GRAPE IPM GUIDE FOR MINNESOTA PRODUCERS

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Introduction

Integrated Pest Management (IPM) utilizes all suitable techniques and methods in as compatible a manner as possible to maintain the pest population at levels below those causing economic injury (FAO 1975). Integrated pest management (IPM) thus is a philosophy based on several guiding principles including the use of control options that are environmentally sound, socially acceptable and economically feasible. These principles promote using pest management options in a way that minimizes impact on the environment, increases grower profits, and provides consumers with quality produce. The foundation of IPM is built on information about both the crop and the pest. Information about the crop that is useful typically includes production practices, soil type and pH, and at what growth stages is the plant susceptible to a particular pest infestation. Likewise, information about the pest that is useful in making management decisions includes when the pest is present in relation to the susceptible growth stage of the crop, what stage of the pest is most easily managed, and what pest level causes economic loss.

These pieces of information can be used individually, or in combination to make effective management decisions. For example, in grapes, *Harmonia axyridis* (multicolored Asian lady beetle) is present in the vineyard throughout the growing season, as indicated by yellow sticky card or visual sampling. However, *H. axyridis* does not become a pest until grapes reach maturity. In fact, *H. axyridis* may even be considered beneficial during vegetative growth stages, feeding on other insects that may pose a threat to grape foliage. Because we know that *H. axyridis* is a pest when grapes are mature, the management, or treatment window is focused on when the grapes are ripe. This allows us to conserve *H. axyridis* in its beneficial capacity, and minimize the use of insecticides prior to the susceptible growth stage. This is just one example of how IPM can be used to effectively and efficiently manage pests in grapes.

Because factors such as rainfall, temperature, and crop yield, vary from year to year and vineyard to vineyard, pest management carries a certain degree of uncertainty. A primary goal of IPM is to minimize these uncertainties and therefore the risk involved in growing grapes. It is our hope that this grape IPM manual will provide Minnesota grape growers with the tools necessary to be successful in managing pests in their vineyards with minimum inputs.

Anthracnose
Elsinoe ampelina

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Grape anthracnose, also called 'bird's-eye rot', is a significant disease in regions with rainy, humid and warm climates. It is not a native pathogen to the U.S. and was most likely introduced via plant material imported from Europe in the mid 1800s. Anthracnose is economically important because it can reduce fruit quality and yield, as well as weaken the vine. It is a relatively minor problem in Minnesota vineyards.

Symptoms

Symptoms, expressed as lesions on shoots and berries, are most commonly seen by growers. Anthracnose infects the stems, leaves, tendrils, young shoots and berries.

Vegetative

Young, infected shoots develop small isolated sunken lesions with round or angular edges and a violet to brown margin. The center of the lesion may extend to the pith of the shoot and a callus will form around the edge. These lesions can cause shoots to crack and become brittle. Anthracnose lesions on shoots can be confused with hail damage; the difference is that anthracnose has raised black edges. Anthracnose infection on the petioles exhibits symptoms similar to the shoots.

Anthracnose on grape leaf
(Photo courtesy of M. Ellis, Ohio State Univ.)

Young leaves are most susceptible to anthracnose. Infected leaves develop many circular lesions with brown or black margins and round or angular edges. The centers will become grayish white and dry. The center tissue will eventually drop out of the lesion creating a "shot-hole" appearance. These lesions may coalesce and cover the entire leaf or develop along vein margins. If veins are infected, lesions will prevent proper development causing malformation or complete drying of the leaf.

Fruit

Berry clusters are susceptible to anthracnose before flowering through veraison. Small, reddish circular spots develop first on the berry. They average ¼" in diameter and may become sunken and have a narrow, dark brown to black margin. The center of the lesion begins as a violet color but becomes velvety and whitish gray over time. This coloration gives the pathogen its common name "bird's eye rot". Berry

Anthracnose on grape berries
(Photo courtesy of M. Ellis, Ohio State Univ.)

lesions can extend to the pulp, causing cracking and opening the berry to secondary infections. Lesions on the rachis and pedicels are similar to those of the shoots.

Disease Cycle

The causal organism of anthracnose is the fungus *Elsinoe ampelina.* Overwintering structures, called sclerotia, stay on infected shoots and produce many spores, conidia, in the spring when there is a wet period of 24 hours and temperatures above 36^{o}F (2^{o}C). The conidia are spread to other plant tissue by free water or rain over 2mm or more. These conidia will germinate, causing a primary infection when free water is present for 12 hours and the temperature is between 36-90^{o}F (2-32^{o}C). The higher the temperature the faster infection will take place. Disease symptoms will develop within 13 days at 36^{o}F and within 4 days at 90^{o}F. Ascospores, spores produced within a sexual fruiting body, also form on infected canes or berries left on the trellis or on the vineyard floor.

Asexual fruiting bodies, called acervuli, form on necrotic areas once the disease is established. These acervuli produce conidia in wet weather which are the secondary source of inoculum for the rest of the growing season.

Temperature and moisture are the key components in influencing disease development. Anthracnose can be very damaging during heavy rainfall and hail.

Control Strategies

The most efficient way to control anthracnose is the use of good cultural practices. Sanitation is a critical component in controlling anthracnose. Prune out and destroy any diseased parts from the vines or vineyard floor, during dormant season. This will reduce overwintering inoculum in the vineyard.

Avoiding susceptible varieties such as *V. vinifera* and some French hybrids, is also important in reducing the impact of anthracnose. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying and allows for full spray coverage and canopy penetration.

Since anthracnose can infect wild grapes, remove any plants near the vineyard. Wild grapes act as an excellent source of inoculum and the disease can develop unnoticed. If the wild grapes can not be removed from nearby wooded areas make sure to clear them from surrounding fence rows since conidia are easily spread by splash dissemination.

Implementing a properly timed spray program assists in managing anthracnose if it is established in a vineyard. A dormant application of liquid lime sulfur should be applied in early spring, prior to bud break. This can be followed by foliar applications of fungicides, from bud break to veraison, during the growing season. For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/. In Minnesota, anthracnose is rarely a problem when a good fungicide program for controlling downy mildew is followed.

There is a limited variety of organic sprays allowed under regulation. Organic growers can use Lime Sulfur or copper sprays, as well as cultural practices, to control anthracnose. Make sure to verify that each registered fungicide is permitted within the organic certification program.

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Black Rot
Guignardia bidwelii

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The black rot fungus, *Guignardia bidwelii,* is a pathogen native to North America and can cause significant crop damage in Minnesota, under the right environmental conditions. Most Minnesota hardy varieties, Frontenac, Frontenac gris and Marquette, are somewhat resistant.

Symptoms

While black rot can infect all parts of the vine, the most significant losses are caused by berry infection. In warm humid climates, susceptible varieties can experience complete loss if the pathogen is left uncontrolled. Fortunately, this level of infection is rarely seen in Minnesota.

Vegetative

Young leaves are susceptible to infection as they unfold, but become resistant once they mature. If infected, small, circular spots that are tan with a dark brown perimeter appear in spring and early summer. They appear about two weeks after the initial infection. Within a few days small black fruiting bodies, pycnidia, will develop around the necrotic area.

Lesions will appear on the petioles in spring and early summer. These lesions may expand and girdle the entire petiole killing the leaf. Infected young shoots will develop elongated black cankers throughout the growing season. If there are numerous cankers blighting of the tips can occur.

Fruit

Early stages of black rot on berries *(J. Hilton, U of MN)*

Berry infection is the most serious phase of black rot, possibly leading to significant economic losses. Berries are susceptible to infection immediately prior to bloom through four weeks after bloom. The first sign, easily missed, is the appearance of a small, whitish dot that is quickly surrounded by a reddish, brown ring. This ring can grow from 0.1mm to 2mm in one day. Within a few days the berry will start to dry out, loosing their spherical shape and becoming flat on one side. These berries will appear light or chocolate brown and quickly turn dark brown and develop black spores on the surface. Eventually, these infected berries will shrivel and become mummies that serve as a secondary inoculum or overwintering structure for the pathogen.

Late stages of black rot on berries *(J. Hilton, U of MN)*

Disease Cycle

Guignardia bidwellii, the causal organism of black rot, overwinters in mummy berries on the vineyard floor or still hanging on the vine. In the spring, with a rain of 0.3mm or more, ascospores and conidia are released and dispersed by wind and water. This process can continue for up to eight hours after one rainfall. Research has shown that ascospores from mummies on the ground are discharged when shoot growth is 1-inch until three weeks after bloom. Mummies left on the vine will discharge ascospores and conidia throughout the growing season.

Ascospores cause primary leaf and blossom infections. These infections occur, in the presence of free water, within six hours at 80°F. A longer wet period is required at cooler temperatures and no infection occurs when temperatures are over 90°F. Once leaves are infected they develop brown circular lesions within eleven days. Black spherical fruiting bodies, pycnidia, develop in a circular pattern just inside the margin of the lesion. Each pycnidium produces hundreds of thousands of conidia which are dispersed by rains lasting 1-3 hours. The conidia will germinate and infect leaves, blossoms and young fruit. It is important to understand that one ascospore can result in millions of secondary conidia infecting the entire vineyard.

Table 1. Time until infection based on temperature

Temperature (°C)	Temperature (°F)	Hours of Leaf Wetness
7.0	45	no infection
10.0	50	24
13.0	55	12
15.5	60	9
18.5	65	8
21.0	70	7
24.0	75	7
26.5	80	6
29.0	85	9
32.0	90	12

R.A. Spotts, Ohio State University

Control Strategies

The most efficient way to control black rot is the use of good cultural practices. Sanitation is a critical component to controlling black rot. If possible, clear all mummies from the ground after leaf drop or till them into the soil prior to bud break. It is critical to remove all mummies from the vines during dormant pruning, since they appear to discharge ascospores and conidia throughout the growing season. This will reduce any overwintering inoculum in the vineyard.

As with any disease, choosing resistant varieties is also an important strategy in reducing the impact of black rot. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying and allows for full spray coverage and canopy penetration.

Implementing a properly timed spray program is essential for managing black rot in the vineyard. Monitoring and spraying should begin immediately before bloom through four weeks after bloom. Black rot can be controlled by proper timing, cultural practices and effective fungicides. For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/.

There are a variety of organic sprays allowed under regulation. Many organic growers utilize fixed copper or sulfur products to control black rot. Chemical methods include ferbam, mancozeb, captan, or nova. Make sure to verify that each registered pesticide is permitted within the organic certification program.

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Bunch Rot
Botrytis cinerea

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Botrytis bunch rot is known as both the vulgar rot and the noble rot when referring to its effect on wine. Both vulgar and noble rot are caused by *Botrytis cinerea*, and the type of rot is dictated by specific climatic changes. *Botrytis* bunch rot, or gray mold of grape, is responsible for an annual loss of approximately 20%, and costs to control *Botrytis* were 780 million dollars in 2002 (Genescope 2002). The greatest losses on grapes due to *Botrytis* are found in tight-clustered varieties of *Vitis vinifera* and French Hybrids (Ellis 2004). Fortunately for Minnesota vineyards, our hardy grapes and relatively dry fall climate have helped to minimize the impact of this pathogen in our area.

