc on ornamental plants, consuming leaves and flowers.

The larvae (grubs) attack plants below ground and feed on the fine roots of grasses and some trees, shrubs, and vegetables. Large plantings of turf grasses (e.g., lawns and athletic fields) are especially attractive as egg-laying sites. While damage to grasses is initially difficult to detect, it becomes apparent during late summer and early fall when grubs are large. The compromised grass

Plant Hosts of JB	
Adult hosts	**Larval hosts**
• Rose	• Kentucky bluegrass
• Maple	• Fescue grasses
• Elm	• Perennial ryegrasses
• Grape	• Bentgrass
• Apple	• Corn roots
• Stone fruits (cherry, plum, peach)	• Pea roots
• Blackberry	• Bean roots
• Raspberry	• Beet roots
• Asparagus	• Asparagus roots
• Bean	• Tomato roots
• Corn	• Onion roots
• Ornamental leaves and flowers	• Fine roots of young ornamental trees and shrubs
• Basswood/linden	• Large turf areas for egg-laying
• Crabapple	
• Birch	

roots are inefficient in uptake of water and nutrients, and eventually turn leaves and stems yellow and brown. Severely injured turf will die. Feeding damage appears as patches of dead and dying plants mixed with healthy, unaffected grass. Turf with damaged roots is easily pulled back (like pulling back covers on a bed) to reveal the grubs underneath *(Fig. 1.23)*. The damaged turf will also feel spongy and soft under-foot.

JB larvae prefer fescues, perennial ryegrasses, Kentucky bluegrass, and bentgrass. The high susceptibility of these grass species is problematic as they tend to be more disease and drought tolerant, and thus preferred by turf managers for their lower maintenance costs. Bentgrass, bluegrass, and ryegrasses are often planted on golf courses making them readily available for JB infestation if left unprotected. The grubs can also feed upon fine roots of young ornamental trees and shrubs, and garden crops such as corn, peas, beans, beets, asparagus, tomato, and onion.

Plant Injury Symptoms of JB	
Adult injury	**Larval injury**
• Holes in flower buds and petals • Holes in soft fruits • Holes in corn silks • Skeletonized leaves w/ veins in tact • Chewed plant stems (in some cases) • Consumed leaves and flowers of ornamental plants	• Yellow/brown leaves and stems of grass • Dead turf grass if severely injured • Patches of dead/dying grass mixed with healthy/ unaffected grass • Turf w/ damaged roots easily pulls back (like bed sheets) • Damaged turf feels spongy/ soft under-foot

Monitoring

Accurate and rapid identification of JB infestation is facilitated by knowledge of when, where, and what JB can feed upon. Effective monitoring is critical for rapid detection of JB. There are three main approaches to monitoring for JB.

1. A commercially available lure trap. The lure has two components: a pheromone, or sex attractant, and a floral lure that attracts both male and female beetles to the trap. The traps are funnel-shaped with a "directional vane" on top and a beetle collection container on the bottom *(Figs. 7.17-7.19)*. Traps are either all green in color or bicolor with yellow and green. The all-green traps are more discreet and capture fewer non-target insects (e.g., pollinators); however, the bicolor trap is more attractive to JB *(Fig. 7.19)*.

   JB adults fly toward the attractive odors of the trap, hit the vanes, and fall through the funnel and into the container where they are retained. The funnels often have a slick film coating to facilitate beetles sliding into the trap. Some traps have an insecticide inside to kill the beetles. Depending on the level of JB infestation, garbage bags have been used in place of smaller containers due to the high number of JB in the area.

   In locations with high JB populations, use caution when selecting sites to place traps. Trap attractants can cause large congregations of adults, many of which do not make it into the trap. This can result in heavy damage to plants in the vicinity of the trap.

   Traps should be placed in representative locations for monitoring, but at a reasonable distance from high value host plants to avoid unacceptable plant injury. Traps should be emptied as frequently as possible (1-3 days) to prevent dead beetles from rotting and releasing ammonia, which is known to repel other JBs.

