Chapter 8

Pest Management

Grapes are subject to attack by many different pests, including nematodes, fungal, bacterial, and viral pathogens, insects, and wildlife, such as deer and birds. Weeds, which compete with the vines for soil moisture and nutrients, may also be included in this list. Recognizing and understanding the nature of these pests is essential to minimizing crop losses. This chapter briefly describes the major pests that routinely threaten bunch grapes in North Carolina and discusses control measures.

Many pest and disease problems can be managed by adjusting cultural practices to make conditions unfavorable for pests or pathogens. Despite use of cultural controls, however, chemical pesticides are usually required for effective control of many of the fungal diseases and some of the insects that attack many of the popular grape varieties. Pesticide recommendations change often because of changes in registrations, product manufacture, and product efficacy. Current information on chemical control measures for grapes can be obtained through your county Cooperative Extension center; however, understanding the biology of the pests helps greatly in using chemical control measures effectively. Some chemicals have very specific modes of action; they are therefore effective on some pests but useless against others. More detailed and comprehensive information on disease and insect identification may be found in the publications listed at the end of this chapter.

Diseases

Numerous diseases caused by fungi, bacteria, nematodes, and virus and virus-like organisms affect bunch grapes in North Carolina. While many of these diseases occur in other grape growing regions of the world, summer bunch rot diseases are more severe in North Carolina than in most other growing regions because of the state's warm and wet climate. Some vineyards have suffered losses of 50 percent or more due to bitter rot and ripe rot. Good sanitation, diligent canopy management to facilitate drying, and a rigorous, well-timed spray program are necessary to successfully manage fruit and foliar diseases of bunch grapes in North Carolina vineyards. Treatment options for bunch grape disease management can be found at http://www.smallfruits.org/SmallFruitsRegGuide/Guides/BunchGrapeSprayGuide.pdf.

Fungal Diseases

Anthracnose, Bird's-Eye Rot

Anthracnose is primarily important on American bunch grapes, and is favored by the rainy, warm climate. Epidemics are sporadic but can cause significant economic loss once established in a vineyard, reducing fruit quantity and quality and weakening the vine.

Anthracnose is most common on fruit and young shoots but may occur on all succulent plant material. Fruit lesions are small, circular, and red. As the lesions enlarge (up to 1/4 inch in diameter) and become sunken, the centers become gray (Figure 8-1) and are often surrounded by a reddish-brown margin, resulting in the typical "bird's-eye" symptom. Infected grapes often crack, leaving the seed exposed (Figure 8-1). If an early infection is arrested, the surface of the fruit can appear scabby. Lesions on shoots and leaves are similar in color to those on fruit, sunken, and have reddish-brown borders (Figure 8-2). Young leaves are more susceptible and can be malformed if veins are infected. Stem infections can cause cracking of stems and formation of callus tissue, and shoots can be girdled and die if the lesions coalesce.

Figure 8.1 Anthracnose on fruit.

Figure 8.2 Anthracnose on shoots.

Anthracnose is caused by the fungus *Elsinoe ampelina*. The pathogen overwinters in old lesions and as fruiting bodies (sclerotia) on infected canes. Sclerotia germinate in the spring after a 24-hour period of wetness, producing mycelium and eventually spores (conidia). Fruiting structures (ascocarps) can also form on infected debris to produce ascospores. Conidia and ascospores, both serving as primary inoculum, germinate and infect green tissue. Temperatures of 75 to 79°F are optimum for infection. Clusters are susceptible to infection prior to flowering until veraison. Once the fungus is established in the host, fruiting bodies (acervuli) form lesions that exude pinkish masses of conidia. Splashing rains spread the conidia to adjacent clusters resulting in secondary infections.

Management Options

Cultural - Sanitation is very important in anthracnose management. Because the fungus survives on canes, pruning out and destroying infected shoots, cluster stems, and fruit during the dormant season reduce the amount of primary inoculum of the pathogen in the vineyard. Canopy management that facilitates air circulation and reduces drying time, including shoot positioning and leaf removal, will also aid in disease control.

Chemical - Where the disease is a problem, apply lime sulfur during the dormant season to reduce the overwintering inoculum and apply fungicides every 10 to14 days from bud break until veraison.

Bitter Rot

Bitter rot is one of the most important summer bunch rot diseases of *Vitis* spp. in North Carolina, causing 10 to 30 percent loss of ripening fruit. Diseased fruit develops an unpleasant, bitter taste that affects the quality of wine produced and/or the ability to market the crop.

Leaf infections occur as tiny, sunken reddish-brown flecks with yellow halos. Lesions on stems and petioles are round to elliptical, slightly raised, and reddish-brown to black in color. Flecking of the sepals and blighting of the flower buds can also occur. Infected grapes soften and become completely covered with concentric rings of fruiting bodies known as acervuli. Light colored fruit often turn brown, while dark colored fruit appear roughened and sparkly when acervuli develop (Figure 8-3). Infected fruit may abscise, or may dry into mummies and stay firmly attached. Bitter rot is often confused with black rot, but the black rot pathogen primarily infects immature or green fruit before veraison while the bitter rot fungus infects fruit at maturity.

The fungal pathogen that causes bitter rot, *Greeneria uvicola* (syn. *Melanconium fuligineum*), overwinters on plant debris, canes, and mummified fruit. In the spring, spores (conidia) from acervuli are carried by rain to all green parts of the vine, including the pedicels. The pathogen invades the pedicels and becomes latent, or inactive, until fruit mature. Fruit become increasingly susceptible to infection from bloom to veraison. In the weeks leading up to harvest, the pathogen grows from the pedicels into the ripening fruit, causing them to rot and eventually become completely covered with concentric rings of fruiting bodies. Secondary infections can occur when conidia from infected grapes are rain splashed to fruit that has been mechanically wounded by birds, insects, or hail, or has cracked following heavy rains.

Management Options

Cultural - Good weed control and canopy management practices, including pruning, leaf removal, and shoot positioning, promote air circulation and light penetration, which improve drying of leaves and clusters and will result in a less favorable environment for bitter rot development. It is essential to prune out dead spurs and cordons and other infected plant material during the dormant season to reduce the inoculum carried over to the next season. Bunch grapes vary in susceptibility from resistant to highly susceptible.

Figure 8.3 Symptoms of bitter rot.

Chemical - Successful management of bitter rot involves protecting fruit with fungicides during favorable infection periods of warm wet weather from bloom to harvest. The spray program devised to control black rot will help to manage early season bitter rot activity, but to prevent fruit infections and subsequent rot, late season and preharvest fungicides should be applied.

Black Rot

Black rot is the most common early-season fruit rot disease of bunch grapes in North Carolina. Most varieties of vinifera, French/American hybrids and American bunch grapes are susceptible. Crop loss due to black rot can range from 5 to 80 percent, depending on weather conditions, level of inoculum, and susceptibility of the variety.

Black rot disease affects leaves, shoots, tendrils, and fruit of grapevines. Leaf spots are characteristically tan, circular lesions with small black fruiting structures (pycnidia) scattered within them (Figure 8-4). Infections on young shoots, tendrils, and petioles first appear as small dark lesions that later develop into elongated, often sunken lesions. Elongated black cankers may develop on shoots, and can eventually girdle them, causing a shoot blight. Lesions on fruit are initially small and scabby but as they expand they

Figure 8.4 Black rot lesions on a grape leaf.

become sunken. As the entire fruit becomes colonized, it turns light brown in color, and begins to shrivel (Figure 8-5). Numerous dark brown to black pycnidia develop over the surface. Eventually, the fruit dry and shrivel, turning into hard, blue-black mummies (and Figure 8-5).

Black rot is caused by the fungus, *Guignardia bidwellii*. The fungus overwinters on stem cankers, on clusters left hanging on the vine, and on

Figure 8.5 Black rot caused these grapes to dry and shrivel.

mummified fruit on the soil. During spring rains ascospores and/or conidia are ejected and carried by rain and wind to leaves, blossoms and young fruit. Lesions may develop on all young, green tissues when temperatures and duration of leaf wetness are favorable for infection. Infection may occur after 6 hours of wetness at 81°F, but at 50°F, 24 hours of wetness is required. Very little infection occurs above 90°F. Fruit are most susceptible to infection from mid-bloom to about 6 weeks after bloom, and become resistant to infection at maturity.

Management Options

Cultural - Mummified fruit and infected canes are the major source of primary inoculum for early season infections, and should be removed from the vine and vineyard floor before spring arrives; mummies may be disked into the soil. Good canopy management practices are essential for control of black rot. Shoot thinning, leaf removal, pruning, cluster thinning, and shoot positioning are all cultural practices that open the vine canopy to air and light, reducing the amount of moisture trapped within the canopy, and allowing better penetration and spray coverage of biological or chemical fungicides.

Chemical - Fungicide applications for black rot control are most critical in the prebloom and first two postbloom sprays. In vineyards where black rot is a problem, it may be necessary to initiate fungicide treatment 2 weeks earlier. Wetting and temperature requirements necessary for infection to occur have been defined for black rot on bunch grapes (Table 8-1).

Table 8.1 Hours of Continuous Leaf Wetness Required for a Black Rot Infection by Temperature.

Temperature	Hours
50	24
55	12
60	9
65	8
70	7
75	7
80	6
85	9
90	12

Source: R.A. Spotts, The Ohio State University.

Botrytis Bunch Rot, Gray Mold

Botrytis bunch rot is the most important bunch rot disease of grapes worldwide, and can cause serious losses in the vineyard and in transit or storage. *Botrytis* infection is favored by cool weather and free moisture on the surface of fruit. Bunch rot is most severe on varieties with thin skins or tight fruit clusters, under heavy canopies, and in areas of high humidity.