Botrytised wines are known under the names of Sauternes from Bordeaux, Tokaji from Hungary, and Rheingau from Germany (Jackish 1985). They require a skilled winemaker and many years to produce, but the effort is well worth it. Many wineries charge anywhere an average of $40-150 for a .75ltr bottle compared to charging $12-$40 for a normal white wine (La Cave 2007).

Symptoms

Some symptoms may be observed in early spring, but the most obvious are not seen until after veraison, the ripening of the berry, when it is too late to prevent.

Vegetative

Symptoms of *Botrytis* on leaves (photo courtesy of Jay W. Pscheidt, Oregon State Univ.)

The first symptoms of *Botrytis* may be observed in early spring on buds and young shoots. Infected shoots and buds may turn brown and dry out. Before bloom leaves may exhibit large, irregular, reddish brown, necrotic patches that are usually localized on the edge of the lamina (Pearson 1998). A gray mold may or may not be observed on the leaf. *Botrytis* can invade the inflorescences before bloom, which causes the bloom dry out and fall off the vine (Pearson 1998). This stage of infection can lead to high yield losses. The pathogen then moves to the end of stamens of aborted berries still attached to the clusters. From these infections *Botrytis* moves to the pedicel or rachis creating small patches that start out brown and turn black. By the end of the season, these infections can girdle the rachis causing any berries below the infection site to wither and drop off (Pscheidt 2007).

Botrytis on white grapes (Photo courtesy of Ed Hellman, Oregon State Univ.)

Fruit

Berry infection is the most common type of infection and can seriously reduce the quality and quantity of the crop (Ellis 2004). After veraison, grapes are infected through the epidermis or wounds. *Botrytis* will progressively invade the entire cluster. It will develop faster in tight clusters where berries are compressed together. The infection tends to start in the center of a cluster and spread out to the entire bunch (Pearson 1998).

Infected berries will appear in late summer. The first sign may be small brown spots on maturing berries or the skin may slip off easily when rubbed (Pscheidt 2007). White grapes will start to turn brown while purple grapes turn reddish in color. If the weather is dry the grapes will dry out, but wet weather will cause them to burst and a gray mold will form on the surface (Pearson 1998). Rotted berries will eventually shrivel and drop off the vine as mummies, hard dead grape tissue (Ellis 2004).

Disease Cycle

Botrytis cinerea has a wide host range attacking both cultivated and wild plants (Agrios 2005). It can live as a saprophyte, attains food, on necrotic, senescent or dead tissue (Pearson 1998). This pathogen overwinters as sclerotia, hard resistant structures, on debris in the vineyard floor or on the vine (Agrios 2005). These sclerotia are resistant to harsh weather and will usually germinate in the spring.

In the spring, *Botrytis* sclerotia germinate and produce conidia, thought to be the primary source of inoculum for prebloom infection of leaves and clusters. The conidia are disseminated by both wind and rain to plant material and germinate when temperatures are between 34-86^{o}F (1-30^{o}C). If free water is present, germination is stimulated by nutrients from pollen or leaves, whereas if there is no free water germination occurs when the relative humidity is at least 90%. Under optimal temperatures and relative humidity, or free water, infection can occur within fifteen hours (Pearson 1998).

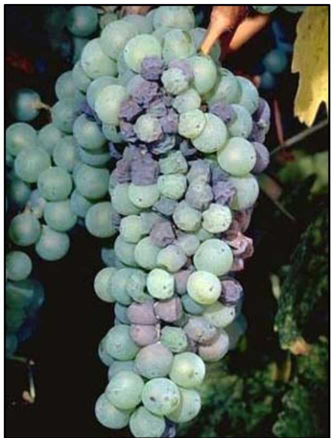
Later in the season hyphae will penetrate directly through the epidermis of healthy berries. Wounds caused by insects, powdery mildew, hail or birds help to facilitate infection (Agrios 2005). Swelling in tightly packed clusters can cause berries to rupture creating excellent infection sites for the pathogen. After infecting the berry, *Botrytis* may stay dormant until the fruit sugar content increases and the acid level decreases enough to support the pathogens growth (Ellis 2004).

Control Strategies

Proper site selection is the first step in controlling *Botrytis* bunch rot. Start with a site where vines are exposed to sun all day since this pathogen thrives in wet and humid conditions. Choosing resistant varieties, such as Frontenac and Frontenac Gris, is also important in reducing the impact of *Botrytis* bunch rot (Rombough 2002).

The most efficient way to control *Botrytis* bunch rot is the use of good cultural practices. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying. This will help reduce the high relative humidity the pathogen needs to infect the plant. Remove leaves around the grape cluster at shatter (Pscheidt, 2007). This will increase air circulation directly around the cluster. Avoid applying excessive nitrogen that will stimulate lush tender growth that is more susceptible to the pathogen (Rombough, 2002). In addition, clear crop debris from the ground after leaf drop or incorporate it into the soil at the beginning of the season. This will reduce the overwintering inoculum in the vineyard.

Noble Rot


Botrytis on a grape cluster
(Photo courtesy of William J. Moller, UC IPM Online)

Under specific climatic conditions *B. cinerea* is known as the noble rot. This type of infection is highly sought after in many regions of Europe, creating some of the world's best sweet white wines. In order for this pathogen to become the noble rot, the temperature needs to be between 68-77^{o}F (20-25^{o}C) and the relative humidity between 85-95% during the infection phase. Following infection, the relative humidity needs to decrease to 60%, which is the key factor in dehydration of the berries (Dharmadhikari 2007).

The best known botrytised wines, Sauternes, are produced naturally in France, Hungary and Germany. The natural conditions in the field make it possible to sporadically make these sought after wines. However, some vineyards in California are producing botrytised wines by artificially infecting grapes with *B. cinerea* and altering the growing conditions. They hold the humidity at the required level for up to fifteen hours then drop it back down. Other wineries in New York are infecting ripe harvested grapes with naturally occurring *B.* and holding them at specific temperatures and humidity for two weeks (Cornerstone Communications 2003). These techniques are new in the wine industry and come with some risk.

Botrytis cinerea creates many changes within the berry. The mycelium penetrates the grape skin allowing the berry to dry. This dehydration leads to a concentration of sugars. The osmotic pressure inside the berry causes the metabolic activity of the pathogen to decrease enabling vintners to create the sweet botrytised wine (Dharmadhikari 2007).

The pathogen causes significant changes in the composition of the grape, therefore special vinification techniques must be used by the vintners. Since the botrytised grape must has a higher sugar content than normal must, it ferments much slower. It is necessary to continually monitor the volatile acidity during and after fermentation to protect the wine from oxidation. The winemaker must also monitor to adjust the amount of alcohol, acid, and sugar to inhibit laccase, which causes browning (Jackisch 1985). The wine is usually fermented in oak and stored in oak casks. Unlike other wines, it is racked every three months for one year and then fined at the end of the first and second year (Jackisch, 1985). Botrytised wines are not ready to be bottled for three years, unlike normal wines, justifying the added expense to the consumer.

Depending on humidity, vintner knowledge and winemaker skill, *B. cinerea* can be a winery's best friend or worst enemy. If this pathogen infects the vineyard early in the season a significant yield loss can be expected. If it attacks grapes at the end of the season and the humidity stays high entire clusters will be lost or ruin the quality of the wine. This common and aggressive pathogen can sit out the harsh seasons, can live off dead tissue, and even wait for sugar levels to increase in the grape. Because of this, any growers producing susceptible grapes must follow a rigorous spray and cultural practice program. If a vintner is lucky and the grapes are infected but the humidity drops, then high quality and high priced botrytised wines may be created. Many growers do not take this risk and work hard to keep *B. cinerea* out of their vineyards.

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Downy Mildew
Plasmopara viticola

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Downy mildew is the single most damaging disease of grapes in Minnesota due to the warm and wet climate during the vegetative growth of the vine. Downy mildew injures grapes by causing deformed shoots, tendrils and clusters. The fungus also causes premature defoliation which impacts fruit ripening and increases susceptibility to winter damage. A major outbreak of this disease can cause severe losses in yield and quality.

Symptoms

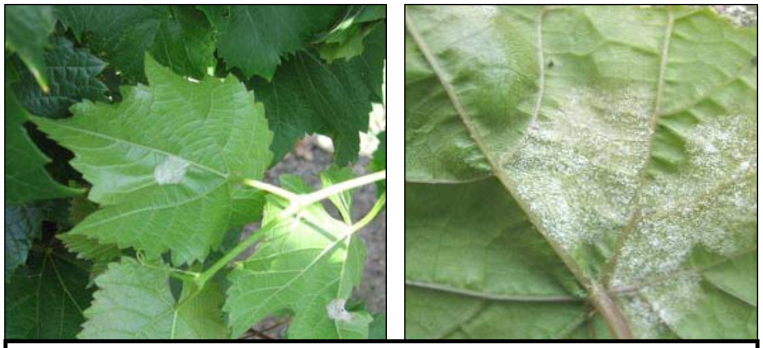
In the Midwest, symptoms usually do not appear before bloom, early season infections do occur.

Vegetative

Upper leaf surface with Downy Mildew *(J. Hilton, U of MN)*

Infected leaves will develop yellowish-green lesions on the upper surface 7 to 12 days after infection. As lesions develop, the affected area becomes brown, or necrotic, and is limited by veins. Fungal sporulation occurs on the lower leaf surface in the form of a delicate, dense, white growth. This downy growth is what gives the disease its name. Leaves that are severely infected may curl and abscise from the vine. This defoliation can decrease winter hardiness and reduce sugar levels in the developing fruit. This type of infection is also the main source of inoculum for berry infection and overwintering for the next season.

Young shoots, tendrils, petioles and inflorescences are also infected by downy mildew. Infected shoot tips will generally thicken, curl and become white with spores. They will, eventually, turn brown and die. Other new growth will exhibit similar symptoms and if they are attacked early enough will die off.



Lower leaf surface with downy mildew, left, and close up view, right *(J. Hilton, U of MN)*

Fruit

Berries infected with downy mildew (Photo courtesy of The Ohio State University)

Young berries are highly susceptible to downy mildew infection. When infected, they appear grayish in color and are covered in a downy felt. Young fruit becomes resistant to infection three to four weeks after bloom. Infected white varieties will turn a dull gray-green while red varieties will turn pinkish red. The infected berries will remain firm in the cluster and are easily distinguished from healthy ripening berries.

Disease Cycle

Plasmopara viticola, the causal agent downy mildew, overwinters on leaf debris as oospores. In the spring these oospores germinate in water when the temperature reaches 52°F (11 °C) and form sporangium. These sporangia release swimming spores, zoospores, which are dispersed to plant tissue via rain/water splash. Once the zoospores are dispersed they swim to the stomata, enter by forming germ tubes and invade inner plant tissues.

Sporangiophores, treelike structures, emerge from the stomata of plant tissue. Sporangia are on the tips of the sporangiophores. This growth requires 95-100% humidity, four hours of darkness and a temperature of 64-72°F (18-22°C). The sporangia are then dispersed by wind or rain/water splash to the stomata of plant tissue. They will germinate in free water with a temperature of 72-77°F (22-25°C) and release zoospores. These zoospores cause secondary infections within two hours of wetting, with a temperature of 77°F (25°C), or within nine hours at a temperature of 43°F (6°C). Infected leaves will start exhibiting symptoms of yellow lesions, seven to twelve days after infection. The secondary infection cycle is dependent on the frequency of suitable weather conditions.