2. Scout for adults in the summer by inspecting susceptible plants, such as rose, apple, stone fruits, basswood/linden, crabapple, asparagus, and birch. Visually survey crops and ornamentals. Look for common JB plant feeding symptoms *(Figs. 7.7-7.16)*, and if suspected, monitor frequently for live JB. JB prefer warm, sunny conditions, so visual monitoring should be done during the day and on the sunny side of the plant.

3. Begin monitoring for larvae in the spring by collecting soil and root samples *(Fig. 7.20)* from damaged turf where JB is suspected to occur *(Fig. 7.21)*. Pull apart the roots and soil to look for mature larvae *(Fig. 7.22)*. Examine turf grass for feeding injury and larvae *(Figs. 7.20-7.23)*. Turf grass that has been fed upon will be yellow to brown, and dying or dead. Leaves and crowns of grass plants will pull away easily from the roots. Grubs may be visible in the soil underneath damaged sod. Another clue to the presence of white grubs in sod is predator digging activity, such as from birds, skunks, badgers, and other grub-eating predators. Inspect disturbed areas of turf for damage and grubs.

Management

Control of JB can be difficult, as adults and larvae often occur on different host plants. Additionally, adults are highly mobile and can easily infest new areas. Effective JB control requires an integrated pest management approach that integrates all control options – cultural, mechanical, biological, and chemical.

Cultural Control

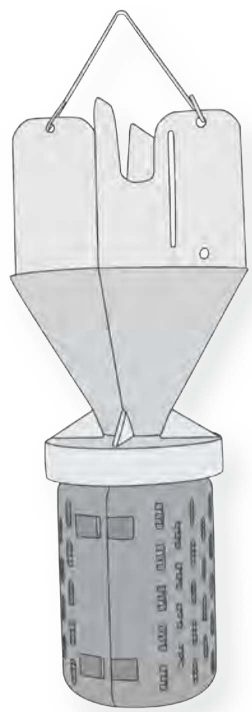
HABITAT MODIFICATION

Keep plants healthy by following a recommended irrigation and fertilization schedules. Encourage natural enemies by planting a diversity of flowering plants that produce pollen and nectar. Include a mix of plants that adult beetles avoid, such as lilac, forsythia, dogwood, magnolia, and American holly to discourage adult aggregations on ornamentals.

Mechanical Control

MASS TRAPPING

Mass-trapping can be an effective way to reduce small and localized populations of JB. For best effect, place the traps (see trap description above) near attractive plants of lower value. The sex pheromone and floral lure combination may cause a large congregation of JB on plants near the trap. For example, an old or over-grown planting of roses will be highly attractive to JB, but can be “sacrificed” as a mass-trapping location. Place insecticide kill-strips inside trap containers to kill adults as they are caught and prevent their escape (see sources of monitoring supplies list at the end of the chapter).



HAND REMOVAL

Removing JB by hand can be an effective method for small-scale, localized population reduction. Beetles can be easily removed by shaking plants or plant parts over a container filled with water and a few drops of dish soap. Dish soap helps facilitate the capture of the beetles by breaking the water tension, allowing beetles to sink into the water and drown rather than escape. Adults can also be hand-picked from small plants.

Biological Control

There are a number of natural predators, pathogens, and parasitoids of JB. One of the most common biological control methods to be used against JB is to apply *Bacillus popillae*, the bacterium that causes Milky Spore Disease. This bacterium releases spores that are ingested by the grub. The spores germinate in the grub’s gut, infect the gut cells, and eventually enter the hemolymph, or blood. The grubs die, releasing millions of spores back into the soil to repeat the cycle. This method takes time to build up in the soil (2-4 years) and can suppress populations of related beetles, both beneficial and detrimental.

Insect-parasitic nematodes (*Steinernema* and *Heterorhabditis* spp.) can be effective biological control agents of JB. These nematodes have a symbiotic relationship with specific bacteria. The nematodes inoculate the insect host with the bacterium by carrying it into the insect body through natural openings (mouth, breathing tubes, and anus). The bacteria break down insect tissues and multiply. The nematodes feed on the bacteria, develop, and reproduce, eventually killing the insect host. The nematode offspring then go in search of new soil insects to attack. The two most effective nematode species are *Steinernema glaseri* (not currently commercially available) *and Heterorhabditis bacteriophora*. *H. bacteriophora* is commercially available and can be applied similarly to a soil-drench insecticide. Research has shown *Steinernema kushidai* to be as effective as some organophosphate insecticides, such as diazinon, although this species is not commercially available.