Leaf infection by the bunch rot pathogen, *B. cinerea,* occurs under cool, moist conditions in spring prior to bloom, and appears as a dull green spot that turns into a reddish-brown necrotic lesion. Young shoots and blossoms may also become infected, resulting in significant yield losses. Small brown patches may appear on pedicels or rachises that later turn black, causing portions of the cluster to shrivel and drop. The fungus infects and rots ripening berries, causing the fruit of white varieties to become brown and purple varieties to become reddish. The most common symptom of the disease appears when fluffy, gray-brown growth containing spores becomes visible, eventually spreading throughout the entire cluster (Fig 8-6).

The causal fungus, *B. cinerea,* overwinters on canes, bark, dormant buds, and debris on the vineyard floor as dormant mycelium, or as hard, resting structures (sclerotia) in berry mummies or on canes, which are resistant to adverse weather conditions. Conidia produced in the spring are rain-splashed and windblown to newly emerging leaves. Infection may occur at temperatures as high as 86°F, but the optimum temperature for infection is between 59 and 68°F. Tissue that is dead or has been injured by hail, wind, birds, or insects is usually colonized before healthy tissue. Early-season powdery mildew infected fruit are also more susceptible to infection. Since spore production and infection are favored by wetness and high humidity, fruit infection in North Carolina may occur throughout the season from bloom to closing, and after veraison when sugar concentrations increase in fruit. As harvest approaches, spores from infected fruit may spread to other fruit in the cluster as well as to other clusters.

Figure 8.6 Botrytis bunch rot.

Management Options

Cultural - Good botrytis control starts with good sanitation practices. Before spring arrives, it is extremely important to remove all of last year's fruit from the trellis, as well as canes, bark, and debris from the vineyard floor. Because *B. cinerea* thrives under moist conditions, good canopy management practices, including shoot thinning, leaf removal, pruning, cluster thinning, and shoot positioning, are essential for reducing humidity and increasing air circulation. Varieties of bunch grapes vary in their susceptibility (Table 8-2). The disease tends to be more severe on varieties and clones with tight clusters.

Chemical - Fungicide applications are most critical in the veraison and preharvest sprays, and if the season is wet, sprays may be necessary at bloom and closing as well. Additionally, it is important to prevent early season powdery mildew infections since infected fruit are more susceptible to infection by *B. cinerea.* If conditions become wet at harvest, picking early can reduce the amount of fruit lost to botrytis bunch rot.

Table 8.2 Relative Susceptibility of Varieties of Bunch Grapes to Common Fungal and Bacterial Diseases.

Sources: www.hort.purdue.edu/hort/ext/sfg/2003_pdfs/03complete.pdf- www.ext.vt.edu/pubs/viticulture/463-019/463-019pdf; www.nysaes.cornell.edu/hort/faculty/reisch/bulletin/table/tableindex2.html; attra.ncat.org/attra-pub/grape.html- www.nysaes.cornell.edu/hort.faculty/reisch/bulletin/wine/index2.html; Dr. David Lockwood, University of Tennessee

Variety	Black rot	Downy mildew	Powdery mildew	Phomopsis	Botrytis	Bitter Rot	Crown Gall
Baco Noir	++++	+	++	+	++		+++
Cabernet Franc	++++	++++	++++		+	+++	++++
Cabernet Sauvignon	++++	++++	+++	++++	+	+++	++++
Carmine							
Catawba	++++	++++	+++	++++	+		+
Cayuga White	++++	+++	++	+	+		+++
Chambourcin	++	++	+++	++	++	+	+++
Chancellor	++	++++	++++	+++	++		+++
Chardonel	++	+++	+++		+++		+++
Chardonnay	+++	++++	++++	++++	++++	+++	++++
Concord	++++	+	++	++++	+		+
Cynthiana (Norton)	+	++	+	+	+	0	+
DeChaunac	++	+++	+++	+++	+		+++
Delaware	++++	++++	+++	++++	++		+
Foch	++	+	+++		+		+
Fredonia	++	++++	+++	++	+		+
Gewurztraminer	++++	+++	+++		+++		++++
Himrod	+++	+++	+++		+		+
Malbec			++				
Marechal Foch	++	+	++	+	+		+
Melody	++++	++	++		+	+	+
Merlot	++++	++++	++++			+	
Mourvèdre						++++	
Moore's Diamond	++++	+	+++		+++		
Niagara	++++	++++	+++	++++	+		+++
Petite Verdot						++++	
Pinot Blanc	++++	++++	+++		+++		++++
Pinot Grigio	++++	++++	++++		+++		++++
Pinot Noir	++++	++++	++++		++++		++++
Reliance	++++	+++	++	+++	++		++++
Riesling	++++	++++	++++	+++	++++	+	++++
Rosette	+++	+++	++++	+++	++		+++
Rougeon	+++	++++	++++	++++	+++		+++
Sangiovese					+	+++	
Sauvignon Blanc	++++	++++	++++		++++	++	++++
Seyval Blanc	+++	+++	+++	+++	++++	++	+++
Syrah						+++	
Traminette	+	+++	+		+	+	++
Venus	+++	+++	+++		++++		+
Verdelet	+++	++	+++	+	+		
Vidal Blanc	++	+++	+++	+	+	++	+++
Vignoles	+++	+++	++++	++	++++		+++
Viogner						++++	
Villard Blanc	+++	+++	+++		+		
Villard Noir		+	+++		+		
Viognier	++++	++++	++++		+		
Zinfandel			++		++++		

KEY: 0= resistant, += slightly susceptible, ++= moderately susceptible, +++= very susceptible, ++++= extremely susceptible

Downy Mildew

Downy mildew affects most varieties of grapes in North Carolina. It is most important early in the spring and as temperatures cool in the late summer and fall.

The disease is characterized by yellowish-green lesions (oil spots) that form on the upper surfaces of leaves and turn reddish-brown, necrotic, or mottled, as they expand. A cottony mass of fungal mycelium develops on the underside of leaves (Figure 8-7) and gives the lesions a downy white appearance that is also characteristic of the disease. All green parts of the vine that have mature, functioning stomata, including fruit, leaves, and young shoots, can become infected and covered with a white, downy, sporulating mass of mycelium. Infections of young berries can be mistaken for powdery mildew. When cluster infections occur late in the season, grapes do not soften and appear mottled and light green to red in color. Severely infected leaves often fall prematurely.

The fungus that causes the disease, *Plasmopara viticola*, overwinters as oospores in leaf debris on the vineyard floor and as mycelium in buds and leaves. At about 10-inches shoot growth, the fungus becomes active during rainy periods, producing zoospores that splash to the undersides of leaves, encyst, and form germ tubes that invade the stomata when temperatures reach 52°F. Seven to 10 days after infection, yellowish-green lesions form on the upper leaf surfaces. During the evening, when humidity is greater than 95 percent, sporulating structures produce sporangia that are disseminated by wind and rain to susceptible tissue. The sporangia liberate zoospores that can initiate secondary infections. Epidemics develop through secondary spread of the fungus, which is most severe during periods when warm humid nights are followed by rain the next day.

Figure 8.7 Downy mildew on the underside of a grape leaf.

Management Options

Cultural - Ensure that soils are well drained, and use good canopy management practices to open the vine canopy to air and light to reduce the amount of trapped moisture and shorten the duration of wetting periods. Fallen leaves and vine debris that harbor overwintering inoculum should be shredded with a flail mower and then disked into the soil or removed from the vineyard. Most bunch grape varieties are highly susceptible to downy mildew (Table 8-2).

Chemical - Primary infections can occur from 2 to 3 weeks before bloom until fruit set, and fungicides are most critical during this time, particularly in problem vineyards. Fungicides should be applied either before infection conditions occur or within 5 days after a potential infection event (eradicant fungicides). Use the 10:10:24 rule of thumb to monitor for conditions that favor primary infection. According to the rule, favorable conditions for infection occur after 10 mm (approximately ¼-inch) of rain have fallen while temperatures are 10°C (50°F) or more over a 24-hour period. In order for infection to occur during the 10:10:24 event, the soil must have been wet for 16 hours, followed by rain, and then 2 to 3 hours of leaf wetting. Postharvest applications of fungicides are important for protecting foliage and preventing premature defoliation.

Macrophoma Rot

Macrophoma rot tends to be more important on muscadine than bunch grapes in North Carolina. Early-season infections remain latent and there are no visible symptoms until the fruit begin to mature. When fruit begin ripening, lesions develop that are dark, circular and flat, or slightly sunken (Figure 8-8). The centers of the lesions

Figure 8.8 Macrophoma rot.

develop a tan color and become embedded with scattered fruiting bodies called pycnidia. As the lesion expands the entire grape may develop a soft watery rot. Fruit eventually drop from the vine, becoming shriveled, hollow, and covered with pycnidia.

The causal fungus, *Botryosphaeria dothidea*, overwinters as pycnidia on infected stems and fruit. Conidia are released from the pycnidia throughout the growing season, and are dispersed to shoots and fruit by wind and rain. Infection is believed to occur from bloom until harvest.

Figure 8.9 Phomopsis infection on shoots.

Management Options

Cultural - To successfully manage macrophoma rot, begin by reducing the amount of over-wintered inoculum left on the trellis and ground from the previous season. Infected stems and fruit are the major source of primary inoculum for infections, and should be removed from the vine before spring arrives. Practice good canopy management for control of macrophoma rot. Shoot thinning, leaf removal, pruning, cluster thinning, and shoot positioning are all cultural practices that open the vine canopy to air and light, reducing the amount of moisture trapped within the canopy, and allowing better penetration and spray coverage.

Chemical - Fungicide applications to control macrophoma rot should begin after bloom and continue throughout the fruit ripening period.