Control Strategies

Proper site selection is the first step in controlling downy mildew. Choose a site where vines are exposed to sun all day through the growing period. Choosing resistant varieties, such as Frontenac, Frontenac gris, Marquette or Marechal Foch, is also important in reducing the impact of downy mildew. The use of good cultural practices can help reduce the incidence of this disease. Utilize pruning and training systems to improve air circulation which promote rapid leaf drying. This will help reduce the wetting period the pathogen needs to infect the plant. Summer pruning and shoot positioning will also help with full spray coverage and canopy penetration.

Clear crop debris from the ground after leaf drop or incorporate it into the soil at the beginning of the season. This will greatly reduce the source of overwintering inoculum in the vineyard. Proper weed control and good soil drainage will reduce the relative humidity which increases the spread of the pathogen.

Implementing a properly timed spray program is essential for managing downy mildew in the vineyard. Downy mildew can be controlled by proper timing and effective fungicides. The most critical time to spray is just prior to bloom and then again approximately fourteen days later. Rainy weather later in the growing season will also cause further outbreaks of this disease. For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/.

Currently the only fungicides approved as an organic option are those containing copper hydroxide and copper sulphate. These sprays only protect vines from new infections; they do not eliminate existing infections and are not systemic. Unfortunately, the use of copper in organic agriculture is of environmental concern. New research is being conducting testing alternatives to copper. These alternatives include plant extracts, biological controls and substances that trigger the vines' immune system. So far, none of these alternatives have proven to be economically viable in controlling downy mildew. This means the best way to organically control this pathogen is through proper cultural practices. Make sure to verify each registered pesticide is permitted within the organic certification program.

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Eutypa Dieback
Eutypa lata

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Eutypa dieback in vine (Photo courtesy of P. Rolshausen, Univ. of Connecticut)

Grape Eutypa dieback is one of the most destructive woody tissue diseases found in commercial grape production. The pathogen is the canker-and-shoot dieback phase of what was called dead-arm disease, and is a growing problem in the Midwest. It is important to note that for many years, phomopsis was thought to be the cause of dead-arm disease. Researchers discovered, in 1976, that this disease was actually cause by two fungal pathogens: phomopsis, which causes the spotting phase of the disease, and eutypa dieback.

Symptoms

The symptoms of eutypa dieback are seldom seen in grapevines under six years old. Younger vines can be infected but will not exhibit noticeable symptoms for two to four years after infection.

Vegetative

The most obvious signs for grower to look for in the field appear in the spring when healthy shoots are 12-24 inches long. Shoots growing on infected canes will appear deformed and discolored. Young leaves will appear smaller, cupped and chlorotic (yellow). They may develop small necrotic spots and tattered margins. These leaf and shoot symptoms are not as obvious later in the growing season due to healthy vigorous growth obscuring diseased growth. The leaf symptoms will become more pronounced each year until the infected portion of the vine dies.

Eutypa dieback in vine (Photo courtesy of M. Ellis, Ohio State Univ.)

The earliest symptom is a canker that develops around pruning wounds, made several years earlier, on the older wood of the main trunk. They are rather difficult to see because they are covered with bark. A flattened area may be observed on the trunk indicating the canker under the bark. Removing the bark reveals a defined discolored area of wood bordered by white, healthy wood. When the infected wood is cut in a cross section a wedge-shaped zone of necrotic sapwood extends from the point of origin of the canker to the center of the trunk.

Fruit

The fruit of infected vines do not exhibit many symptoms. Clusters on infected shoots may have a mixture of small and large berries. This alone is not definitive proof of a eutypa dieback infection.

Disease Cycle

Eutypa lata, the causal agent of eutypa dieback, can survive over many years in the trunks of infected living vines and dead grape wood. Eventually, reproductive structures, called perithecia, are produced on the surface of infected wood. When free water is available, as either snowmelt or rainfall, ascospores are discharged and disseminated via air currants for long distances. Spores are released in the winter and early spring, the same time vines are being pruned. The ascospores can land on the pruning wounds and germinate causing a new infection. Ascospores germinate within 11-12 hours when the temperature reaches 68-77^{o}F (20-25^{o}C). Symptoms develop after several growing seasons.

Control Strategies

The most efficient way to control eutypa dieback is the use of good cultural practices. Eutypa dieback is viable in the field for many years. Due to this viability it is important to prune out and destroy any diseased parts from the vines or vineyard floor, during dormant season. Infected vines must be cut off below the canker or discolored wood. If the canker extends below the soil line, the entire vine should be removed to ensure removal of the pathogen. Early spring is the best time to remove infected vines. Burning or burying infected plant material will reduce overwintering inoculum in the vineyard. If possible, use only pathogen-free propagation materials or nursery stock to avoid introducing infection into the vineyard.

Currently, there are no eutypa dieback-specific fungicides, organic or conventional, available on the market.

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Phomopsis Cane and Leaf Spot
Phomopsis viticola

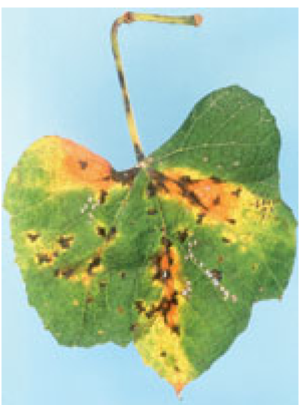
Joy Hilton, Department of Horticulture, and Dimitre Mollov, Plant Disease Clinic, Department of Plant Pathology, University of Minnesota

Grape Phomopsis cane and leaf spot, once called dead-arm disease, is a growing disease in the Midwest. In some states 30% crop loss has been reported in a growing season where weather conditions were conducive to pathogen growth. Fortunately, that level of damage has not been seen in Minnesota vineyards. Most crop loss is due to infection of the rachis and the berry.

It is important to note that for many years, phomopsis was thought to be the cause of a dead-arm disease. Researchers discovered, in 1976, that this disease was actually cause by two pathogens phomopsis, which causes the spotting phase of the disease, and Eutypa dieback, which case the canker and shoot dieback phase.

Symptoms

Vegetative



Phomopsis on grape leaf (Photo courtesy of M. Ellis, Ohio State Univ.)

The most common symptoms observed in the field are those on the shoots of the vine. Chlorotic spots with dark centers spread over infected tissue and develop into black spots or elliptical lesions. These lesions tend to coalesce, when numerous, and appear as dark blotches covering as much as the first three basal internodes of the shoot. These lesions may make the shoots susceptible to wind damage, but they do not directly cause crop loss. It is important to understand that these shoot lesions are an extremely important source of inoculum for cluster and fruit infections in the spring.

Infection of the leaf blades appear as small, light green or chlorotic spots with dark green centers. Leaves may be puckered along the veins or the margins may be turned under. Dark brown spots can also appear along primary or secondary veins and petioles. These necrotic spots may drop out creating a ‘shot-hole’ effect on the leaf. Cluster stems are also infected causing blight or breakage.

Fruit

Fruit and the rachis can become infected throughout in the growing season, but are most susceptible in early spring. When the green fruits become infected they appear normal with the pathogen remaining latent. When the fruit starts to ripen closer to harvest, the pathogen becomes active causing the fruit to rot. The fruit will turn light brown and shrivel, resembling black rot infected fruit. It is important to remember that phomopsis symptoms appear at harvest, whereas black rot symptoms usually appear before harvest.

Disease Cycle

Phomopsis viticola, the causal agent of phomopsis can and leaf spot, overwinters as pycnidia on infected wood between one and three years old. When the pycnidia are wet they exude spores that are washed or splashed to developing shoot tips. These spores germinate when temperatures are between 34-90^{o}F (1-32^{o}C). With an optimal temperature of 74^{o}F (23^{o}C) and free water, or 100% relative humidity, infection can take place within a few hours. Symptoms will appear within 21-30 days after infection.

If there is a known problem in one area, it can become severe when rain continues for several days in early spring. When the temperature is between 41-45^{o}F (5-7^{o}C) shoot growth slows, causing any shoots between 3-10 cm to become very susceptible to infection. If the cool and wet weather is prolonged the pathogen can thrive and infection can spread causing and epidemic. With successive cool, wet springs, the inoculum will build up and infections will become more severe over time.

It is important to understand that the pathogen tends to spread within a vine, not from vine to vine so spread within the vineyard is localized. Long distance spread of phomopsis is normally caused by transportation of infected or contaminated propagation materials or nursery stock.

Control Strategies

The most efficient way to control phomopsis cane and leaf spot is the use of good cultural practices. Aeration is critical in controlling this pathogen. Pick a vineyard location with good air drainage and arrange the rows so that air movement after a rain is maximized. Establishing good ground cover in the rows and mulching under the vines will reduce splash dissemination and spread of the pathogen. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying and allows for full spray coverage and canopy penetration.

Phomopsis is viable in the field for several years. Due to this extended viability it is important to prune out and destroy any diseased parts from the vines or vineyard floor, during dormant season. Burning, burying or discing infected plant material will reduce overwintering inoculum in the vineyard. Use only pathogen-free propagation materials or nursery stock to avoid introducing infection into the vineyard.

If spray treatments are required, spring foliar applications are recommended when rainfall is predicted after budbreak. Sprays should be applied before the first rain after budbreak, before shoot length reaches 0.5 inches and again when shoots reach 5 inches in length. Contact materials, such as copper or sulfur, may need to be reapplied after significant rainfall.

There are not currently any phomopsis specific fungicides approved for organic certification. Most growers use a copper based spray, applied once or twice, early in the growing season. For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/. Make sure to verify that each registered fungicide is permitted within the organic certification program.

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Powdery Mildew
Uncinula necator

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Powdery mildew is one of the most important grape diseases worldwide. In Minnesota, it is a significant disease of grapes, however, it is less economically important than downy mildew. Uncontrolled, powdery mildew reduces vine growth and yield, and can also effect fruit quality and winter hardiness. *Vitis vinifera* and some hybrids (especially those derived from *V. amurensis*) tend to be more susceptible than American varieties.

Symptoms
If powdery mildew is left untreated on the berry it can destroy infected clusters. Foliar infections can reduce photosynthesis causing reduced Brix levels and vine growth.

Vegetative


Powdery mildew on upper surface of leaf

On leaves, powdery mildew appears as white or grayish-white patches on the upper surface. These patches can expand until the entire upper surface of the leaf is coated. Uninfected cells, next to infection sites, may become necrotic. Occasionally, these spots resemble the “oil spot” symptom of downy mildew. Heavily infected leaves may dry out and prematurely drop. When young leaves are infected they will become distorted and stunted as they expand.

Young, infected shoots develop dark brown lesions that remain as brown patches on the dormant stems. Petioles and cluster stems are also susceptible to infection. If infected they become brittle and break during the growing season.

Fruit

Blossom clusters can become infected causing flowers to wither and drop without setting fruit. Cluster infections occurring shortly after bloom may result in poor fruit set and crop loss. Actual berry infection causes the highest level of economic loss. Affected berries may show small spots, similar to the leaves, or may be covered by the white, powdery growth. If the epidermis of fruit is infected before it attains full size it will not grow properly.