In locations where JB is more abundant, a parasitic wasp, *Tiphia* sp., attacks JB grubs with a stinger to induce temporary paralysis, and then attaches an egg to the grub’s body. The wasp larva will hatch and feed on the grub, killing it in the process. Each female wasp can parasitize up to 50 JB larvae. The occurrence of this parasitoid wasp has not been confirmed in Utah.

Conservation and encouragement of beneficial insect populations in the landscape, garden, and crops can help suppress pest insects, such as JB. Ants and ground beetles are common predators of JB grubs. Avoid the use of broad-spectrum insecticides (those that kill many types of insects, including beneficial ones), and grow diverse flowering plants to provide nectar and pollen food resources to enhance populations of beneficial insects.

Chemical Control

Application of insecticides to target JB adult and larval life stages can be an effective management strategy when JB populations have exceeded economic or aesthetic injury thresholds. Use an integrated pest management (IPM) approach: implement cultural, mechanical, and biological methods first, and then use chemicals as necessary to lower JB populations to acceptable levels. Timing of application and choice of insecticide mode-of-action, or class, are important factors in designing an effective chemical control program for JB.

Japanese Beetle

TURF

The treatment threshold for Japanese beetle grubs in turfgrass is 8-10 per ft^2 (0.09 m^2) or 2-3 larvae per 6 in x 6 in (15.2 cm x 15.2 cm) square with obvious visible damage. The threshold can be increased to up to 15 larvae per ft^2 in a healthy lawn where plant stress is minimal. In mid to late June, use a long-lasting "reduced risk" insecticide, such as imidacloprid (Merit®) or chlorantraniliprole (Acelepryn®), to target eggs before they hatch intro grubs. Other reduced risk insecticides include Concern®, Pyganic®, and Surround®; however, these chemicals do not have a long residual. Highly infested turf may need an additional treatment of trichlorfon (Dylox®) in July to kill grubs. Here are some guidelines for effective chemical control in turfgrass:

- If the thatch layer exceeds ½ in (1.3 cm) deep, use a light aerification treatment to enhance soil penetration.
- Apply ½ in (1.3 cm) of water 48 hours before chemical application to bring feeding grubs closer to the soil surface.
- Immediately apply ½ - ¾ in (1.3 – 1.9 cm) of water after application to push the chemical down to the root zone.
- Repeat irrigation every 4 or 5 days to promote chemical movement in the soil.

CROPS, GARDENS AND, ORNAMENTALS

Adults are active for only two months or less (see JB life history illustration), and they are highly mobile. Application of foliar insecticides to trees, shrubs and other ornamentals is not recommended because insecticides are expensive and generally ineffective in landscape situations. However, insecticides may help to protect commercial crops, gardens, nursery stock, and high value landscape plantings.

Recommended Insecticides

Table 7.1. Insecticides recommended for control of JAPANESE BEETLE LARVAE IN COMMERCIAL TURF GRASS GRASS in Utah.

Table 7.2. Insecticides recommended for control of JAPANESE BEETLE ADULTS IN COMMERCIAL FRUIT production in Utah.

Table 7.3. Insecticides recommended for control of JAPANESE BEETLE LARVAE IN HOME TURF GRASS in Utah.

Table 7.4. Insecticides recommended for control of JAPANESE BEETLE ADULTS IN HOME FRUIT production in Utah.