Phomopsis Cane and Leaf Spot and Fruit Rot

Phomopsis is a fungal disease of canes, leaves, and fruit and was previously referred to as "dead arm." However, "dead arm" is now known to be two different diseases that may occur together: phomopsis canker and eutypa dieback. Eutypa dieback is characterized by cankers and dieback of the cordons, while phomopsis lesions and cankers on stems are shallow and do not result in dieback of the cordons. Bunch grape varieties vary in their susceptibility to phomopsis fruit rot (Table 8-2).

Phomopsis infections can occur on all green tissues. Distinct black elliptical lesions on shoots (Fig 8-9.) are the most common symptoms observed. If shoot lesions become numerous, they coalesce and appear blackened and scabby. Cracks may form in large lesions during periods of rapid shoot growth. Lesions on leaves are usually circular, while those on the petioles are elongated. Both appear brown or black and are often surrounded by a small yellow halo. Rachis infections are common and are characterized by necrotic circular to elongated lesions. Fruit rot does not occur in many grape-growing areas, but in North Carolina, the pathogen may infect fruit, causing it to turn brown and become covered with black, pimple-like fruiting bodies (Figure 8-10). These fruit eventually shrivel into mummies that are often confused with black rot mummies.

Phomopsis viticola, cause of phomopsis cane and leaf spot and fruit rot, overwinters as black fruiting bodies (pycnidia) on canes, wood, and fruit infected the previous season. In springtime, when weather is cool and wet, tiny spores (conidia) are released from pycnidia and are splashed by rain to young shoots and leaves. Distinct black lesions form on shoots and leaves, and if wet weather continues, serve as an additional source of inoculum for infections of rachises and young fruit. These infections may occur from just prior to bloom until fruit is pea-sized, at which time the fungus becomes latent due to the warmer summer temperatures. At harvest when grapes mature, the latent infections become active and the fruit eventually rot, turn brown and shrivel into mummies. Pycnidia are produced over the surface of the rotting fruit.

Management Options

Cultural - Good horticultural practices that facilitate drying within the canopy in conjunction with sanitation are key to successful management of phomopsis disease. Dead wood, rachises, diseased canes, and mummified fruit on the vine and ground are all overwintering sites for *P. viticola* and need to be carefully removed from the vineyard during the dormant season to reduce the inoculum carried over to the next season.

Chemical - The prebloom through postbloom sprays are most important for preventing fruit infections. In problem vineyards, fungicides may need to be started at 1-inch shoot growth.

Figure 8.10 Phomopsis fruit rot.

Powdery Mildew

Powdery mildew is one of the most common grape diseases worldwide. All varieties of *Vitis vinifera*, French-American hybrids, and *V. labrusca* grown in North Carolina are susceptible (Table 8-2). Severe infections can reduce vine growth and yield and predispose fruit to rot fungi. The disease is named for the ash-gray to white growth of the fungus on the surface of infected leaves and fruit. Infections on leaves first appear as small yellow green blotches, about 1/2 inch in diameter, on the upper leaf surface. As lesions enlarge they become covered with the diagnostic white mycelial growth (Figure 8-11). On some varieties, veinlets on the lower leaf surface turn brown beneath the lesions. Young heavily infected leaves may become distorted. Lesions tend to "disappear" during hot summer weather, often leaving darkened areas on the leaf where the infections

Figure 8.11 Powdery mildew on a grape leaf.

were present. Infections of fruit and cluster stems are characterized by ashy gray to white growth on the surface (Figure 8.12). Fruit infections later appear as web-like russet on the surface. Heavily infected fruit often split and crack as they mature.

Figure 8.13 Powdery mildew on fruit and cluster.

The causal fungus, *Uncinula necator*, overwinters as hyphae in dormant buds or on canes as sexual fruiting structures known as cleistothecia. Leaves emerging from infected buds are covered with whitish mycelium and conidia (spores) that are blown by the wind to emerging leaves and fruit clusters, initiating infections. Primary infections can also occur from ascospores produced in cleistothecia. These infections are most common on the lower leaf surface of leaves growing near the bark of the canes where the cleistothecia have overwintered. Temperatures of 68 to 81°F are optimum for infection, though infections can occur from 43 to 90°F. At optimum temperatures, lesions can develop in 5 to 7 days. Periods with high humidity (85 percent is optimum) without free moisture on the leaf surface favor disease development. Numerous secondary infection cycles can occur during the growing season. Fruit are susceptible from just before bloom until about one month after bloom. Inconspicuous "diffuse" infections on berries can increase the severity of berry rots at harvest. New leaves are susceptible through the growing season, though the disease usually becomes less active during the hot summer months, and becomes active again in the late summer and fall once temperatures cool.

Management Options

Cultural - Cultural practices are important in reducing disease severity. Select planting sites with good air circulation and good sun exposure. Training and pruning practices that open the vine canopy to allow air movement can help reduce disease severity. Choose a less susceptible variety (Table 8.2).

Chemical - Fungicide applications for powdery mildew control should begin at 3 to 10 inches of shoot growth (3 to 5 inches of shoot growth where powdery mildew has been a problem in the past) and continue on a regular schedule until 4 weeks after bloom. Sprays beyond this time may not be needed but vines should be scouted on a regular basis for new outbreaks. The disease often becomes a problem after harvest, and vines should be scouted regularly to determine if sprays are needed at this time. Failure to control postharvest outbreaks of powdery mildew may result in early defoliation, predisposing the vines to winter injury. Rotate fungicides and use the full labeled rate to avoid the development of resistance.

Ripe Rot

Ripe rot is one of the most important summer bunch rot diseases in North Carolina. As infected fruit mature, lesions first appear as slightly sunken or flattened rotted areas. Tiny black fruiting bodies (acervuli) develop within the lesion in a circular arrangement. Rotting fruit are characteristically covered with masses of sticky, pink or salmon-colored spores of the causal fungi (Figure 8.14). As lesions expand, the entire grape eventually rots, and may drop or become shriveled or mummified as it decays.

Ripe rot is caused by *Colletotrichum gloeosporioides*, *C. acutatum,* and *Glomerella cingulata.* These fungi overwinter in canes, pedicels, and mummies, and infect fruit and pedicels in the summer during any time of development. However, these infections remain inactive until the fruit ripen, after which acervuli develop and produce characteristic pink spore masses in wet weather. The disease increases rapidly and may cause severe losses as the fungus spreads from fruit to fruit during rainy periods.

Management Options

Cultural - Before spring arrives, remove overwintered mummies and pedicels, dead spurs, and weak or dead cordons. Shoot thinning, leaf removal, pruning, cluster thinning, and shoot positioning are all cultural practices that open the vine canopy to air and light, reducing the amount of moisture trapped within the canopy, and allowing better penetration and spray coverage of fungicides. Varieties vary in susceptibility. Seyval Blanc, Syrah, Cabernet Sauvignon, and Sauvignon Blanc are susceptible; Chambourain is among the most resistant.

Chemical - Fungicide applications are critical from bloom until harvest if the disease is a problem.

Sour Rot

Sour rot is a common disease of ripe grapes in North Carolina. The disease can be very destructive if rainy periods occur just prior to harvest. Affected fruit become soft and watery, and fruit of light-skinned varieties usually turn tan to light brown (Figure 8.15). Masses of black, brown, or green spores may cover the surface of the fruit. Clusters with sour rot often have a pungent vinegar-like odor.

The exact cause of sour rot is often impossible to determine. As harvest time approaches, many different microorganisms, including species of fungi, bacteria, and yeasts, may attack grapes. Fungi associated with sour rot include *Aspergillus*, *Alternaria*, *Penicillium*, and *Rhizopus*. These fungi are naturally present on plant surfaces and soil debris, and are spread by wind, rain, or insects to ripening fruit. Ripening fruit begin rotting as soon as they are injured. Any type of crack in the skin can allow entry of the sour rot organisms, whether caused by birds, insects, hail, powdery mildew infections, or cracking due to fruit swell following heavy rains. Tight clustered varieties are particularly susceptible to sour rot. The vinegar-like smell is caused by the production of acetic acid by *Acetobacter* bacteria, which are carried by fruit flies and beetles to the clusters.

Figure 8.14 Ripe rot.

Management Options

Cultural - The best approach to control sour rot is to prevent fruit injury by birds, insects, and diseases like powdery mildew. Fruit damage due to growth-related causes can be prevented by cultural methods, including fruit thinning and

Figure 8.15 Sour rot.

canopy management, while closely monitoring irrigation and fertilizer use. If a rain period is forecast, and fruit are mature or nearly mature, harvesting prior to the rain will minimize fruit losses to sour rot.

Chemical - Fungicide sprays are generally not effective in preventing sour rot.

Figure 8.16 Zonal leaf spot.

Minor Foliar Diseases

Many foliar diseases of *Vitis* spp. occur periodically in North Carolina as a result of unusual weather conditions, in nonsprayed or poorly sprayed situations, or after the season is over and fungicides are no longer applied. These diseases generally do not cause a lot of damage, but under certain weather conditions, they may potentially cause considerable defoliation if not controlled.

Figure 8.17 Leaf blight.

Zonate Leaf Spot, Target Spot

Zonate leaf spot, caused by the fungus *Cristulariella moricola*, is characterized by large, circular lesions with a concentric zonate appearance (Figure 8.16). As the leaf spots age, the central portion may disintegrate and fall out. The fungus attacks the leaves of many woody plants in the forest, such as wild grapes, maple, sassafras, and service berry, and inoculum can spread from them into the vineyard. Infections can occur throughout the growing season. Cultural practices that increase air circulation such as shoot positioning and thinning aid in management of the disease. Following a standard spray program for grapes usually controls this disease.