If a berry is severely infected, powdery mildew kills the epidermal cells while the pulp continues to expand. The internal pressure causes the berry to split. This splitting opens up the fruit to secondary bunch rot infections. Infected red and purple varieties will fail to color and have a blotchy appearance. Some berries will develop a netlike pattern of scar tissue over the surface and may produce off-flavors in wine. Berries are susceptible to infections until they reach 8% Brix content, from bloom through a few weeks after bloom.

Disease Cycle

Uncinula necator, the cause of Powdery Mildew, overwinters in Minnesota as cleistothecia, fruiting bodies, in bark crevices on the grape vine. In the spring cleistothecia discharge ascospores, airborne spores, when they receive an average of 0.10 inch of rain and an air temperature of 50^{o}F. The ascospores are discharged within 4-8 hours of the rainfall and are carried by wind to any green surface of the growing vine.

The first infections are often observed as individual colonies growing on leaves closest to the bark. The pathogen develops another type of spore, conidium within 6-8 days, if the temperature is between 43-90^{o}F (6-32^{o}C). The optimal range for development is 68-81^{o}F (20-27^{o}C) and temperatures above 95^{o}F (35^{o}C) have been reported to inhibit or kill colonies. High relative humidity, 40%-100%, rather than free rain, is conducive to the production of this pathogen. These conidia and fungal mycelia are what give the powdery appearance to infected tissue and cause further spread of the pathogen.

Control Strategies

Proper site selection is imperative in controlling powdery mildew. Start with a site where vines are exposed to sun all day since this pathogen thrives in low, diffuse light. Choosing resistant varieties, such as Frontenac and Frontenac gris, is also important in reducing the impact of powdery mildew. The most efficient way to control powdery mildew is the use of good cultural practices. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying. This will help reduce the high relative humidity the pathogen needs to infect the plant. Shoot positioning and summer pruning will also help with full spray coverage and canopy penetration.

Clear crop debris from the ground after leaf drop or incorporate it into the soil at the beginning of the season. This will reduce any overwintering inoculum in the vineyard. Proper weed control and good soil drainage will reduce the relative humidity which increases the spread of the pathogen.

Implementing a properly timed spray program, starting early in the season, is essential for managing powdery mildew in the vineyard. Monitor and spray susceptible varieties, particularly *vinifera* varieties*,* regularly. Look for white powdery spots on the upper surface of the leaves and powdery fungal growths on the berry or discoloration during ripening. Powdery mildew can be controlled by proper timing and effective fungicides. For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/.

There are a variety of sprays allowed under organic regulation. Many organic growers utilize sulfur products to control powdery mildew starting at budbreak. They need to be applied every seven days or reapplied whenever they are washed off by rain or irrigation, which may not be cost effective in Minnesota. There are various oils, biofungicides and soaps used to control powdery mildew. Make sure to verify each registered pesticide is permitted within the organic certification program.

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Sour Rot

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Sour rot of grapes is caused by various undesirable yeasts and acetic acid bacteria rather than a single pathogen. Sour rot impacts both grape yield and wine quality by spreading throughout grape clusters. Infected grapes give an unpleasant, vinegary finish to wines and increases volatile acids.

Symptoms of infected grapes appear similar to botrytis rot. Grapes leak juice that smells like vinegar. White varieties will appear brick colored and red varieties will appear purple or brown. Large numbers of fruit flies are common and will spread the infection to other clusters.

Sour rot infection is favored by warm, humid, wet weather and tight clustered varieties with little room for berry expansion. The most efficient way to control sour rot is to plant loose-clustered varieties like Frontenac and La Crescent., and utilize pruning and training systems to improve air circulation which promotes rapid fruit drying. Leaf removal between fruit set and veraison may also be beneficial.

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Bitter Rot
Melanconium fuligineum

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Bitter rot of grapes has not yet been observed in Minnesota, but is still an important disease to understand. The fungus creates a very bitter taste in infected berries, and if only 10% of the berries used in a winemaking are infected an entire batch of wine may be undrinkable. This fungus is more common in Southern climates, but may become an issue for Minnesota growers as our climate changes.

Symptoms

The symptoms of bitter rot can be easily confused with those of black rot. The main difference is that bitter rot symptoms appear as brown lesions only on ripe grapes, not on green grapes like black rot. Bitter rot lesions spread around the berry, in concentric circles over a short period of time. The berries will hold their shape, but appear dull brown.

Control Strategies

Melanconium fuligineum, the causal agent of bitter rot, overwinters in plant debris in the vineyard. Mummies, dried berries from the previous season, are the most common source of inoculum. Fungal growth is favored by warm, humid, wet weather.

The most efficient way to control bitter rot is the use of good cultural practices. Sanitation is the critical component to controlling bitter rot. Clear all mummies from the ground after leaf drop or till them into the soil prior to bud break. This will reduce any overwintering inoculum in the vineyard. Utilize pruning and training systems to improve air circulation which promotes rapid leaf drying and allows for full spray coverage and canopy penetration.

For the most current spray recommendations refer to the Ohio State University Extension web site, http://ohioline.osu.edu/b861/. If seeking organic certification make sure to verify that each registered fungicide is permitted within the organic certification program.

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Crown Gall
Agrobacterium tumefaciens

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Crown gall of grapes is caused by the bacterium *Agrobacterium tumefaciens* and is common throughout the world where grapes are grown. Vines suffering from winter injury due to cold winter temperatures are much more likely to be affected, because the pathogen infects through injury to the lower trunk and callus formation following trunk splitting initiates gall development. In the absence of any trunk injury, vines may carry the bacterium for many years without forming any galls.

Symptoms and Disease Cycle

Crown gall on grape vine
(Photo courtesy of M. Ellis, Ohio State Univ.)

Symptoms begin near the base of the trunk as small, smooth cankers. Galls can also occasionally be observed on fruiting canes and even on roots. Infected grape vines have weak vigor with chlorotic leaves and usually smaller clusters. These plants are more prone to injury by low temperatures.

The bacterium, *A. tumefaciens* is found in the soil, infected plant debris, vines and galls. Infection occurs through wounds, i.e. winter damage, late pruning, hail damage. Subsequent to infection the bacteria injects small piece of its DNA into the host DNA, resulting in plant cell transformation. The foreign bacterial DNA 'programs' the host cells to produce metabolites (opines) utilized by the pathogen. The infected hyperplastic and hypertrophic host cells result in the gall formation. The galls are in fact the plant's own misshaped parenchyma and vascular cells. The involvement of the vascular bundles (phloem and xylem) results in limiting water and nutrient transport – girdling and eventually killing the plant. Experimental data shows that *A. tumefaciens* infects the plant systemically. Any propagating material from infected plants has the potential of spreading the disease.

Control

The major measure to prevent this disease is to use disease-free stock when establishing a new vineyard. In established vineyards infected vines should be removed from the site prior to replanting. Avoiding mechanical injury during cultural practices will reduce the incidence of the disease. Utilizing chemicals to control crown gall has proven ineffective. Crown gall can usually be avoided by planting cold hardy varieties that are not susceptible to trunk splitting winter injury.

Fanleaf Degeneration

Dimitre Mollov, Plant Disease Clinic, Department of Plant Pathology, University of Minnesota

Fanleaf Degeneration (Howard F. Schwartz, Colorado State University)

Fanleaf degeneration is caused by the Grapevine Fanleaf Virus (GFLV). Symptoms produce fan-shaped leaves resembling 2,4-d injury. The vines have abnormal branching, proliferating shoots, and short internodes. GFLV affects fruit set and quality. Clusters are smaller and have irregular ripening. The virus is spread by the dagger nematode *Xiphinema index.* The roots of infected vines can serve as inoculum for months after the vine has been removed.

Controlling the disease can be accomplished by several ways. The main prevention method for the disease is by controlling the virus vector. Fumigation prior of planting can be the best way of bringing down the population of *X. index*. Once a vineyard is established, eliminating the vector is not possible. Resistant germplasm to GFLV and the vector can also be utilized. The main control measure is to use virus-free material, planted in nematode free soil. Fortunately, GFLV is quite rare in Minnesota.

Tomato/Tobacco Ringspot Virus Decline

Dimitre Mollov, Plant Disease Clinic, Department of Plant Pathology, University of Minnesota

Tomato and tobacco ringspot virus decline is caused by two closely related viruses: Tomato Ringspot Virus (TomRSV) and Tobacco Ringspot Virus (TRSV) respectively. Based on symptoms these two viruses cannot be separated. In the year infection occurs, mosaic and leaf chlorosis is usually evident. More severe symptoms are pronounced in the second year. The vines are generally weaker and buds die more readily from freezing winter temperatures. Smaller leaves, shorter internodes, and reduced yield are typical symptoms for these two viruses. In the third year the vine is significantly stunted but may survive for more than three years with no yield. The control of TomRSV and TRSV is mainly by using virus-free material but resistant varieties and rootstocks may be utilized. Large numbers of plant species can host these viruses; therefore weed infestation should be reduced.

Grape Berry Moth

Tederson Galvan, Suzanne Wold-Burkness, and E.C. Burkness, Department of Entomology, University of Minnesota

The grape berry moth (GBM), *Endopiza vitana* Clemens (Lepidoptera: Tortricidae), is a major pest of grapes in the Eastern U.S., and is capable of causing serious economic loss to commercial vineyards in the Midwest. It is native to the eastern United States, and can be found as far west as the Rockies. The grape berry moth feeds only on grapes and has two to three generations per year in Minnesota. Damage is caused by larvae feeding on flower clusters and fruit.

Identification

Grape berry moth adult on a sticky trap *(E.C. Burkness & T.L. Galvan, U of MN)*

The adult grape berry moth is an inconspicuous, mottled brown-colored moth with a bluish-gray band on the inner halves of the front wings. It is approximately 1.2 cm long, with a wingspan of 0.8 to 1.3 cm. The newly hatched larva is creamy white with a dark brown head and thoracic shield. Later instars are green to purple in color, and are 0.8 cm in length when fully grown.

Biology & Life Cycle

Grape berry moths overwinter as pupae within curled grape leaves and in the leaf litter along the edges of woods and under vines. Adult moths emerge in mid to late May, and mate. Females lay eggs on or near grape flower clusters. Larvae hatch from eggs in 4-8 days, depending on temperature. Emergence of the overwintering generation peaks in mid-June and continues to mid-July. Larvae that hatch in June make up the first generation. Larvae feed on stems, blossom buds, and berries. Often they feed inside webbing which can cover the entire cluster. Larvae will burrow into berries that are 0.3 cm in diameter, and will successively feed on 2-3 berries. When the first generation is mature, larvae either move to a leaf where they cut out a circular flap to construct a pupation chamber or pupate in the fruit cluster where they fed.

First generation adults begin to fly in late July, and the flight peaks in early August, however, adult moths continue to emerge until early September. Second generation larvae usually burrow into berries where they touch or where the berry is connected to the stem. Conspicuous red spots develop on the berries at the point of larval entry, and are referred to as "stung" berries. Larvae of the second generation complete their development in late September and pupate in fallen leaves and debris on the ground. Typically this is the 2nd and last generation of the year but with high summer temperatures a 3rd generation may be possible.

Damage

Grape berry moth injury *(E.C. Burkness & T.L. Galvan, U of MN)*

The larvae cause economic injury in three ways: 1) contamination of fruit, 2) reduction in yield, and 3) entry points for diseases.