Sources of Monitoring Supplies

AgBio
Westminster, CO
303-469-9221
agbio-inc.com

Scentry
Billings, MT
800-735-5323
scentry.com

Great Lakes IPM
Vestaburg, MI
800-235-0285
greatlakesipm.com

Gemplers
Mt. Horeb, WI
800-382-8473
gemplers.com

Trésé
Salinas, CA
408-758-0205
trece.com

Alpha Scents
West Linn, OR
503-342-8611
alphascents.com

For Additional Information, Search the Internet for:

Managing the Japanese beetle: a homeowner's handbook, USDA APHIS

Managing Japanese beetles in fruit crops, Michigan State University Extension

Japanese beetle management in Minnesota, University of Minnesota Extension

How to choose and when to apply grub control products for your lawn, Michigan State University Extension

Looking ahead to white grub control, University of Illinois Extension

Utah Pests Fact Sheet, Japanese Beetle

Pest Management Tables for Commercial and Home Use

Table 7.1a. Insecticides recommended for control of **JAPANESE BEETLE LARVAE IN COMMERCIAL TURF GRASS** applications in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Carbamates (1A)					
carbaryl	Carbary 4L, Dursban 50W-WSP[R]	Begin application when insect populations reach recognized economic threshold levels. Consult the cooperative extension service, conssultants or other qualified authorities to determine apporpriate theshold levels and timing for treatment in your area.	NL	7 d	Toxic to aquatic invertebrates, and bees.
Organophosphates (1B)					
chlorpyrifos	Chlorpyrifos 4E AG[R], Govern 4E[R], Lorsban Advanced[R], Lorsban-4E[R], Nufos 4E[R], Vulcan[R], Warhawk Clearform[R], Warhawk[R], Whirlwind[R], Yuma 4E[R]	Spray when grubs are young and actively feeding near the soil surface, usually during late July and August or as recommended by your local Agricultural Extension Service specialist.	NL	NL	Toxic to fish, aquatic invertebrates, small mammals, birds, and bees.
trichlorfon	Dylox 6.2 GR		NL	7 d	
Pyrethroids, Pyrethrins (3A)					
lambda-cyhalothrin	Demand G, Nufarm Lambda-Cyhalothrin 1 EC[R]	For grub suppression treat any time between late July and early October.	NL	NL	Toxic to aquatic invertebrates, and bees.
Neonicotinoids (4A)					
clothianidin	Arena 0.25 G, Arena 50 WDG	Make applications through peack egg hatch of target species. For applications after egg hatch or when obvious turf damage has occurred use the upper end of the rate range.	NL	NL	Toxic to wildlife, aquatic invertebrates, and bees. **clothianidin & imidacloprid:** Restricted to post-bloom applications only; petals must have dropped.
dinotefuran	Zylam 20 SG, Zylam Liquid	Apply when insect pest populations begin to build, but before populations reach economically damaging levels.	NL	NL	