Leaf Blight, Isariopsis Leaf Spot

Leaf blight is caused by the fungus *Pseudocercospora vitis*. The pathogen was named *Isariopsis clavispora* at one time and the disease is still often referred to as isariopsis leaf spot. On *V. vinifera*, hybrids, and *V. labrusca*, leaf blight is characterized by large, irregular shaped spots, which are initially dull red to brown in color but turn black and brittle with age (Figure 8-17). It is most common late in the season on poorly sprayed grapes. Cultural practices that increase air circulation such as shoot positioning and thinning aid in management of the disease. The disease is usually controlled when a standard spray program is followed.

Rupestris Speckle

Rupestris speckle is believed to be a physiological disorder, associated with *V. rupestris* and hybrids that have been derived from it (e.g. Chambourcin). The disorder is characterized by small, circular to irregular, necrotic spots, often surrounded by a yellow halo (Figure 8.18). Spots are more common on the older leaves. Although numerous spots may occur on leaves, little defoliation usually results. There is no control for this disorder.

Bacterial Diseases

Pierce's Disease

Pierce's disease is a potentially devastating disease of grapevine, and it is the principal limiting factor in the production of *V. vinifera*/French American hybrids and *V. labrusca* (American bunch grapes) in North Carolina. By midsummer, margins of leaves infected by the Pierce's disease bacterium develop a scorched appearance (Figure 8.19). Leaves may become yellow before scorching, while red varieties may show some red discoloration. The scorched leaf blades may eventually drop, leaving petioles attached to the cane. The bark on canes matures irregularly, leaving patches of green tissue (green islands) surrounded by mature brown tissue. Fruit clusters may ripen prematurely and become shriveled or "raisined." These symptoms are more extreme in hot dry weather, and some varieties are more susceptible than others. Severely infected vines may die within 1 year of infection or, in the case of chronically infected vines, may live for 5 years or more. In these vines bud break is delayed and new shoot growth is stunted.

Pierce's disease is caused by *Xylella fastidiosa*, a gram-negative bacterium that survives and multiplies within the water conductive system (xylem) of its plant hosts. *X. fastidiosa* has a diverse natural host range with over 100 herbaceous and woody plant species. Many of these plant species are thought to be symptomless hosts, yet may serve as reservoirs of inoculum for later insect transmission. Sharpshooter leafhoppers (Cicadellidae) and spittle-bugs (Cercopidae) acquire and transmit the bacterium as they feed in the xylem of plants. Two of the primary vectors of the Pierce's disease bacterium in North Carolina are the sharpshooters *Oncometopia ovloona* and *Graphocephala versuta*.

Figure 8.18 Rupestris speckle on a grape leaf.

Management Options

Pierce's disease management should involve several disease management practices:

- *Site selection* - The Pierce's disease bacterium does not survive cold winter temperatures in grapevines. Consequently, the risk of the disease is least in the mountains and increases from the piedmont to the coastal plain.
- *Variety selection* – All vinifera varieties are susceptible to Pierce's disease, yet some are more tolerant to the disease than others, and young vines are more susceptible than mature ones. There are a number of Pierce's disease-

Figure 8.19 Systems of Pierce's disease on leaves.

Figure 8.20 Crown gall.

resistant varieties, many of which were developed for production in Texas and Florida, but they have not been tested for suitability in much of North Carolina where the risk for Pierce's disease is high.

- *Vegetation management* - Since diseased vines are often found between 150 to 200 feet from the vector source, one management approach reduces the reservoir of inoculum by removing nearby reservoir hosts that are breeding sites for the various vectors and/or systemic hosts of *X. fastidiosa*. A large number of native plants harbor the *X. fastidiosa* bacterium in North Carolina, including oak, sycamore, hickory, sweet gum, wild cherry, Bermudagrass, pokeweed, wild grape, blackberry, Virginia creeper, wild rose, and sumac. It is still unknown which strains of *X. fastidiosa* infecting these native plants can also cause Pierce's disease on grape.
- *Removal of infected vines* - Infected vines should be removed as soon as they are detected, or should be flagged and removed the following spring if bud break is delayed to reduce the possibility of vine to vine spread in the vineyard.
- *Pruning practices* - When Pierce's disease symptoms are found only at the terminal end of canes, normal dormant pruning practices may remove infected wood. If infection is more severe, cutting the trunk off just above the graft union may generate symptom-free vines.
- *Insecticides* - Before insecticides can be used effectively in a management program, studies are needed to determine the species of leafhoppers responsible for transmitting the Pierce's disease bacterium in North Carolina.

Crown Gall

Crown gall is a common disease in all grape-growing areas of the world, but North Carolina's temperature fluctuations in the spring and fall have resulted in a high incidence of crown gall. Galls are likely to be found in or along cracks created by freezing injuries. As the wine industry further expands into areas where freezing temperatures frequently cause injuries, the incidence and severity of crown gall will dramatically increase.

Galls begin as small protuberances at the site of an injury, usually at the crown or soil line. Aerial galls can also develop at pruning injuries. Gall surfaces become rough as they age and enlarge to several inches in diameter (Figure 8.20). Crown gall infection at grafting and budding sites results in poor growth or death of scion shoots. Vines with galls may be weak and less productive, while younger vines may die. Bunch grape varieties and rootstocks differ in their susceptibility to crown gall disease.

Crown gall disease of grapevine is caused by a bacterium (*Agrobacterium vitis*) that may survive in the soil and grape roots for several years after vines are removed. The bacterium must enter into vines through wounds, which frequently occur as a result of frost injury. The crown gall pathogen can enter the vine at a wound site and be translocated throughout the vine, where it may induce galling at other wound sites.

Management Options

Site selection is an important consideration for limiting the occurrence of crown gall. Vineyards established in areas that are prone to seasonal temperature fluctuations and resulting freeze injury will be more likely to have crown gall problems. Grapevines that appear to be crown gall-free for several years may develop the disease when conditions conducive to infection (generally freeze injury) occur.

Purchase pathogen-indexed nursery stock - Nursery stock should be purchased from a reputable nursery. Discard vines with visible galls. Remember, healthy-looking propagation material may already be systemically infected with the crown gall bacterium.

Cultural - Cultural practices that may assist in managing crown gall are multiple trunking, which allows production to continue on gall-free trunks after infected trunk(s) are removed, and hilling-up of soil up around the crown during the dormant period. Avoid cultural practices that may injure the base of the vine. Good sanitation practices are essential to prevent spread of contaminated material on tools and equipment from vineyard to vineyard. Also, contaminated irrigation sources can carry the pathogen from infested areas to noninfested areas. Removal of infected vines and leaving soil fallow or planting a nonsusceptible crop (legumes or grasses) for 2 to 3 years may help to reduce the chance of carryover of the pathogen, depending on the amount of grape debris that is left in the soil and its rate of decomposition.

Chemical/Biological - Several products are used in an attempt to control crown gall, but no commercially available product will eradicate infections once they have occurred. Products painted onto gall tissue will kill galls at the application site, yet due to the systemic nature of the disease, new galls are likely to appear the following year. Biological control products for crown gall made from *Agrobacterium radiobacter* (strains K-84, K1026) are not labeled for grapes and are not active against the strain of the crown gall bacterium that affects grapes.

Grapevine Yellows

Grapevine yellows is a destructive disease of grapevines in many areas of the world, but has only been found Virginia in the Southeast. It is caused by two different strains of a phytoplasma (a bacteria-like organism). The disease is most prevalent on Chardonnay and Riesling, but Sauvignon Blanc and Cabernet Sauvignon are also affected. Initially, yellow patches develop on leaves of one or two shoots. Leaves tend to curl downward and are brittle in texture. Affected shoots fail to harden and may have a weeping appearance. Flowers and bunches may wither and abort before harvest. In Virginia affected vines usually die within 1 to 3 years. The pathogen is spread in the vineyard by leafhoppers, which acquire the bacterium from infected vines in the vineyard or reservoir hosts surrounding the vineyard. Because little is known about the vectors and reservoir hosts of the grapevine yellows phytoplasma, effective control programs have not been developed for the disease in Virginia. Infected vines should be rogued as soon as they are observed to reduce vine-to-vine spread in the vineyard.

Viral and Virus-like Diseases

There are numerous viral diseases, and other graft transmissible diseases believed to be caused by viruses, that affect grapes. However, few of these diseases cause problems due to current nursery certification programs. Leafroll is the only virus disease that has been confirmed in North Carolina. Tomato/tobacco ringspot virus decline has been found in Virginia and has the potential to become a problem in North Carolina.

Leafroll

Vines displaying symptoms of leafroll virus are scattered throughout many vineyards in North Carolina. Symptoms are most obvious in the late summer and early autumn when leaves on affected vines display colors between green veins ranging from red to purple in red varieties to yellow to red in white varieties. Affected leaf margins tend to roll downward, giving the disease its name. Death of vines is not usual, yet yields may be reduced 20 percent and the fruit may ripen later than fruit on noninfected vines. The virus can be transmitted in the vineyard by mealybugs and soft-bodied scale insects.

Management Options

Purchase vines only from nurseries that participate in virus certification programs. Rogue infected vines to prevent vine to vine spreading. There is no information on the use of insecticides to manages the vectors in North Carolina.

Tomato and Tobacco Ringspot Virus Decline

Tomato and tobacco ringspot virus decline have not been reported from North Carolina but occur in Virginia and states to the north. Because tomato ringspot virus and tobacco ringspot virus occur in many wild hosts, it is likely the disease will be found in North Carolina vineyards. However symptoms tend to be more severe in colder growing regions, so the disease may never become very important here. Symptoms caused by the two viruses are the same and tend to vary with variety and region of the country. Interspecific hybrids tend to be more severely affected than varieties of vinifera. Vidal blanc is one of the varieties most severely affected by tomato ringspot virus in Virginia. Initial symptoms on Vidal blanc are sparsely filled fruit clusters or clusters with many small fruit. Shoots on other varieties may have shortened internodes and small chlorotic or distorted leaves. Infected vines may die during the winter or produce mostly stunted basal suckers by the third year after infection. Most infected vines eventually die.