Late-instar first generation larvae, and all larval instars of the second generation feed only on the berries. Injured berries ripen prematurely, split open and shrivel (see picture, left). Webbing produced by larvae prevents the berries from dropping. Feeding by GBM larvae not only reduces yield and contaminates the crop, but their feeding creates infection sites for fruit rots and feeding by fruit flies. At harvest, severely infested clusters may contain several larvae. Wine made from this fruit may be poor quality.

Management

Monitoring

Most vineyards have either consistently high or low damage from GBM each year. Because of this, researchers at Cornell have come up with a relatively simple risk assessment that growers can use to assess the potential threat of GBM damage in their vineyard. Three major factors that predict GBM damage severity in a vineyard are 1) whether vineyards are bordered by wooded areas or hedgerows, 2) winter temperature and snow cover in the vineyard and 3) GBM infestation history in the vineyard. See the 1991 publication, *Risk Assessment of Grape Berry Moth and Guidelines for Management of the Eastern Grape Leafhopper*, for more information http://nysipm.cornell.edu/publications/grapeman/files/risk.pdf

Sticky trap in vineyard *(T.L. Galvan, U of MN)*

Sticky traps with a pheromone lure can be used to monitor GBM emergence. Traps should be placed in the vineyard in the early spring, prior to bloom (see picture, left). A minimum of 3 traps/10 acre vineyard block should be used. Traps should be hung from the top wire of the trellis, and placed around the perimeter of the vineyard. Check the traps twice a week for the presence of GBM and record the date of the first moth capture.

Visually examining grape clusters is necessary to determine the severity of grape berry moth damage. As a part of the Cornell IPM program, the following sampling protocol is recommended: select four areas in the vineyard to be sampled (two in the center of the vineyard, and two on the edge of the vineyard). Visually inspect, at random, 10 clusters on each of five vines (a total of 50) in each of the four areas. Record the number of GBM-damaged clusters in each area. Compute separate totals for the center areas and the edge areas to determine the percentage of damaged clusters. For the July sampling date, treatment should be applied if the percentage of the clusters with damage exceeds six percent.

Cultural & Physical Control

Destroying dead leaves may reduce grape berry moth emergence in the spring. In addition, burying leaf litter covering leaves with one inch (2.5 cm) of compacted soil will prevent emergence. Both of these actions must be completed three weeks prior to bloom.

In light infestations, injured berries can be removed by hand; however this may not be a feasible option for larger vineyards.

Biological Control

Trichogramma spp. (Hymenoptera: Trichogrammatidae), an egg parasitoid, can provide some control of GBM. However, since grape berry moth is not a preferred host, relying solely on the resident population of *Tichogramma spp.* is unrealistic. Instead, augmenting the population with releases of *Trichogramma sp.* may be necessary to provide noticeable control. In New York, Cornell researchers made inundative releases of *T. minutum* and found significantly lower levels of berry injury from GBM in plots where releases were made, compared to control plots and plots treated with conventional insecticides

Chemical Control

Where grape berry moth is an annual problem, post bloom sprays of insecticides may be necessary, and mid to late summer may be needed to control the second generation. The number of spray applications depends on the amount of infested berries a grower is willing to accept. Several insecticides provide good control of GBM, and can be found in the Midwest Small Fruit Pest Management Handbook.

Mating Disruption

Mating disruption is based on the principle that when a specific pheromone is released in the air in sufficiently high quantity, the males are unable to orient to the natural source of pheromone, and fail to locate the calling female which prevents reproduction. The strategy is implemented by installing pheromone dispensers (Isomate GBM Plus, http://www.pacificbiocontrol.com/Labels%20&%20MSDS_files/GBMPlus-1PP(2004,Dec).pdf) prior to moth emergence at a rate of 200-400 dispensers per acre (higher rates for high-risk vineyards). The dispensers are easily attached to the upper training wire of the trellis. This strategy has proven effective in both Eastern and Midwestern vineyards.

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Grape Flea Beetle

Suzanne Wold-Burkness, E.C. Burkness, and Tederson Galvan, Department of Entomology, University of Minnesota

Grape flea beetles, *Altica spp*. (Coleoptera: Chrysomelidae) are small beetles that have enlarged rear legs that allow them to jump like a flea when disturbed. Two species of grape flea beetle, *Altica chalybea* and *A. woodsi* have been found in Minnesota, however, only the presence of *A. woodsi* has been confirmed. Both species are often found at the same time on the same host plant, *Vitis spp*. and Virginia creeper, *Parthenocissus quinquefolia*, and are capable of causing economic damage to grapes.

Identification

Grape flea beetle adult *(E.C. Burknss & T.L. Galvan, U of MN)*

Grape flea beetles are small insects, approximately 0.3 – 0.5 cm long, shiny, with enlarged hind legs used for jumping. In the field, they can be identified by their size and coloration. *A. chalybea* is dark blue or blue-purple, larger than *A. woodsi*, and the body is 0.3-0.5 cm long, whereas *A. woodsi* is blue-green in color and somewhat smaller (0.4 cm).

Biology and Life cycle

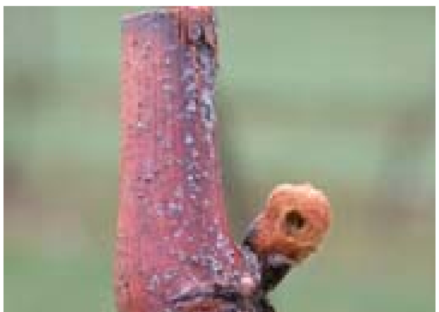
Grape flea beetle larvae *(E.C. Burkness & T.L. Galvan, U of MN)*

Both species have similar biology, life cycle, and feeding behavior, but differ slightly in their oviposition behavior. *A. chalybea* oviposits on buds and bark crevices, whereas *A. woodsi* oviposits on the underside of leaves later in the season.

Both *Altica spp.* overwinter as adults under the soil surface, in wood crevices, under rocks and fallen trees, and in vineyards. In the early spring, adults emerge from overwintering sites, feed upon grape buds, and mate. Females lay cylindrical shaped eggs near grape buds under the bark of the grape vines. Larvae emerge in about two weeks, and feed on leaves. First instars of *A. chalybea* feed on the upperside of leaves, while those of *A. woodsi* feed on the underside of leaves. Newly hatched larvae are dark brown but eventually turn light brown and are 0.7 to 0.9 cm in length at maturity. Between late June and late July, larvae fall on the ground to pupate just below the soil surface. Adult beetles emerge in late July to early August, feed on grapevine leaves, but do not mate or lay eggs. Adults move to overwintering sites in the fall. There is one generation per year.

Damage

Grape flea beetle adult on a damaged bud *(T.L. Galvan & E.C. Burkness, U of MN)*



Grape flea beetle damage to grape bud *(E.C. Burkness & T.L. Galvan, U of MN)*

Damage is caused by adult beetles feeding on primary buds, which prevents them from developing into shoots, thus resulting in a decreased yield. The greatest economic loss occurs when beetles feed on buds from "bud swell" until the "first leaf separates from the shoot tip" stages (see Appendix A). Once shoot growth reaches 7 cm, damage caused by the grape flea beetle normally does not affect yield. Location of vines can affect the intensity of an infestation, with vines on the borders of the vineyard and next to wooded areas having higher infestations. In addition, weather can also affect the intensity of the damage. Cooler springs will extend the period of development when buds are more susceptible to the beetle feeding, thus increasing the chance of economic loss.

Although primary damage is caused by adult flea beetle to the developing buds, larval damage can also occur on the foliage and is typically limited to several leaves and vines. However, larval damage does not usually affect grape quality or yield.

Management

Monitoring

Grapes should be sampled during the "bud swell" to the "first-leaf separated from shoot-tip" stages, which is generally during late April – early May. Sampling should be done twice per week by checking for damaged buds and flea beetle adults. The current suggested threshold is 5% damaged buds.

Cultural/Physical Control

Remove debris and leaf litter on the edges of wooded areas located near vineyards to eliminate overwintering sites. In addition, shallow disking the area between grape rows can also help destroy overwintering pupae.

Chemical control

Several insecticides provide good control of grape flea beetle, and can be found in the Midwest Small Fruit Pest Management Handbook.

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Multicolored Asian Lady Beetle

Suzanne Wold-Burkness, E.C. Burkness, and Tederson Galvan, Department of Entomology, University of Minnesota

The multicolored Asian lady beetle, *Harmonia axyridis* (Coleoptera: Coccinellidae), MALB, has recently become an economically significant contaminant pest in the wine-making process in the eastern and Midwestern United States. MALB is a predatory lady beetle native to eastern Asia that was first detected in Minnesota in 1994. Since its initial detection in the U.S., MALB has rapidly spread to cover much of the continental United States and parts of Canada.

Identification

MALB adults are approximately 0.5-0.8 cm long and round. The coloration of MALB adults ranges from orange to red with zero to 19 black spots, to black with red spots. The most distinguishing feature of adult MALB is the black "M"-shaped marking on the center of the pronotum (shield-shaped area behind the head). Eggs are yellow and oval-shaped. MALB larvae are alligator-shaped with black and orange markings, and are spiny in appearance.

MALB eggs on a grape *(T.L. Galvan & E.C. Burkness, U of MN)*

MALB adult, larva, and pupa *(U of MN)*

Biology & Life Cycle

In the spring, MALB adults leave their overwintering sites and mate. Adults then seek out colonies of aphids. Eggs are laid in clusters of 20-30 on the underside of leaves near aphid colonies. Larvae develop through four instars. At temperatures near 80ºF, development from egg to adult requires about 18 days. The developmental rate will increase with increasing temperature.

Grape berry with splitting (*T.L. Galvan, U of MN*)

At the end of the summer, MALB starts to prepare for winter by accumulating fat and sugar reserves. MALB adults move to vineyards, orchards, and other autumn ripening crops to feed on injured fruit (Koch and Galvan 2008). In the vineyard, grape clusters that have been injured due to physiological splitting, yellowjackets or birds are an attractive option for MALB. The proportion of injured berries increases in the 2-3 weeks prior to harvest offering accessible feeding sites for MALB populations that are searching for fat and sugar reserves. This may be a primary explanation as to why grape growers in the Upper Midwest notice MALB on previously injured grapes near harvest.

Adult MALB migrate from fields and wooded areas to buildings in the fall. Ohio researchers have found that the fall migratory flights generally begin on the first day temperatures exceed 64ºF following the first cold spell with temperatures dropping to near freezing. MALB seek out cracks or holes where they will spend the winter in clusters of few to many individuals. There are two generations of MALB each year.

MALB adults on a building *(U of MN)*

MALB adult aggregation *(U of MN)*

Damage

MALB adult on a grape berry *(E.C. Burkness & T.L. Galvan, U of MN)*

MALB can be a devastating contaminant in wine production. MALB is difficult to remove from clusters of grapes during harvest. Subsequently, some of the MALB may be crushed with the grapes during processing. The flavor of the resulting wine can be tainted by the alkaloids contained in MALB. Adults tend to aggregate on clusters with injured berries just before harvest, and eventually they may be incorporated with the grapes during wine processing (Koch et al. 2004, Pickering et al.2004). Once disturbed or crushed, MALB releases a yellow fluid, via reflex bleeding, that contains alkaloids and alkylmethoxypyrazines that are thought to be used as a defense mechanism or an aggregation pheromone. In addition, alkylmethoxypyrazines could be responsible for affecting wine flavor after MALB has been crushed along with the grapes. Tainted wine and the unacceptable taste associated with it could lead to economic losses for the wine industry in Minnesota and other states and provinces in the Great Lakes region.