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 7.1a, continued. Insecticides recommended for control of **JAPANESE BEETLE LARVAE IN COMMERCIAL TURF GRASS** applications in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Neonicotinoids (4A), continued					
imidacloprid	Amtide Imidacloprid 2F T&O, Criterion 0.5 G, Enforce 75WSP, Lada 2F, Malice 0.5 G, Malice 2F, Malice 75 WSP, Mallet 2F T&O, Mallet 75 WSP, Merit 2F, Merit 75WP, Merit 75WSP, Pheonix Hawk-I 2L, Pheonix Hawk-I 75WSP, Widow, Merit 0.5G, rokoz Zenith 0.5 G	Make application prior to egg hatch of the target pest.	NL	NL	Toxic to wildlife, aquatic invertebrates, and bees. **clothianidin & imidacloprid:** Restricted to post-bloom applications only; petals must have dropped.
thiamethoxam	Meridian 0.33G, Meridian 25WG	Make application from egg hatch to second instar (grubs less than half their full size).	NL	NL	
Diamides (28)					
chlorantraniliprole	Acelepryn, Acelepryn G	Apply from early April to early September for preventative and early curative control. The need for an application may be based on historical monitoring of the site, previous records or experiences, current season adult trapping or other methods.	NL	7 d	Toxic to aquatic invertebrates, oysters, and shrimp. Conserves adult predators.
cyantraniliprole	Ference		NL	NL	
Unknown (UN)					
azadirachtin	Azatrol EC[O], Molt-X	Spray as soon as possible when pests are expected or when pests first appear.	0 d	7-10 d	Toxic to fish and aquatic invertebrates.
Other; Pyrethroids, Pyrethrins (3A)					
piperonyl butoxide; pyrethrins	Evergreen EC 60-6	Apply before pests reach damaging levels.	NL	3-7 d	Toxic to aquatic organisms, fish, aquatic invertebrates, and bees.
Other					
peppermint oil; rosemary oil	Ecotec[O]	Spray when pests first appear. Repeat application every 5-7 days.	0 d	5-7 d	May be toxic to bees.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 7.1b. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL TURF GRASS** applications in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Carbamates (1A)					
carbaryl	Sevin SL Carbaryl	Begin application when insect populations reach recognized economic threshold levels. Consult the cooperative extension service, conssultants or other qualified authorities to determine apporpriate theshold levels and timing for treatment in your area.	NL	7 d	Toxic to aquatic invertebrates, and bees. **Labeled for use on lawns for japanese beetle adults.**
Pyrethroids, Pyrethrins (3A)					
beta-cyfluthrin	Tempo SC Ultra	Apply when pests first appear.	NL	NL	Toxic to aquatic invertebrates, and bees. **Labeled for use on lawns for japanese beetle adults.**
bifenthrin	Bisect L, Menace 7.9% Flowable, Menace GC 7.9% Flowable[R], Phoenix Firebird Pro[R], Sniper[R], Up-Star Gold, Up-Star SC[R]		NL	NL	
deltamethrin	Deltagard T&O 5SC, Deltagard T&O Granular, Suspend SC		NL	NL	
lambda-cyhalothrin	Demand G, Lambda-Cy EC[R], Scimitar CS, Scmitar GC[R]		NL	NL	
Pyrethroids, Pyrethrins (3A); Neonicotinoids (4A)					
bifenthrin; imidacloprid	Tempest	Apply when pests first appear.	NL	NL	Toxic to fish, aquatic invertebrates, and bees. **Labeled for use on lawns for japanese beetle adults.**

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 7.1b. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL TURF GRASS** applications in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Neonicotinoids (4A)					
imidacloprid	Malice 75 WSP	Make application prior to egg hatch of the target pest.	NL	NL	Toxic to wildlife, aquatic invertebrates, and bees. **Labeled for use on turfgrass for japanese beetle adults.**

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 7.2. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Carbamates (1A)					
carbaryl	Carbaryl 4L, Sevin 4F, Sevin SL Carbaryl, Sevin XLR Plus	Begin application when insect populations reach recognized economic threshold levels. Consult extension service, consultants or other qualified authorities to determine apporpriate theshold levels and timing for treatment in your area.	3 d grape, caneberry, & strawberry: 7 d	7-14 d grape, caneberry, & strawberry: 7 d	Toxic to aquatic invertebrates, and bees.
Organophosphates (1B)					
malathion	Cheminova Malathion 57%, Fyfanon Helena, Malathion 5, Malathion 57 EC, Malathion 8 Aquamil	Consult local experts for proper timing of applications.	1-7 d caneberry: 1 d grape: 3 d	3-11 d caneberry: 7 d grape: 14 d	Toxic to aquatic organisms, fish, aquatic invertebrates, and bees.
phosmet	Imidan 70-W		7-14 d	NL	
Pyrethroids, Pyrethrins (3A)					
bifenthrin	Bifenture EC[R], Brigade 2EC[R], Brigade WSB[R], Discipline 2EC[R], Fanfare ES[R], Sniper[R], Tailgunner[R], Tundra EC[R]	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels.	For grape only: 30 d	NL	Toxic to fish, aquatic invertebrates, and bees.
bifenthrin; zeta-cypermethrin	Hero EW[R], Hero[R]		For grape only: 30 d	For grape only: 7 d	
fenpropathrin	Danitol 2.4 EC Spray[R]		3-14 d grape: 21 d	10 d grape: 7 d	
gamma-cyhalothrin	Declare[R], Proaxis[R]		14-21 d	5 d	
lambda-cyhalothrin	Grizzly Too[R], Grizzly Z[R], Kendo[R], Lambda T[R], Lambda-Cy EC[R], Lambdastar[R], Lambdastar 1CS[R], Lambdastar Plus[R], Lamcap[R], Nufarm Lambda-Cyhalothrin 1 EC[R], Paradigm[R], Province[R], Silencer[R], Warrior II with Zeon[R], Warrior with Zeon[R], Willowwood Lambda-Cy 1EC[R]		14-21 d	5-7 d	
pyrethrins	Pyganic EC 1.4 II[O], Pyganic EC 5.0 II[O], Tersus		0 d	3 d	
zeta-cypermethrin	Mustang[R], Mustang Maxx[R]		14 d grape: 1 d	7 d grape: 7 d	