Both tomato ringspot virus and tobacco ringspot virus infect many common wild (reservoir) hosts including chickweed, plantain, dandelion, and red clover and are transmitted by the dagger nematode (*Xiphenema americanum*) to grapes. This nematode is common in most soils in the piedmont and mountains of North Carolina.

Management Options

Purchase vines only from nurseries that participate in a virus certification program. Avoid susceptible varieties, such as Vidal Blanc, and use resistant rootstocks, such as 5C and C-3309 Sample vineyard soil for nematodes before planting. Control broadleaf weeds between rows as they can serve as reservoir hosts for the virus. Preplant soil fumigation may be needed if the population of the dagger nematode is high.

Nematodes

There is very little information about the importance of nematodes on grapes in North Carolina. These roundworms attack the roots causing a decline in vigor and yield, but they rarely kill vines. Nematode damage is usually not uniform throughout the vineyard but is localized in certain areas, often associated with soil type. Nematodes that have the potential to cause problems include the root knot nematode (*Meloidogyne* spp.), the dagger nematode (*Xiphinema* spp.), the lesion nematode (*Pratylenchus* spp.), and the ring nematode (*Mesocriconema xenoplax*). Sample soil prior to planting to determine if there are damaging populations of nematodes present because there are few management options once vines are planted.

Root Knot Nematode

Root knot nematodes are most damaging in sandy soils. Consequently they are not likely to be a problem in most grapes growing regions in the piedmont and mountains. These nematodes feed on the inside of roots. Feeding sites are characterized by swellings (galls) on young feeder roots, and large galls on older roots. High populations result in reduced vine vigor and yield. Symptoms are most pronounced under water stress or where there are nutritional deficiencies.

Dagger Nematode

The dagger nematodes, *Xiphinema* spp., are common in many soils in the piedmont and mountains of North Carolina. These nematodes feed on tips of the fine feeder roots, which become necrotic and stop growing, resulting in small galls or a "witches broom" appearance as new roots appear and are damaged. High populations can result in significant reduction in vine vigor. In addition to causing damage to the roots, the dagger nematode can transmit several virus diseases including grape fanleaf virus (GFLV), tomato ringspot virus (TomRSV), and tobacco ringspot virus (TRSV).

Lesion Nematode

Lesion nematodes are widespread in many piedmont and mountain soils in North Carolina. They feed on the finer roots causing lesions, which result in poor root development and reduced vine vigor.

Ring Nematode

The ring nematode is usually a greater problem in the sandy soils of the coastal plain than the heavier soils in the piedmont and mountains. Above-ground symptoms are similar to those caused by the lesion nematode.

Insects and Mites

Numerous insects and several mite species can attack bunch grapes. Some, such as the grape berry moth, are chronic pests in almost all vineyards. Many others, such as aerial phylloxera, affect a small proportion of vineyards in numbers large enough to require the use of control measures. The insects described in this section are often found in damaging numbers in commercial Virginia and North Carolina vineyards.

Japanese Beetles

Among the most visible feeders of grape foliage are Japanese beetles, which account for the greatest number of insecticide applications in many vineyards. Despite the insect's intensive feeding and the resultant grower concern, vigorous grapevines can tolerate a certain amount of beetle defoliation.

Japanese beetles overwinter as larvae in the soil, where they feed on grass roots in the autumn and spring. Following pupation, adult beetles emerge in late spring and may be present in vineyards until September. The adult beetles are approximately ½ inch long and are green with copper-colored wings. The beetles feed on leaves, often in large numbers, but rarely feed on fruit. Feeding is concentrated on the upper, younger leaves of the canopy. Mating occurs and eggs are deposited in the soil, where the young larvae feed on grass roots and where they overwinter.

A certain amount of defoliation is tolerable with established, vigorous grapevines. As a rule, if vines retain at least 15 healthy leaves per shoot, no delay of fruit maturation should occur. Occasional insecticide sprays may be necessary to keep feeding within tolerable limits. Young or weak vines should be protected more diligently. Broad-spectrum insecticides, such as carbaryl, are effective against Japanese beetles but have the undesirable effect of reducing beneficial insect populations. Indeed, intensive insecticide applications can increase the incidence of certain secondary pests, such as European red mites. Thus, insecticides should be used judiciously.

A bacterial insecticide is commercially available for lawn and turf application to control Japanese beetle larvae feeding. This product (milky spore disease) may reduce injury to turf by larval feeding but it is unlikely to have a measurable impact on the number of adult beetles that fly into a vineyard. Similarly, attractant traps are unlikely to trap enough adults to reduce beetle levels effectively. Traps may actually attract more beetles from afar and result in greater feeding injury than if traps were not used.

Grape Berry Moth

The grape berry moth is widely distributed east of the Rocky Mountains. It overwinters in pupal form. Adults emerge in early to mid-May in Virginia but somewhat earlier in North Carolina. Mating occurs and the first generation eggs are deposited on flower clusters at or before bloom. Newly hatched larvae feed on the blossoms and small berries, webbing clusters together and often destroying the entire cluster. In three to four weeks the larvae become full grown and pupate. Second-generation moths emerge in 10 to 24 days and repeat the mating and egg deposition processes. At least three and possibly four generations of grape berry moths have been observed in Virginia. Second and subsequent generation larvae feed on developing berries. After véraison the infested berries may be prone to fruit-rotting organisms.

Adult moths, which do no direct damage to grapes, have a wing spread of about ½ inch and are drab brown with a gray or blue band across the back. The larvae are greenish or gray-green and may exceed ½ inch in length. Some reduction in damage may be obtained through cultivation of leaf litter under the trellis in early spring before first-generation adults emerge. Pheromone mating disruption has been found effective under certain conditions in Virginia.

Grape Phylloxera

The grape phylloxera is native to the eastern United States. The biology of this plant louse is very complicated. One form of this aphid-like insect feeds on foliage, where it causes gall-like growths. Other forms feed on the roots of the grape. American species of grape, such as *Vitis riparia, V. labrusca,* and *V. rupestris,* are generally tolerant of the root feeding that occurs, although their foliage may be heavily infested with aerial forms. *V. vinifera* varieties are severely injured by phylloxera root feeding and for this reason must be grafted to pest-resistant rootstocks in this region. Several commercially important hybrid grape varieties, including Seyval and Villard blanc, are highly susceptible to aerial phylloxera feeding. Six or more generations occur per year, and galling may be severe enough to warrant an insecticide application. Feeding and galling are most severe on young, recently emerged leaves.

Grape Root Borer

The grape root borer is the larval stage of a clearwing moth. The adults resemble a wasp. They are dark bronzed brown and yellowish orange and measure about 1 inch in length. The larvae measure 1 inch or more in length and are generally white with brown heads. Eggs are laid on foliage in late summer. One moth may lay as many as 400 eggs during August and September. Eggs hatch promptly; the larvae drop to the soil and bore into the crown and larger roots, where they feed for two or three years. The extensive injury to roots results in loss of vine vigor, reduced yields, and eventual death of the vine. Pupation and emergence usually occur in the summer of the second year. Pupation takes place in cocoons near the soil surface. In Virginia, adults emerge from mid-July to late July, and their shed pupal cases may be observed near the base of affected vines. Adult moths do not feed on grapes, but mating occurs and additional eggs are laid.

Control of this destructive insect is difficult. Registered insecticides for the larval stage are available, but their efficacy is uncertain. One cultural control measure involves mounding soil beneath the vines after the larval stage has pupated in late June. In theory, the adults are then unable to dig to the surface when they exit their cocoons. Timing of mounding is critical and varies with vineyard location: if done too early, the larvae simply tunnel into the mounded soil before pupating; if done too late, the adults may have already emerged.

Climbing Cutworms

Climbing cutworms are a group of related moth species whose larvae can feed on grapevine buds. Cutworm feeding results in lack of shoot development from swollen buds or destruction of recently emerged shoots. Cutworm larvae feed at night and seek shelter in soil and debris during the day. The larvae are smooth, brown or gray, and have stripes running the length of their bodies. A quick search around the base of an affected vine can usually reveal the pest.

Feeding begins in the spring when buds begin to enlarge. The extent of damage depends not only on the cutworm population but also on the duration of the bud-break stage. During cool springs, when the period from bud swell to bud break is delayed, damage can be extensive. Vineyards should be monitored carefully for cutworm feeding in the period leading up to bud break and for a week or two thereafter. Treatment with an insecticide is warranted if feeding affects more than 2 percent of the buds. Cutworm control can be improved by spraying in the late afternoon or early evening to ensure that fresh residues are present when feeding commences.

Bees and Wasps

Bees and wasps usually feed on ripe grapes through injuries caused by other insects, birds, and splits in the skins of overripe berries. Some large wasps are capable of causing direct injury to berries, but honey bees and most wasps are only opportunistic feeders attracted to split or otherwise damaged berries. Insecticides with either zero or very short preharvest interval restrictions may be sprayed to provide some control of bees and wasps. Pickers with severe allergies to bee stings should be advised of sting risks if bees are present at harvest. Latex rubber gloves can provide some protection against stings. Although not extensively tested, some growers have reported limited success at reducing bee populations by locating and destroying nests and by using commercially available bee traps.