Management

Cultural

Research from the University of Minnesota suggests that MALB have a preference for grape clusters that have existing damage from splitting, fungal disease, or grape berry moth feeding damage. Therefore, managing your vineyard to prevent these problems reduces the attractiveness and infestation of grape clusters by MALB. In addition, varieties with a tight cluster structure tend to have high rates of splitting; therefore, variety choice may influence MALB infestations.

Monitoring & Thresholds

MALB on a yellow sticky trap *(T.L. Galvan, U of MN)*

Early detection of movement of populations into vineyards can be accomplished by using yellow sticky traps. The sticky traps should be placed in the vineyard beginning about 4 weeks before harvest is anticipated.

In addition to monitoring movement into the vineyards, clusters should be examined to determine the need for an insecticide application. Because MALB can affect the flavor of the wine, sensory thresholds, which look at the interaction among flavor compounds in the wine, are being used. Currently, a suggested threshold is set at approximately 0.3 MALB/cluster, which would lead to 10% of wine consumers being able to detect MALB taint in the wine (Galvan et al. 2007b). However, this threshold can change depending on grape variety, wine style, and the grower's risk perception (Galvan et al. 2007b). Since each wine grape variety has unique physical and chemical characteristics, each will probably have its own sensory threshold.

Physical

Removal of MALB prior to crushing the grapes is imperative to prevent tainted wine. Vigorously shaking grape clusters while harvesting may dislodge MALB adults, however, this may not be economically feasible due to the increase in harvest time. Wine that has been contaminated by MALB can have the taint remediated by adding oak chips, activated charcoal, and deodorized oak, however, it will not completely removed the taint from contaminated wine (Pickering et al. 2006b).

Chemical

To determine the need for insecticide application, a presence/absence sampling plan is recommended where the sampler selects 26 clusters per block or variety at random and determines the MALB infestation level. A cluster is considered infested if 1 or more MALB are found in the cluster. So once you see one MALB you don't have to count any more MALB in that cluster because it is infested and you can move on to your next cluster, which allows the samples to be taken in less time. For a taint level in the wine where 10% of consumers could detect the taint, the treatment threshold would be 18% of the clusters infested with at least 1 MALB. The 18% of clusters infested is equivalent to a 0.3 MALB/cluster density the 18%, or 5 infested clusters out of the 26 sampled. (Galvan et al. 2007a). Products that provide good control of MALB can be found in the Midwest Small Fruit Pest Management Handbook.

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Yellowjackets

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Yellowjackets, *Vespula spp*., (Hymenoptera: Vespidae) are actually considered a beneficial insect because they pollinate plants and prey upon insects that are identified as pests. However, in late summer and early fall when their populations peak, the diet of the yellow jacket changes from insects to sugar sources such as grapes. Feeding causes damage to the grapes. Addtionally, yellowjackets pose a stinging hazard in the vineyard to the people harvesting the grapes.

Identification

Yellowjacket on a grape cluster *(E.C. Burknss & T.L. Galvan, U of MN*

The yellowjacket is about 1.3 cm long and has alternating yellow and black bands on the abdomen. Foraging yellow jackets are often mistaken for honeybees because of their similar appearance and the fact that they are sometimes attracted to the same food source. Honeybees are slightly larger than yellow jackets and are covered with setae (hair) which are mostly absent on yellow jackets. Foraging honey bees can be identified by the pollen baskets on the rear legs that are often loaded with a ball of yellow or green pollen. The yellow jacket has a smooth stinger that can be used to sting multiple times, whereas the honey bee has a barbed stinger than can be used to sting only once.

Biology & Life Cycle

Yellow jackets are social insects that have a colony division of labor between undeveloped female workers, males and fully developed female queens. Newly mated queens are the only members of the colony that overwinter. In spring, the overwintered queen emerges and begins the establishment of a nest which is normally located in a soil cavity such as an abandoned mouse nest or hollow tree. Other possible nest sites are in buildings, including attics, porches, eaves or sheds.

The queen builds a small paper nest and lays several eggs which hatch and mature in to adult workers. This first generation of infertile workers undertakes all tasks of nest expansion including foraging for food, defending the colony entrance and feeding the queen and larvae. The colony rapidly increases in size and the number of adult yellow jackets within each colony may reach several hundred by August.

Nests are constructed of several layers of comb made of tiny bits of wood fiber chewed into paper-like pulp. During this peak population period, the colony produces "reproductive cells" that mature and provide future queens and reproductive males that eventually leave the nest for mating flights. Mated queens fall to the ground and seek out a protected overwintering place such as a brush pile, a hollow tree or a building. Males do not overwinter and die after they have successfully mated.

Damage

Yellowjacket feeding on an injured grape *(E.C. Burkness & T.L. Galvan, U of MN)*

Yellowjackets feed on ripe grapes in late summer and early fall, damaging the crop. They also may be a danger and annoyance to pickers.

Management

Cultural

Harvest the grape clusters as soon as they ripen to discourage yellowjacket feeding. Remove any overripe or damaged fruit from the vineyard area. In addition, do not leave any food items near the vineyard, as they may attract yellowjackets to the area.

Trapping

Traps containing *n-heptyl butyrate* which mimics the odor of fruit. can be used outside the perimeter of the planting to discourage yellowjackets from feeding on grapes. Place traps before the berries begin to ripen. Place traps early (July or early August) to improve chances of success. Once the yellowjackets find the ripened fruit, the traps will be of little benefit.

Chemical

It is not an effective management option to use an insecticide.

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Grape Phylloxera

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Galls on a grape leaf caused by grape phylloxera *(E.C. Burkness & T.L. Galvan, U of MN)*

Grape phylloxera, *Daktulosphaira vitifoliae* (Homoptera: Phylloxeridae), is a serious pest of commercial grapevines worldwide. There is both a root (radicole) and foliar (gallicole) form of this insect. Although the two forms behave differently, both belong to the same species of phylloxera that occurs on the leaves and roots of grapes. In Minnesota, only the foliar form is believed to cause damage since American varieties are tolerant to the root form of phylloxera.

Grape phylloxera is thought to have originated in the Eastern United States, where damage is now most prevalent on leaves of French-American hybrid grapevines. High populations of foliar phylloxera can result in premature defoliation, reduced shoot growth, and reduced yield and quality of the crop.

Identification

Grape phylloxera nymph inside of a gall *(E.C. Burkness & T.L. Galvan, U of MN)*

Adult grape phylloxera are tiny aphid-like insects with a yellow body. The foliar form of grape phylloxera causes the formation of tiny galls to form on the leaf. The galls extend below the leaf surface and fully enclose the insect. The gall opens to the upper leaf surface which allows the nymphs to exit.

Biology & Life Cycle

The foliar form of phylloxera overwinters as eggs under the bark of grapevines. Egg hatch coincides with leaf emergence and expansion in the spring. The nymphs, which are referred to as crawlers, are mobile and move between leaves to establish new feeding sites. Feeding by nymphs induces the formation of galls on the leaves. After the first instar, the nymphs tend to feed in one place. There are four instars prior to the wingless adult stage. Multiple generations are observed each year.

Damage

Severe gall formation on a grape leaf *(T.L. Galvan, U of MN)*

Foliar phylloxera can reduce the photosynthetic activity of grape leaves. In addition, the leaf galls cause distortion, necrosis, and premature defoliation. Premature defoliation may delay ripening, reduce crop quality, and predispose vines to winter injury. Populations must reach very high densities before yield is affected, and this is rare. The impact of infestations over years on the overall health and vigor of the vine is unknown.

Feeding by root phylloxera on European grapevines, *Vitis vinifera* nearly destroyed the French wine industry in the late 1800's. The epidemic was eventually brought under control by grafting *V. vinifera* varieties onto resistant American, *Vitis labruscana*, rootstocks. A major resistance breeding program conducted in Europe targeting the root form of grape phylloxera resulted in grape varieties commonly referred to as French-American hybrids. French-American hybrids are important in eastern North America for wine production, but some are particularly susceptible to foliar grape phylloxera.

Management

Cultural

The root form is effectively managed by using resistant or tolerant rootstocks. However, once an infestation occurs, eradication of phylloxera from a vineyard is unlikely, but steps can be taken to keep the infestation at a tolerable level.

Monitoring

Vineyards should be scouted for the foliar form on infested leaves after shoot length has reached five inches. Small galls will be evident on the underside of the terminal leaves.

Chemical

Control of the foliar form of phylloxera may be achieved by applying insecticides during the bloom stage. Early season control of this pest is critical. Several insecticides provide good control of grape phylloxera, and can be found in the Midwest Small Fruit Pest Management Handbook.

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Japanese Beetle

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Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae), feeds on nearly 300 species of plants, including fruits, vegetables, ornamentals, field and forage crops and weeds. This insect was first detected in New Jersey in 1916, and is thought to have been introduced from the soil surrounding plants imported from Japan. Japanese beetles have spread throughout most states east of the Mississippi River. However, partial infestations also occur west of the Mississippi River in states such as Arkansas, Iowa, Kansas, Minnesota, Missouri, and Oklahoma.

Identification

Japanese beetle adults *(E.C. Burkness, U of MN)*

Adult beetles can be identified by their brilliant metallic green, with copper-brown forewings that do not entirely cover the abdomen, five lateral brushes of white hairs on each side of the abdomen, and two brushes of white hair on the last abdominal segment. Eggs are approximately 0.10 cm in diameter and are laid in grassy areas near vineyards. Larvae are typical white grubs, c-shaped, and are limited to feeding only on the roots of grass and weeds.

Biology & Life Cycle

Japanese beetle overwinter as late-instar larvae in the soil. In the spring when the soil begins to warm, larvae move toward the surface where they continue to feed and pupate. New adult beetles emerge from the ground in June and July and begin feeding upon foliage. Eggs are laid in the soil in July and August in grassy areas. Larvae begin to hatch in late July and go through three molts before fall. In August, young grubs begin feeding on plant roots. Grubs continue to feed and grow until cold weather provides the cue for them to tunnel 3 to 12 inches down in to the soil and make overwintering cells. There is one generation per year.

Damage

This pest can be a problem particularly in new vineyards using grow tubes. The adults are skeletonizers, in that they eat the leaf tissue between the leaf veins but leave the veins behind, giving the leaf a lace-like appearance. Leaves fed upon by Japanese beetles soon wither and die.

Feeding damage from Japanese beetle *(T.L. Galvan, U of MN)*

Management

Monitoring/Trapping

Japanese beetle traps are sold in many garden centers. Commercially available traps attract the beetles with two types of baits; one mimics the scent of female beetles and is highly attractive to males while the other bait is a sweet-smelling food-type lure that attracts both sexes. This combination of ingredients is very powerful and can attract thousands of beetles in a single day. These traps can be used as an indicator of Japanese beetle presence; however, some researchers discourage the use of the traps because they believe that they actually bring more beetles into the vineyard, thus increasing the potential for feeding damage.