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Japanese Beetle

Table 7.2, continued. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Pyrethroids, Pyrethrins (3A); Neonicotinoids (4A)					
beta-cyfluthrin; imidacloprid	Leverage 360	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels.	7 d	14 d	Toxic to fish, aquatic invertebrates, and bees.
bifenthrin; imidacloprid	Brigadier[R], Skyraider[R], Swagger[R]		For grape only: 30 d	For grape only: 14 d	
cyfluthrin; imidacloprid	Leverage 2.7[R]		7 d	14 d	
imidacloprid; lambdacyhalothrin	Kilter[R]		14-21 d	7-10 d	
lambda-cyhalothrin; thiamethoxam	Endigo ZC[R]		14-35 d	7-10 d	
Neonicotinoids (4A)					
acetamiprid	Assail 30 SG, Assail 70WP	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels.	7 d caneberry: 1 d grape: 3 d strawberry: 1 d	10-12 d caneberry: 7 d grape: 14 d strawberry: 7 d	Toxic to aquatic invertebrates and bees. **clothianidin & imidacloprid :** Restricted to post-bloom applications only; petals must have dropped.
clothianidin	Belay		For grape only: 0 d	For grape only: 14 d	
dinotefuran	Scorpion 35SL		For grape only: 28 d	For grape only: 7 d	
imidacloprid	Admire Pro, Advise 2 FL, Advise Four, Amtide Imidacloprid 2F, Amtide Imidacloprid 4F, Couraze 2F, Couraze 4, Couraze 4F, Macho 2.0 FL, Malice 75 WSP, Mana Alias 4F, Midash 2SC AG, Montana 2F, Montana 4F, Nuprid 1.6 F, Nuprid 2SC, Nuprid 4F Max, Pasada 1.6 F, Provado 1.6 F, Sherpa, Wrangler		0-7 d	7-10 d	
	Admire Pro, Advise 2 FL, Advise Four, Alias 2F, Alias 2F Flowable, Amtide Imidacloprid 2F, Amtide Imidacloprid 4F, Couraze 2F, Couraze 4, Courze 4F, Macho 2.0 FL, Mana Alias 4F, Midash 2SC AG, Montana 2F, Montana 4F, Nuprid 2SC, Nuprid 4.6F Pro, Nuprid 4F Max, Wrangler	Apply a single application post harvest to coincide with renovation of strawberry fields and during active egg-laying period of beetles.	14 d	NL	Toxic to aquatic invertebrates and bees. **Labeled for soil applications on strawberries for Japanese beetle larvae.**