European Red Mite

The European red mite is the principal mite pest of grapes in this region. This mite overwinters as tiny brick-red eggs concentrated around the nodes of canes. The eggs hatch in early spring, and nymphal stages begin feeding on young leaves. Adult mites are red and no larger than the period at the end of this sentence. Six or more generations may occur per year, with the peak population often occurring in late August or September. Deposition of winter eggs begins in August and continues into the fall. Mite feeding causes grape leaves to develop a uniform chlorotic or brownish cast, sometimes referred to as mite bronzing. Older leaves show symptoms before younger leaves. With severe infestations, the impaired photosynthesis caused by mites can delay sugar accumulation. Infestation and foliar symptoms usually develop in "hot spots" but will soon spread to entire vineyard blocks if the mite population continues to build unchecked by miticides or natural predators.

If European red mites were numerous in the previous year and overwintering eggs are common, a superior oil spray should be applied at the rate of 2.0 gallons of oil per hundred gallons of water per acre. Apply the oil about the time of bud break. Sprays applied much earlier will have less effect on mite eggs. Superior oil may be applied after green tissue is exposed; however, the oil should not be mixed with other pesticides and should not be applied if a frost is expected within 48 hours. Oil acts by suffocating the eggs and is most effective if applied just before mite eggs hatch. Oil sprays will delay or prevent mites from reaching economically damaging levels. If population development is sufficiently delayed, natural enemies may be able to suppress the buildup.

When miticides are needed, apply well-timed sprays. Apply sprays only to economically important populations. An action threshold for use on grapes has been provisionally set at 5 mites per leaf (10 mites per leaf on labrusca types). Such recommended treatment levels are approximations because of variability among varieties, crop loads, plant stress, weather, and other environmental interactions. When mites exceed these levels, monitor populations closely to determine foliar injury. Heavy bronzing of foliage must be prevented, but minor bronzing is tolerable. In fact, if minor visible injury is tolerated, the likelihood of eventual biological control increases. Most miticides currently available work best on motile (nonegg) stages. Applying such a spray kills the active mites present, but many eggs will survive and hatch. This surviving generation may require a second miticide application 7 to 10 days after the first spray.

Miticides should be used cautiously. Most are relatively expensive, and mites have a tremendous potential to develop resistance to miticides, making control measures ineffective. Mites are secondary pests, rising to economic status after elimination of their natural enemies by sprays for key pests such as Japanese beetle and grape berry moth.

Wildlife

Birds

Many species of birds are fond of ripe grapes and will quickly cause appreciable crop loss if not controlled. Birds are daytime feeders and can be identified if you happen to be in the vineyard when they are present. Otherwise, the clues to bird feeding are peck marks in individual berries, remnants of berry skins retained on the rachis (cluster stem), and selective feeding on individual berries of the cluster, leaving the rachis intact. Birds tend to consume the darkest pigmented berries first, leaving the greener, unripe berries for a later day. Feathers in the vine are an obvious clue. Vines under or close to roosting areas such as a treeline or overhead power lines are the most vulnerable. Dark-fruited, small-berried winegrape varieties are particularly susceptible.

Options to control bird feeding are diverse; few are entirely effective. They include recorded distress calls played on audio equipment in the vineyard; electrical wires mounted in the vineyard to shock birds attempting to land; various reflective materials intended to frighten; gas cannons with loud, frightening reports; various balloons and kites suspended above the vineyard intended to simulate bird predators; shooting; and enclosing the vines in netting to exclude birds. All of these devices have limitations. Most birds will eventually overcome their aversion to the various scare tactics. Bird netting, although laborious to apply and remove as well as expensive, is the choice where total, environmentally benign control is desired.

Deer

The white-tailed deer is remarkably adaptable and can be found in rural as well as suburban settings. Deer depredation may be identified by sighting the deer in the vineyard or by their pattern of feeding.

Deer lack upper incisors and feed by tearing off leaves, shoots, and ripening grapes. Their feeding produces jagged edges that distinguish deer browsing from damage caused by other animals. Look for rachises that are torn or shredded and shoot tips and leaves that have been stripped. Deer may be deterred from vineyard feeding by various scare tactics, repellents, fencing, or regulated shooting. Each method has limitations. Whatever method or methods are used, they should be implemented well before the damage becomes intolerable. Once deer have learned about the source of food, it will be exceedingly difficult to discourage them.

SCARE DEVICES. Scaring deer with noisemakers or visual objects offers, at best, a temporary solution. Scare tactics include propane cannons, electronic acoustic recordings, pyrotechnics, and physically patrolling the vineyard with people or dogs. Noise emitters should be moved every few days so that deer do not become accustomed to the sounds. Their disadvantage is that they often become a nuisance to vineyard owners or neighbors. Permitting domestic dogs to roam the vineyard deters deer to a limited degree.

REPELLENTS. A wide range of taste- or odor-active repellents are available (Table 8.8). Taste repellents are usually sprayed directly onto the plant and are formulated to be distasteful to deer. Because of the potential to leave distasteful residues, some of these products may be restricted to use on nonbearing vines or used only during the period before fruit set. As with nonsystemic fungicides and insecticides, sprayable repellents must be reapplied after heavy rains and as new, unprotected growth develops. Odor repellents deter deer by scent alone. Some products include ingredients that deer associate with humans, such as aromatic constituents of soaps. Depending upon formulation, the odor repellents may be sprayed on or around vines or mounted on the trellis. Here are some keys to using repellents effectively:

❑ Apply the repellent before damage occurs. Periods when damage is likely may be predicted by past experience. Do not allow a feeding pattern to become established.

❑ Feeding pressure will be greatest when alternative food sources are scarce. Repellents may work well when other food is available but may fail miserably if little else is available for deer. This may partially explain year-to-year variation in repellent effectiveness or mixed results among different vineyards.

Table 8.8. Examples of Commercially Available Deer Repellents for Crop and Noncrop Use

Product	Manufacturer	Mode of Action	Active Ingredients
Hot Sauce Animal Repellent	Miller Chemical and Fertilizer Company	Taste	Capsaicin
Hinder Deer and Rabbit Repellent	Matson LLC	Taste and odor	Ammonia; mixed rosin and fatty acids
Havahart Deer-A-Way	Woodstream Corporation	Taste and odor	Putrescent egg solids

Note: Products in this table may be obtained through pesticide or fertilizer supply companies. Be certain to read the entire label before purchasing and using these or other crop protection chemicals. Some animal repellants are registered by the U.S. Environmental Protection Agency as pesticides, and use of those products in a manner inconsistent with their labels is prohibited by law.

❑ Monitor the effectiveness of the repellents. Reapply them or alternate with other tactics if necessary.

❑ Rotate repellents or implement alternative strategies so that deer do not become accustomed to a specific odor or taste.

Besides sprayable repellents, at least three other odor-active repellents have shown some measure of effectiveness in vineyards and orchards.

1. Human Hair. The odor of humans deters deer. Hair can be obtained from barbershops. Place a handful in a mesh bag and hang it from trellis wires around the perimeter of the vineyard. Replace it yearly before the fruit ripens.

2. Animal Tankage. A mixture of blood and other animal products from slaughterhouses or poultry-processing facilities may be used as a deer repellent. Place ½ to 1 cup of this mixture in mesh bags and hang them from trellis wires around the vineyard perimeter before the fruit attracts deer. Note, however, that this material may attract dogs and other animals.

3. Soap Bars. Purchase small hotel-use soap bars by the case. Leave the wrappers on to slow weathering. Drill a hole in each bar and thread a string through it; then hang the bars from trellis wires around the perimeter of the vineyard. Fragrant soaps are particularly alarming to deer.

FENCING. Fencing is probably the most effective means of excluding deer from vineyards. Although the initial costs may be high, the near-perfect protection afforded makes fencing economical, especially taking into account the fact that a well-constructed fence will last 20 years or more. Fencing may be either electrified or nonelectric. Nonelectric fences are usually made of a woven mesh and may be 8 to 12 feet in height. The advent of high-tensile-strength (HT) fence wire, coupled with high-voltage, low-impedance electric fence chargers, has made electric fencing the preferred option for deer fences. Many designs exist, but the least complicated may be the most effective and easiest to install and maintain. The six-wire vertical design depicted in Figure 8.18 shows an effective, modified version of the Penn State five-wire design. An optional hot (+) wire located about 4 or 5 inches above the ground will provide good deterrence of raccoons and other small animals; however, it is essential that the soil under the fence be kept free of weeds that can reduce the effectiveness of the fence charger if they contact the positive wires. The six-wire fence is only about 5 feet tall, a height that deer have no difficulty in jumping. However, approaching deer will first attempt to crawl through or under the fence before jumping. The high-energy output of the charger modifies deer behavior, training deer to avoid the fence.

Products for HT electric fencing are available from numerous sources, including those listed at the end of this chapter.* Properly charged fences produce an extremely unpleasant but noninjurious shock. Therefore, electric fences should always be posted to alert people to avoid accidental shock.

Electric fences must be kept charged continuously. Upon being questioned, most growers who complain about ineffective electric fence operation confess that the fence was not constantly charged. It is best to erect the fence before the vineyard ever bears a crop; the deer are much less tempted to investigate what is on the other side. Clear at least 10 feet of brush and trees from the outside (deer side) of the fence. This gives uninitiated deer plenty of room to approach the fence, touch it with their moist noses, and receive a shock. Keep vegetation, including weeds, clear of the charged wires. When vegetation touches the wires, it drains off some of the energy, resulting in rapid battery discharge and insufficient shocking energy. A preemergence herbicide can be applied under the fence to keep weeds down.