Biological Control

Japanese beetle larvae are subject to attack by a bacterium, *Bacillus popillae* (milky disease). This biological control agent can protect grassy areas from large larval populations, but it is ineffective against adults entering the vineyard.

Chemical

There is no proven economic threshold on the number of Japanese beetles or amount of damage that requires treatment. However, if a susceptible variety is being grown and growers have previously experienced high populations of Japanese beetles, then it is recommended that an insecticide be applied when Japanese beetle feeding is apparent on most vines, and skeletonized leaves are found. Spot treatments are adequate in some cases. Several insecticides provide good control of Japanese beetle, and can be found in the Midwest Small Fruit Pest Management Handbook.

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Leafhoppers

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Leafhoppers are small insects which feed on a wide variety of plants. The name leafhopper is derived from the ability of the adults to rapidly initiate flight when disturbed. This habit creates the impression of a hopping motion. The potato leafhopper, PLH, *Empoasca fabae* (Hemiptera: Cicadellidae), is the most common leafhopper in Minnesota vineyards. The grape leafhopper, *Erythroneura spp*., can also be present in Minnesota, however it is less common.

Identification

PLH nymphs (on left) and adult (on right) *(E.C. Burkness, U of MN)*

PLH adults are lime green, slender, small (0.3 cm long), and somewhat wedge-shaped with heads that are slightly broader than the rest of their bodies. They usually have 6 small white dots directly behind their head that can be seen with magnification. The nymphs are similar to the adults except that they are smaller, wingless, and paler green (see image, left). Grape leafhoppers are orange-yellow in color, and have dark spots and yellow lines on the forewings. Both the adults and nymphs are very active. The adults jump or fly away as you walk through the vineyard or brush your hand over plants. If you disturb the nymphs, they move very quickly in a distinctive sideways movement across the leaf in an effort to hide on the underside of the leaf. Grape leafhoppers, in contrast, move forward.

Biology & Life Cycle

PLH do not overwinter in the upper Midwest. They migrate from the southern U.S. on wind currents and start arriving in the upper Midwest in mid to late May. Because of this migratory habit populations can vary greatly from one region to another and can even vary within the state. The females, often fertilized, are usually the first to arrive. Large populations continue to migrate through June and early July. PLH lays eggs in the stems of susceptible plants. Eggs hatch in 7 to10 days. Development from egg to adult takes about two weeks. Nymphs feed primarily on the underside of the leaf. Given their limited mobility, nymphs are considered more damaging than adults. There are usually two generations per year in the upper Midwest. However, because of the long oviposition period, infestations usually consist of overlapping generations.

Damage

In general, PLH feeding is concentrated on the youngest grape leaves. Leafhoppers have piercing-sucking mouthparts, and both adults and nymphs cause damage. As PLH feed, they also inject saliva and create physical damage that plugs the vascular tissue. The first signs of feeding are pale leaf veins and curling leaves. Continued heavy feeding can result in premature leaf drop. The fruit may also be affected by lowered sugar content, increased acid, and poor color.

Management

Cultural/Physical

Using cover crops between trellise has been shown to reduce leafhopper populations (Costello and Daane 2003).

Monitoring/Thresholds

Grapevines can tolerate populations of up to 15 leafhoppers per leaf with little or no economic damage.

Chemical

Several insecticides provide good control of leafhoppers, and can be found in the Midwest Small Fruit Pest Management Handbook.

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Apple Twig Borer (Grape Cane Borer)

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The apple twig borer, *Amphicerus bicaudatus* (Coleoptera: Bostrichidae), also referred to as the grape cane borer, is a wood feeding beetle that is widely distributed from the eastern U.S. west to the Rockies.

Identification

Apple twig borer adult (T.L. Galvan, U of MN)

Adults are elongate, approximately 0.5-1 cm long with a reddish brown to brownish black color. Larvae are white with brown head and about 1 cm long when mature.

Biology & Life Cycle

Apple twig borer adult in a grape vine (T.L. Galvan, U of MN)

The apple twig borer overwinters as an adult within burrows made in live canes. As weather warms, they become active in late April and early May. Adults emerge in early spring and deposit eggs from April to June in the bark of grape vines. Young larvae burrow into the vine, usually to the pith, and tunnel along the stem, packing their frass behind them. Larvae mature and pupate in fall and early winter. Many pupae transform to adults in fall. Adults usually hibernate with head downward in larval galleries through winter. Some adults emerge in fall and move to new, living twigs where they burrow in and overwinter. There is one generation per year.

Apple twig borer tunnel in a grape vine (E.C. Burkness, U of MN)

Damage

Vine damage occurs from mid-September into the fall season, when adult beetles burrow into live canes in search of over-wintering sites. However, adult beetles can be found boring into healthy canes, which ultimately leads to cane death.

Feeding by the grape cane borer can reduce node survival and fruitfulness, the number of clusters per cane, and cluster weight. Their damage can also delay establishment of the training system in young vineyards.

Although damaged canes can be pruned out, this requires extra time and labor to accomplish. Also, because the damage is difficult to see, damaged canes are sometimes retained, thus contributing less to the overall yield.

Management

Physical

Infested branches, broken limbs, and all pruned material should routinely be collected and destroyed. Any wilted and dying branches with hibernating beetles should also be pruned and destroyed. In problem areas, favored wild hosts such as wild grape should be cut and destroyed.

The ATB population density that causes economic injury is relatively low, at approximately 3.6 destroyed buds per 50 grape vines, or 3-4 adults per 50 plants in the spring (Beiriger, 1988).

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Eightspotted Forester

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Eightspotted Forester adult (E.C. Burkness, U of MN)

Eightspotted forester larva (T.L. Galvan & E.C. Burkness, U of MN)

The Eightspotted forester, *Alypia octomaculata* (Lepidoptera: Noctuidae) feeds on grape and Virginia creeper. The adult moth is velvety black with two yellow-white spots on each of the four wings, and prominent tufts of orange hair-like scales on each leg.

Adults emerge and oviposit on grape shoots and leaves in May and June. The caterpillars feed on foliage, leaving petioles and larger veins. The larvae are blue-white with bright orange stripes, black lines and black spots. It also has an orange head with black spots, and is 1 1/2 inches long at maturity. When larvae are full-grown they drop to the ground to pupate in the soil and leaf litter. There are two generations per year.

Although commercial vineyards are not damaged severely, small areas within a vineyard may have concentrated infestations and defoliation. There are no specific recommendations for controlling this insect.

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Hornworms and "Hornless Hornworms"

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Achemon sphinx moth larva, the "hornless hornworm" (E.C. Burkness, U of MN)

Sphingid larvae (tomato hornworm, *Manduca quinquemaculata*, tobacco hornworm, *M. sexta*, and achemon sphinx, *Eumorpha achemon*) (Lepidoptera:Sphingidae), are the largest caterpillars found in Minnesota and can measure up to 4 inches in length. Adult moths, sometimes referred to as a "sphinx", "hawk", or "hummingbird" moth, are large, heavy-bodied moths with narrow front wings. Tomato hornworm larvae develop eight white, lateral "v-shaped" marks. Hornworms have a black projection or "horn" on the last abdominal segment. In contrast, the "hornless hornworm", *E. achemon*, loses its horn after the first molt, instead having a prominent "eyespot" marking at the hind end.

Moths emerge from their overwintering site in late spring/early summer. After mating, female moths deposit oval, smooth, light green eggs singly on both the lower and upper surface of leaves. Larvae hatch and undergo 5-6 molts and reach the final instar in 3-4 weeks. Fully-grown larvae then drop off of the plants and burrow into the soil to pupate. Moths then emerge from the soil, mate, and then begin to deposit the eggs of the 2nd generation on tomato plants. By early fall, larvae migrate to the soil to pupate and the pupae will remain in the soil all winter and emerge as moths the following spring. There are two generations per year.

Hornworms feed only on solonaceous plants (e.g., potato, tomato), however, hornworms have been observed on grape foliage (see image, below). *Eumorpha achemon* larvae feed upon grape and Virginia creeper foliage.

Tomato hornworm parasitized by *Cotesia congregatus* on a grape leaf (E.C. Burkness, U of MN)

It is common to find parasitized hornworm larvae in the vineyard. One of the most common parasitoids is a small braconid wasp, *Cotesia congregatus*. Larvae that hatch from wasp eggs laid on the hornworm feed on the inside of the hornworm until the wasp is ready to pupate. The cocoons appear as white projections protruding from the hornworms body. Parasitized hornworm larvae eventually die from the feeding activity of the wasp larvae.

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Bumble Flower Beetle

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Bumble flower beetle
(E.C. Burkness & T,L. Galvan, U of MN)

Bumble flower beetle within a grape cluster (E.C. Burkness & T.L. Galvan, U of MN)

The bumble flower beetle, *Euphoria inda* (Coleoptera: Scarabaeidae), is found throughout most of the states east of the Rocky Mountains. Their name comes from the fact that adult beetles may be mistaken for bumble bees (they fly close to the ground and emit a loud buzzing sound similar to that of a bumble bee).

Adults are often observed at the sites of plant wounds and also on fermenting fruit. Larvae develop in decaying organic matter. Adult bumble flower beetles are approximately 1.3 cm in length, and have yellowish-brown or cinnamon-colored elytra with irregular longitudinal rows of small black spots. The head and thorax are densely hairy, as is the underside of the body, the latter being covered with numerous white hairs.

Since bumble flower beetles feed primarily on fermenting fruit, specific control is usually not required or recommended. Instead, control measures should be directed at eliminating the cause of the fermenting fruit.

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Climbing Cutworms

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Dingy Cutworm (Dept. of Entomology, Univ. of MN)

Cutworms are the larvae of several species of night-flying moths (Lepidoptera: Noctuidae). The larvae are called cutworms because of their feeding behavior, in which they cut down young plants as they feed. There are also species of climbing cutworms that climb plants and feed upon foliage, buds and shoots. The adults are night-flying moths and do not cause damage. As general feeders, most cutworms attack a wide range of plants.

The dingy cutworm, *Feltia ducens*, and variegated cutworm, *Peridroma saucia*, are climbing cutworms found in Minnesota. The dingy cutworm larva, *Feltia ducens*, is pale gray to brown, and tinged with red. A faint, dark V-shaped marking appears on the back of each abdominal segment. The head is pale brown-gray. The most distinguishing characteristic of the variegated cutworm larva, *Peridroma saucia*, is the 4 to 7 pale yellow, circular spots on the back of the larva. The body color is grey to brown with an orange lateral stripe and a series of darker lateral markings.

Damage to grape buds occurs most often in vineyards planted in sandy soil and areas of vineyards where there is excessive weed growth under vines. The most important means of controlling cutworms is to manage weeds and plant residue.

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Grape Cane Gallmaker

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The grape cane gallmaker, *Ampeloglypter sesostris* (Coleoptera: Curculionidae), is a very minor pest of grapes in the eastern U.S. The reddish-brown adult weevils are approximately 0.3 cm long and have a distinctive curved snout. The grape cane gallmaker overwinters in the adult stage in debris on the ground. Egg-laying begins in May or June when shoots are from 25 to 50 cm long. In mid- summer adults begin to emerge from infested canes. Adult emergence continues through September. The gall-like swelling on the cane is caused by oviposition. Galls are usually twice as thick as the cane and 2 to 4 cm long. They are found just above the nodes and are of uniform shape except for a deep longitudinal scar on the side of the gall where the female made the egg cavity. Exit holes may also be found next to the scar.