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Japanese Beetle

Table 7.2, continued. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Neonicotinoids (4A), continued					
thiacloprid	Calypso 4 Flowable	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels.	14-30 d	7 d	Toxic to aquatic invertebrates and bees.
thiomethoxam	Actara, Platinum, Platinum 75 SG		grape: 5 d (**platinum grape:** 60 d) caneberry: 3 d	grape: 14 d caneberry: 7 d	
Avermectins, Milbemycins (6); Pyrethroids, Pyrethrins (3A)					
avermectin B1; zeta-cypermethrin	Gladiator[R]	Apply as required by scouting. Timing and frequency of applications should be based upon insect populations reaching locally determined economic threshold levels.	28 d	21 d	Toxic to fish, aquatic invertebrates, oysters, shrimp, wildlife, and bees.
Avermectins, Milbemycins (6); Neonicotinoids (4A)					
abamectin; bifenthrin	Athena[R]	Ground application only.	For grape only: 30 d	Max. 1 appl. per growing season	Toxic to fish, aquatic invertebrates, oysters, shrimp, and bees.
abamectin; thiamethoxam	Agri-Flex[R]		For grape only: 28 d	For grape only: 21 d	
Oxadiazines (22A)					
indoxacarb	Avaunt	Make first application at initiation of egg hatch or at the first signs of infestation for each generation.	For grape only: 7 d	For grape only: 21 d	Toxic to mammals, birds, fish, aquatic invertebrates, and bees.
Diamides (28)					
chlorantraniliprole	Altacor, Coragen	Apply at the specified rates when insect populations reach locally determined economic thresholds.	grape: 14 d strawberry: 1 d	grape: 7 d strawberry: 7 d	Toxic to aquatic invertebrates, oysters, and shrimp.
cyantraniliprole	Exirel		3 d	7 d	
Diamides (28); Pyrethroids, Pyrethrins (3A)					
chlorantraniliprole; lambda-cyhalothrin	Voliam Xpress[R]	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels.	14-21 d	7-10 d	Toxic to fish, aquatic organisms, aquatic invertebrates, oysters, shrimp, wildlife, and bees.

Japanese Beetle

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Table 7.2, continued. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN COMMERCIAL FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Diamides (28); Neonicotinoids (4A)					
chlorantraniliprole; thiamethoxam	Voliam Flexi	Apply before pests reach damaging levels. Scout orchards and treat again if populations rebuild to potentially damaging levels. Apply higher rates within the listed rate range for heavy infestations.	grape: 14 d strawberry: 3 d	grape: 14 d strawberry: 10 d	Toxic to wildlife, aquatic invertebrates, oysters and shrimp, toxic to bees.
Unknown (UN)					
azadirachtin	Aza-Direct[O], Azatrol EC[O], Molt-X	Spray as soon as possible when pests are expected or when pests first appear.	0 d	7-10 d	Toxic to fish and aquatic invertebrates.
Other; Pyrethroids, Pyrethrins (3A)					
kaolin clay	Surround WP[O]	Start before infestation and continue at 7-14 day intervals.	0 d	7-14 d	Thorough coverage is important to obtain optimum control; white coating on the fruit may require removal after harvest to make fruit marketable. **Surround WP:** Do not widen respray interval past 14 days, for suppresion only
piperonyl butoxide; pyrethrins	Evergreen EC 60-6	Apply before pests reach damaging levels.	NL	3-7 d	Toxic to aquatic organisms, fish, aquatic invertebrates, and bees.

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[O]Organic= approved by OMRI (Organic Materials Review Institute).

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

[R]Restricted use products= require an applicators license to purchase.

Japanese Beetle

Table 7.3. Insecticides recommended for control of **JAPANESE BEETLE LARVAE IN HOME TURF GRASS** in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Pyrethroids, Pyrethrins (3A)					
gamma-cyhalothrin	Spectracide Triazicide Insect Killer for Lawns & Landscapes	Treat for grubs in early July (or when first noticed) through October.	NL	NL	Toxic to fish, aquatic organisms, and bees.
pyrethrins	Bonide Japanese Beetle Killer	Treat for grubs in early July (or when first noticed) through October.	NL	NL	Toxic to fish, aquatic organisms, and bees.
Pyrethroids, Pyrethrins (3A); Neonicotinoids (4A)					
beta-cyfluthrin; imidacloprid	Bayer Complete Brand Insect Killer For Soil & Turf	Apply through May through July.	NL	NL	Toxic to fish.
Neonicotinoid (4A)					
imidacloprid	Bayer 12 Month Tree & Shrub Protect & Feed	Apply before pests reach damaging levels.	21 d	NL	Toxic to aquatic invertebrates. Restricted to post-bloom applications only; petals must have dropped.