Depending upon terrain and how much brush clearing is involved, a battery-operated, solar-recharged, six-wire electric fence can be installed around a 5-acre vineyard for $1,500 to $2,000 in material costs

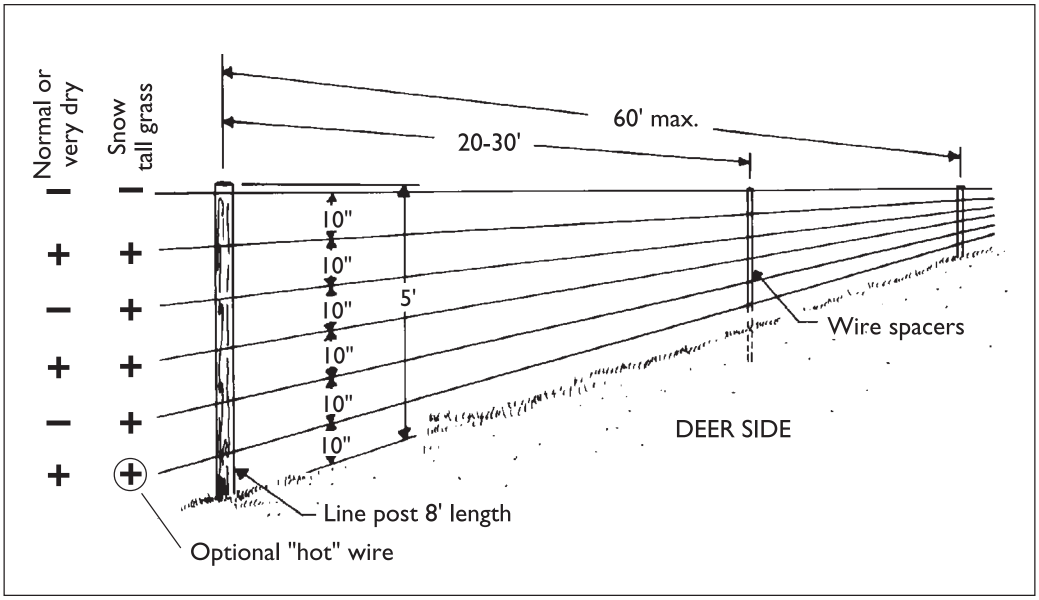


Figure 8.21 An effective design for a six-wire electric fence to exclude deer from the vineyard.

Weeds

Vineyard Floor Management

Pest management in vineyards largely focuses on insect and disease pests due to the direct impact on fruit quality. However, weed and vegetation management impacts a vineyard in numerous ways. A number of weed species have the ability to compete with grapes for nutrients, water, and sunlight. Weeds reduce harvest efficiency, as well. Grasses and broadleaf weeds are the most common, although sedges can be found in vineyards. The most common grass weeds are large crabgrass, fall panicum, and goosegrass, although perennial grasses like bermudagrass or Johnsongrass are sometimes present and can be very competitive. Common broadleaf weeds include dandelion, horsenettle, annual morningglory species, common lambsquarters, and pigweed. The most common sedge is yellow nutsedge. Sedges look similar to grasses, however, their triangular stems distinguish them from grasses.

The Sod/Weed-free Strip

The vineyard floor should be managed to minimize weed competition, prevent erosion, promote worker efficiency, promote integrated approaches to vertebrate (mice and voles) and insect pest management, facilitate equipment movement during wet weather, and maximize the radiant heat benefit. Although asthetics do not directly impact fruit quality, it is important to many managers, especially in vineyards with an adjacent wine-tasting room.

The vineyard floor management system of choice consists of a 6- to 8-foot-wide perennial grass strip between the grape rows. In the grape rows herbicides are directed under the vines to keep a 3- to 4-foot-wide area in the vine row relatively weed-free. (Figure 8.22). The perennial grass strip minimizes competition and supports equipment movement through the vineyard during periods of wet weather.

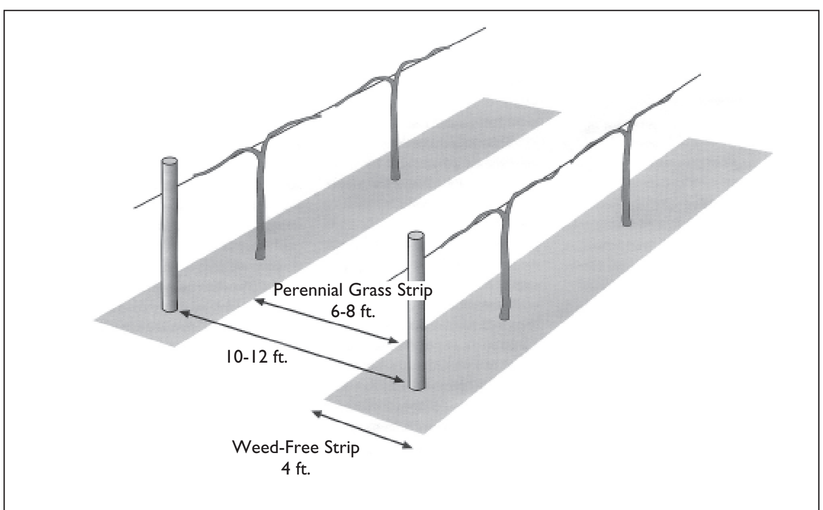
Strip Management

Due to the state's favorable climatic conditions, like a long growing season, good rainfall, and high humidity, weeds thrive in North Carolina. As a result, maintaining a weed-free strip in the vine row is more difficult in North Carolina than other regions of the country. Herbicides offer the most economical means for maintaining a weed-free strip. However, growers interested in organic production, or those preferring to avoid herbicides, other options like tillage, and organic and inorganic mulches are possibilities. All of these options are discussed later in this chapter.

Why a Weed-Free Strip?

Competition Maintaining a weed-free strip in the vine row is especially important in the first and second years of vineyard establishment. Weeds compete with grape vines for water and nutrients, reducing vine growth and yield. Competition for water causes the greatest stress on vines. Although irrigation is common in many vineyards, its efficiency is greatly reduced with the presence of weeds. Research conducted in North Carolina has shown that newly planted vineyards should be maintained weed-free 12 weeks after planting. Herbicide options in newly planted vineyards are relatively limited after spring transplanting. By using grow tubes on newly planted vines, you will have the option of using some very effective herbicides in the first summer season for weed control. Grow tubes are plastic sleeves that create a greenhouse-like environment for the vines to grow in, and also serve to protect new vines from herbicide drift. The number of herbicide options improves for vines in their second growing season, and weed control in the third year and subsequent seasons is achieved with a wide range of preemergence herbicides. In addition, established vineyards shade more of the vineyard floor, minimizing weed emergence and growth.

Figure 8.22 Strip management minimizes erosion, helps with weed and pest management, and maximizes the radient heat benefit.



Radiant Heating – Frost/Freeze Benefit It is well-documented that ground cover management techniques can impact the vineyard microclimate directly impacting vineyard temperature. Research has shown that bare, firm, moist soil has the greatest capacity to absorb heat from sunlight. Heat is reradiated, over a longer time period at night, altering the microclimate by increasing air temperatures in the vineyard and providing additional protection from frost events. In addition, the weed-free surface in the vine row, and closely mown vegetation in the row middle facilitates air drainage, providing additional frost protection.

IPM Benefit Controlling weeds is part of integrated pest management in the vineyard. Weeds provide cover that creates an ideal habitat for voles. Part of vole management includes maintaining a weed-free strip year-round. In addition, weeds under vines provide egg laying sites for grape root borer, and the weeds interfere with soil-applied insecticides used to control grape root borer.

Sod Middle (Species Selection and Management)

As previously discussed, the perennial sod middles are critical for preventing erosion and providing a firm ground cover that allows equipment to move through the vineyard even during periods of wet weather. Ideally, ground cover should be noncompetitive, need minimum mowing, and should be durable. A preferred species is red fescue, but tall fescue has become the most common species used in North Carolina vineyards. Red fescue is not competitive, undesirable for voles, and needs minimal mowing. However, red fescue seed is expensive and can be difficult to establish. Tall fescue seed is readily available and is considerably less expensive than red fescue. Tall fescue can be established easily. If the property was previously used for grazing, it is likely planted in tall fescue. On the other hand, tall fescue is very competitive for water and nutrients and needs mowing more often than red fescue.

Sod can be managed with sublethal rates of glyphosate to minimize the need for mowing. This practice is commonly referred to as "chemical mowing". Chemical mowing can stop growth for 90 to 120 days, therefore eliminating the need for mowing during that time. Specific directions for chemical mowing can be found on glyphosate labels. Grass yellows after chemical mowing with glyphosate.

Herbicide Issues

A number of effective herbicides are registered for use in grape vineyards. Herbicides largely fall into two categories, preemergence (PRE) and postemergence (POST). Preemergence herbicides provide weed control prior to weeds emerging from the soil. Postemergence herbicides control weeds that are emerged from the soil and actively growing. A PRE herbicide is often tank mixed with a POST herbicide in order to control emerged weeds with one application. PRE herbicides have to be activated by rainfall or overhead irrigation in order to work properly. Poor herbicide activation will result in less than desirable herbicide performance. The interval between application and the need for activation varies from one herbicide to another. Some herbicides need activation by rainfall or irrigation within a day while others may wait for 2 or 3 weeks before significant losses in effectiveness occurs. However, the sooner activation occurs from rainfall or irrigation after herbicide application the better.