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Grape Tumid Gallmaker

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Numerous species of gall midges attack grape. The main species is the grape tumid gallmaker, *Janetiella brevicauda* (Diptera: Cecidomyiidae), formerly thought to be a complex of several species. The adult midges oviposit within the unfolding bud or shoot tip. Larvae hatch and enter the vine tissue. As the larvae feed, a gall forms around them. Fully developed larvae exit the gall and drop to the soil where they pupate. Midges (adults) produce from one to three generations per year. No practical control measure for grape tumid gallmakers is known.

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Rose Chafer

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Rose Chafer (Jeffrey Hahn, U of MN)

The rose chafer, *Macrodactylus subspinosus* (Coleoptera: Scarabaeidae) is a common pest of fruit and ornamental plants in the Northeastern U.S., and is sometimes seen in Minnesota vineyards. The adult rose chafer is pale green to tan color, slender, approximately ½ inch long, with a reddish head and long, spiny, reddish brown legs. The adult beetle usually appears in May or June in Minnesota. Because the rose chafer needs sandy soil to lay eggs, plants on sandy sites are most likely to be infested. It feeds on plant material for 3 to 4 weeks, lays eggs in the soil, and then dies soon afterwards. The eggs hatch in 1 to 2 weeks, and the small white grubs feed on the roots of grasses and weeds. The rose chafer overwinters as larvae in the soil.

References

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APPENDIX A: Grape Growth Stages

The following grape diagram is an amended version of the original "***Modified E-L system for identifying major and intermediate grapevine growth stages"*** [Coombe, B. and Dry, P. (eds.). 2004. *Viticulture 1 Resources.* Winetitles. Adelaide, Australia.].

The original document outlines 39 growth stages. Modifications were made for pest management purposes only.

Pictures provided by E. C. Burkness and T. L. Galvan, Dept. of Entomology, Univ. MN

Stage: Dormant
Diseases: Anthracnose (control at this stage is imperative)

Stage: Wooly Bud
Insects: Grape flea beetle

Stage: Bud Burst
Insects: Grape flea beetle, Climbing cutworms, Apple twig borer
Diseases: Phomopsis

Stage: 1st Leaf Separated
Insects: Grape flea beetle
Diseases: Phomopsis

Stage: Inflorescence Swelling
Insects: Grape flea beetle
Diseases: Black rot, Powdery mildew, Downy mildew, Phomopsis

Stage: 14 leaves separated, caps starting to loosen
Insects: Grape flea beetle
Diseases: Black rot, Powdery mildew, Downy mildew, Phomopsis

Stage: Flowering-50% caps off
Insects: Japanese beetle
Diseases: Botrytis, Black rot, Powdery mildew, Downy mildew, Phomopsis

Stage: Fruit Set
Insects: Japanese beetle
Diseases: Botrytis, Black rot, Powdery mildew, Downy mildew, Phomopsis

Stage: Berries BB Sized
Insects: Japanese beetle
***Diseases:** Powdery mildew, Downy mildew

Stage: Berries Pea-Sized
Insects: Grape berry moth, Japanese Beetle
Diseases: Powdery mildew, Downy mildew

Stage: Berries Touching
Insects: Grape berry moth, Japanese beetle
Diseases: Botrytis, Powdery mildew, Downy mildew

Stage: Veraison
Insects: Grape berry moth
Diseases: Botrytis, Powdery mildew, Downy mildew

Stage: Harvest
Insects: Grape berry moth, Multicolored Asian lady beetle, Yellowjacket, Bumble flower beetle
Diseases: Botrytis, Powdery mildew, Downy mildew

APPENDIX B: Glossary of Terms

Abdomen: The third (posterior) major division (tagma) of an insect body.

Action threshold: The pest density at which a control tactic is implemented (an action is taken).

Active ingredient (AI): The component of a pesticide formulation responsible for the toxic effect.

Alate: Winged; having wings.

Alkaloids: Substances found in plants, many having powerful pharmacologic action, and characterized by content of nitrogen and the property of combining with acids to form 'salts'.

Allelochemical: A chemical functioning in interspecific communication.

Apterous: Wingless.

Asexual: Reproduction typically associated with unicellular organisms like bacteria where reproduction is by way of division or budding.

Augmentation: Biological control practices intended to increase the number or effectiveness of existing natural enemies.

Bacterium: A single-celled microscopic plant-like organism that does not produce chlorophyll.

Biological control: The use of living organisms, such as predators, parasitoids, and pathogens, to control pest insects, weeds, or diseases. Typically involves some human activity.

Brood: A clutch of individuals that hatch at the same time from eggs produced by one set of parents.

Caterpillar: The immature stage (larva) of a butterfly, moth, or sawfly.

Chlorosis: A yellowing, whitening, or paling of plant parts which are normally green, such as interveinal chlorosis which takes pace between leaf veins. Caused by a lack of chlorophyll, the root cause can be insect, disease, or nutrient related.

Cocoon: A silken case formed by an insect larva for pupation.

Cultivar: A contraction of "cultivated variety" (abbreviated to cv); a group (or one among such a group) of cultivated plants clearly distinguished by one or more characteristics and which retains these characteristics when propagated; a distinct variety or race of plants that originated under cultivation and persists under cultivation. A cultivar may or may not be referable to a botanical species. Cultivars are given a name, usually distinguished by the use of single quotation marks.

Cultural control: Pest management practices that rely upon manipulation of the cropping environment (e.g., cultivation of weeds harboring insect pests).

Diapause: A physiological state of arrested metabolism, growth, and development that occurs at a particular stage in the life cycle of an organism.

Dormancy: A recurring period in the life cycle of an organism when growth, development, and reproduction are suppressed.

Ecdysis: Splitting and casting off of the old cuticle, the major event in molting.

Economic Injury Level (EIL): The lowest level of a pest that will cause economic damage (ie,. the level of pests where the dollar loss caused by the pest exceed the cost of control).

Economic Threshold (ET): The level of pest infestation when control should be applied to keep an increasing pest population from causing economical losses. The ET is also called the action threshold because it is the pest level where action should be taken so that economic losses are avoided.

Elytra: Hardened forewings that protect membranous hindwings; characteristic of beetles.

Family: A taxonomic subdivision of an order, containing a group of related genera. Family names end in -idae.

Forewings: The anterior pair of wings, usually on the mesothorax.

Frass: Excreta of an insect, particularly a larva.

Fungicide: Any substance that kills or inhibits the growth of a fungus.

Fungus, Fungi (pl.): Any of numerous plants lacking chlorophyll, ranging in form from a single cell to a body of branched filaments. Includes the yeasts, molds, smuts, and mushrooms.

Gall: An aberrant plant growth Produced in response to the activities of another organism, often an insect.

Generalist: A pest or natural enemy that can utilize a wide range of species as host or prey.

Generation: Period from any given stage in the life cycle to the same life stage in the offspring. Typically from egg to egg.

Girdle: Damage that completely encircles a stem or root, often resulting in death of plant parts above or below the girdle.

Gregarious: Forming aggregations.

Hemimetabolous: Having incomplete metamorphosis. Insect undergoes gradual change from molt to molt, with externally developing wing pads.

Holometabolous: Having complete metamorphosis, passing through egg, larval, pupal, and adult stages.

Herbicide: A substance used to kill or control weeds.

Hind wings: The wings on the metathoracic segment.

Indirect pest: A pest insect that feeds on a part of the plant that is not marketed.

Insect: An an arthropod with 6 legs and 3 main body sections: a head, thorax, and an abdomen.

Insecticide: Any substance that kills or inhibits the growth of an insect.

Instar: The immature growth stages of insects between two successive molts.

Integrated pest management (IPM): IPM is a science-based, decision-making process that manages pests through the use of multiple control tactics in a manner that is environmentally responsible, socially acceptable and also economically practical.

Invertebrate: An animal having no internal skeleton.

Larva (pl. larvae): Immature stage of insects with complete metamorphosis.

Metamorphosis: Change in body form between the end of maturity development and the onset of the adult phase.

Molting: The formation of new cuticle followed by ecdysis.

Mycoplasma: A member of the genus Mycoplasma. Mycoplasmas, unlike viruses, can reproduce in the absence of a host and are the smallest free-living organisms; they have a unit membrane but no cell wall as do bacteria.

Natural enemies: Predators, parasites, or pathogens that are considered beneficial because they attack and kill organisms that we normally consider to be pests.

Necrosis: Death of tissue accompanied by dark brown discoloration, usually occurring in a well-defined part of a plant, such as the portion of a leaf between leaf veins or the xylem or phloem in a stem.

Nymph: An immature insect after emerging from the egg, usually restricted to insects in which there is incomplete metamorphosis (hemimetabolous).

Order: A taxonomic subdivision that contains groups of related families or superfamilies; usually ending in -ptera in insects.

Overwinter: A period of rest or hibernation by which insects survive the winter.

Oviposition: The laying or depositing of eggs.

Ovipositor: The egg-laying apparatus of a female insect.

Parasite: An organism that lives in or on another organism (the host) during some portion of its life cycle.

Parasitoid: An animal that feeds in or on another living animal, consuming all or most of its tissues and eventually killing it.

Pathogen: A disease-causing organism.

Pest: An insect, weed, plant pathogen or vertebrate that reduces crop yields, negatively impacts animal or human health or causes structural damage.

Pest resurgence: The rapid rebound of a pest population after it has been controlled.

Pheromone: A chemical used in communication between individuals of the same species, releasing a specific behavior or development in the receiver.

Polyphagous: Feeding on a broad array of plant or animal species.

Predator: An organism that eats more than one other organism during its life.

Proleg: An unsegmented leg of a larva.

Pronotum: The upper (dorsal) plate of the prothorax.

Prothorax: The first segment of the thorax.

Pupa: The inactive stage between larva and adult in holometabolous insects; also termed a chrysalis in butterflies.

Random sample: A sampling plan in which locations for samples are not predetermined either by previous sampling in that field or the relationship of one sample site to another.

Sampling: Estimating the density of organisms (pests or natural enemies) or damage by examining a defined portion of the crop.

Scouting: See Sampling.

Seta (pl. setae): Hair: a sclerotized hairlike projection.

Species: A group of like individuals that can interbreed, mainly within the group (sharing a gene pool) and producing fertile offspring, usually similar in appearance and behavior.

Threshold: The minimum level of stimulus required to initiate (release) a response.

Secondary pest: An insect that does not normally attain pest status except when insecticides destroy its natural enemies.

Systemic insecticide: An insecticide that is absorbed into plant sap and is lethal to insects feeding on or within the treated plant.

Trap crop: A small area of a crop used to divert pests from a larger area of the same or another crop. The pests, once diverted to the trap crop, may be treated with an insecticide.

Variety: An identifiable strain within a species, usually referring to a strain which arises in nature as opposed to a cultivar which is specifically bred for particular properties; sometimes used synonymously with cultivar.

Véraison: Beginning of fruit ripening, recognized by berry softening and beginning of pigmentation in colored varieties.

Worker: In social insects, a member of the sterile caste that assists the reproductive individuals.