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

Table 7.4. Insecticides recommended for control of **JAPANESE BEETLE ADULTS IN HOME FRUIT** production in Utah

Common Name	Example Brands	Timing of Application	PHI[P] (in days)	Protection Interval[PI] (in days)	Comments
Insecticide Class[I]					
Carbamate (1A)					
carbaryl	Sevin Concentrate Bug Killer	Apply when insects or damage appear. Repeat as necessary to maintain control, following specified spray interval listed for the specific site.	caneberry: 7 d	caneberry: 7 d	Toxic to aquatic invertebrates and bees.
Pyrethroids, Pyrethrins (3A)					
gamma-cyhalothrin	Spectracide Triazicide Insect Killer for Lawns & Landscapes	Apply when insects appear or when damage occurs.	14-21 d	NL	Toxic to fish, aquatic organisms, and bees.
Neonicitinoid (4A)					
acetamiprid	Ortho Flower, Fruit & Vegetable Insect Killer Ready-to-Use	Apply to outdoor plants as soon as insect problems are noticed.	7 d	12 d	Toxic to wildlife, aquatic invertebrates and bees. **imidacloprid:** Restricted to post-bloom applications only; petals must have dropped.
imidacloprid	Bayer 12 Month Tree & Shrub Protect & Feed		21 d	NL	
Other					
neem oil	Bonide Neem Oil	Apply this product at first sign of insects. This product is most effective when applied every 7 to 14 days.	NL	7-14 d	Toxic to bees.
sex attractant and floral lure	Spectracide Bag-A-Bug Japanese Beetle Trap, Bonide Beetle Bagger	Place in lawns but do not place the trap near or in the foliage ou want to protect.	NL	NL	Bags are often attacked and damaged at night by nocturnal animals. Replace damaged bags. **Will attract more beetles into your garden.**

[I]Insecticide Resistance Action Committee (IRAC) mode-of-action classification codes. To minimize resistance development in insect populations, rotate among classes.

Effectiveness of products will vary based on their dosage and timing of application. To minimize insect resistance, rotate applications among insecticide classes. All brand names are registered trademarks. Examples of brands may not be all-inclusive, but are meant to provide examples of insecticides registered in Utah. The availability of insecticides and active ingredients in brands can change. Always read the product labels to ensure that target insect is listed. ALWAYS READ THE LABEL FOR REGISTERD USES, APPLICATION AND SAFETY INFORMATION, PROTECTION, RE-ENTRY, AND PRE-HARVEST INTERVALS.

NL= No time listed

[P]PHI = Pre-harvest interval (required wait-time between application and harvest of crop) in days. Days vary depending on crop.

[PI]Protection Interval= Interval required between applications (in days).

Japanese Beetle

Fig. 7.1. Japanese beetle (JB) adults are ½ inch long and metallic green and copper.

Fig. 7.2. JB adults are ½ inch long and metallic green and copper.

Fig. 7.3. JB eggs are 1/16 inch in diameter and found in the soil.

Fig. 7.4. JB 3rd instar larva, or grub, is up to 1 inch long and found in the soil.

Fig. 7.5. The JB pupa is creamy white to tan and found in the soil.

Fig. 7.6. JB life history illustration.

Fig. 7.7. JB adult leaf-feeding and mating.

Fig. 7.8. JB adult leaf-feeding, and skeletonized leaves.

Fig. 7.9. JB adults feeding plum fruits.

Fig. 7.10. Adult JB feeding on apple.

Fig. 7.11. Adult JB feeding on peach fruit.

Fig. 7.12. JB burrowing in raspberry fruit.

Fig. 7.13. JB eating raspberry foliage.

Fig. 7.14. JB adults feeding on an ornamental evergreen.

Fig. 7.15. JB adults feeding on rose flower petals.

Fig. 7.16. JB adults feeding on corn silk.

Fig. 7.17. Installation of JB trap in an ornamental tree.

Fig. 7.18. JB trap in an ornamental tree.

Fig. 7.19. JB traps: bicolor (left) and all green.

Fig. 7.20. Soil corer used to collect soil and root samples when JB damage to turf is suspected.

Fig. 7.21. Turf injury from JB grub feeding.

Fig. 7.22. Exposed JB grubs in damaged turfgrass.

Fig. 7.23. Damaged turf is easily pulled back to expose grubs in the soil.