POST herbicides can be divided into the two categories referred to as contact and systemic. Contact herbicides kill or destroy the area of a plant it contacts. Systemic herbicides move through the leaf surfaces of weeds, into the weed's vascular system where it is able to move through the plant. Herbicides that have POST contact properties include paraquat, and glufosinate (Rely). Examples of herbicides that are systemic include glyphosate, sethoxydim (Poast), and clethodim (Select or Arrow). In order for most POST herbicides to perform properly spray additives may be required. The two most commonly used spray additives are a non-ionic surfactant or a crop oil concentrate. A non-ionic surfactant acts as a spreader to maximize coverage and may aid in penetration. Crop oil concentrates are approximately 15 percent surfactant emulsifier and 85 percent petroleum-based oil. Crop oil concentrates increase herbicide penetration through weed leaf surfaces. POST herbicide labels have specific directions on their label pertaining to spray additives. Always follow label directions.

The effectiveness of POST herbicides can be affected by weed size, growth stage, and soil moisture. In general, small weeds are more easily controlled than large weeds while perennial weeds are more sensitive to glyphosate at specific stages of growth. Ideally, POST herbicides should be applied to non-stressed, actively growing weeds. Weeds stressed from drought can be more difficult to control than non-stressed weeds. However, application timing for POST herbicides should be based primarily on weed size or growth stage when it is most susceptible to the herbicide being applied.

Herbicides – Effective and Economical

Establishment and First Year. Weed control during the initial year of planting and subsequent developmental years is extremely important. The

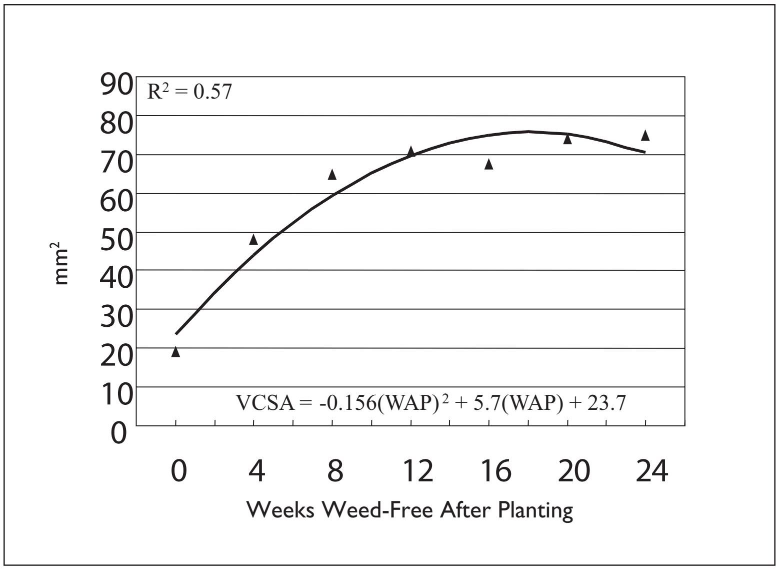
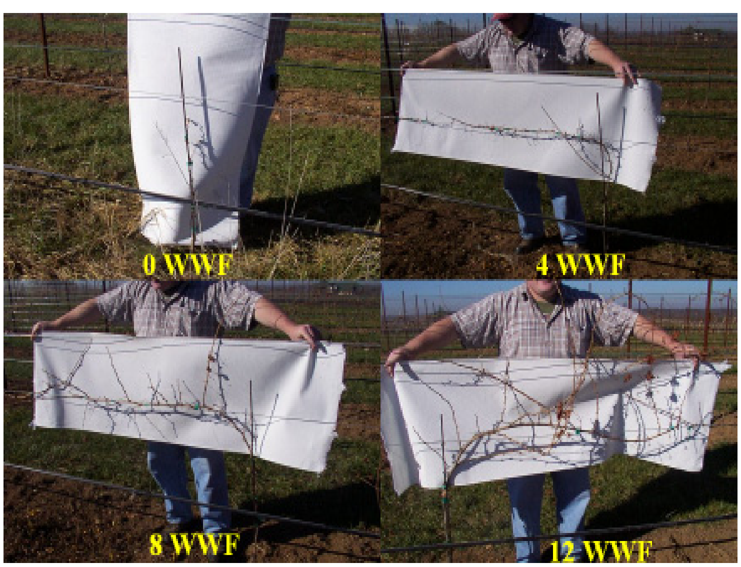


Figure 8.20 Impact of Weed-Free Interval on Vine Cross-Sectional Area

investment for a vineyard is considerable, and vineyards become fully productive only after several years. In order to maximize the return as soon as possible, optimum vine growth during in the formative years of a vineyard is essential.

In many cases, vineyards are planted into an established, perennial sod. After grape rows have been marked off, and prior to planting, glyphosate can be used to kill vegetation. Usually glyphosate applied 4 weeks prior to planting will control cool-season grasses and perennial weeds common to grape production areas. In order to control most warm-season perennial grasses, apply glyphosate. Prior to planting, sub-soiling or other tillage operations can then be performed. At planting, the use of grow tubes are recommended to protect young vines from herbicide injury. Some herbicide labels require shielding of young vines. Once soil has settled around grape roots after planting, a PRE herbicide should be applied. Flumioxazin (Chateau – shielded vines), oryzalin (Surflan), pendimethalin (Prowl), dichlobenil (Casoron), oxyfluorfen (Goal - if trellis system is used), and napropamide (Devrinol) can be applied to newly planted grapes. POST herbicides will need to be applied to control escaped weeds throughout the summer. However, young grape vines must be shielded from paraquat or injury will occur. Grow tubes offer excellent herbicide protection along with increased growth during the first year. Perennial grasses can be very competitive with grapes. Choose a herbicide like sethoxydim (Poast), fluazifop (Fusilade), and clethodim (Select), which are registered for use in newly established vineyards. They are safe, effective options for POST grass control.

Figure 8.21 Differences in Vine Growth Due to Weed-Free Interval



Established Vineyards (2 years or the year after transplanting). In established vineyards, growers have a broader range of herbicide options. There are four programs growers can consider. They include a spring PRE program, which is a traditional approach; the delayed PRE option; the fall/spring split option; and the spring/summer split option.

- ❑ *Spring PRE Program.* Traditionally, a vineyard herbicide program has consisted of a spring PRE herbicide applied with a non-selective POST herbicide like glyphosate or paraquat followed by POST applications of paraquat or glufosinate (Rely) as needed.
- ❑ *Delayed PRE Program* requires a spring glyphosate application. The spring application should be made prior to bud break. Mid to late March is a good application time. Later, when

Table 8.9 Herbicide Program for Grape Vineyards

Crop Age	Fall	Winter	Spring	Summer
Newly Planted			Oryzalin (once soil settles after transplanting)	Oryzalin + paraquat (May or June); Poast or Select (as needed)
			Chateau (once soil settles after transplanting)	Chateau + paraquat (June or July); Fusilade or Poast or Select (as needed)
			Prowl 3.3 or Prowl H2O (vines must be dormant)	paraquat (multiple applications as needed); Fusilade or Poast or Select (as needed)
Vines Established 1 to 2 Years	glyphosate (spot treat for perennial weeds)	glyphosate (mid March)	Oryzalin + paraquat, glyphosate, or Rely (early May)	paraquat or Rely (multiple applications as needed)
	glyphosate (spot treat for perennial weeds)	Chateau + glyphosate, paraquat, or Rely (mid to late March)	Chateau + paraquat, paraquat, or Rely (early June)	Poast (as needed for POST grass control)
	glyphosate (spot treat for perennial weeds)	Solicam (vines est. 2 years) + glyphosate, paraquat, or Rely		Glyphosate, paraquat, Rely, or Poast (as needed)
Vines Established 3 years or more	glyphosate (spot treat for perennial weeds)	glyphosate (mid March)	Simazine + oryzalin + glyphosate, or Karmex + glyphosate	paraquat, Rely, or Poast (as needed)
	glyphosate (spot treat for perennial weeds)	Chateau + glyphosate (mid to late March)	Chateau + paraquat or Rely (early June)	Poast (as needed for POST grass control)
	glyphosate (spot treat for perennial weeds); Simazine + paraquat or Rely (after harvest)		Chateau + paraquat or Rely (mid to late May)	paraquat, Rely, or Poast (as needed)

emerging summer annual weeds reach 2 to 4 inches tall, glyphosate plus a PRE herbicide should be applied. The second application is generally applied the second week of May in western North Carolina. Delaying the PRE herbicide for 6 to 8 weeks extends PRE weed control for 6 to 8 weeks in the summer. The March glyphosate application provides control into early May. Therefore, there is no benefit to applying a PRE herbicide prior to that time.

- *Fall/Spring Split Program.* Grape growers in areas where weeds germinate throughout the winter and summer should consider this program (piedmont). This program begins with a fall PRE application in combination with a nonselective burndown herbicide like paraquat or glufosinate applied after harvest. In late spring a PRE herbicide with glyphosate should be applied for residual summer annual weed control when control from the fall application fails. When a fall PRE herbicide is applied post-harvest, the spring PRE herbicide is applied in late May in western North Carolina.
- *Spring/Summer Split Program* consists of an early spring application of glyphosate with

flumioxazin (Chateau). This application would be applied in late March in western North Carolina. Another application of paraquat or glufosinate with flumioxazin should be applied when control from the initial application fails and emerging weeds are 2 to 4 inches tall. The second application is generally applied in early to mid June in western North Carolina. This program can only be implemented with flumioxazin since other products' labels (like simazine and diuron) do not allow for sequential applications within the same year. Regardless of the PRE herbicide program, perennial weeds like bermudagrass, johnsongrass, brambles, etc., will be troublesome.

Preemergence Herbicides for Newly Planted and Established Vineyards

Dichlobenil (Casoron 4G) at 4 to 6 lb ai/acre (100 to 150 lb/acre) controls many annual and perennial weeds. Apply in January and February for best results. Dichlobenil may be applied in newly planted grapes once soil has settled and plants have recovered from transplanting.

Flumioxazin (Chateau 51 WDG) at 0.19 to 0.38 lb ai/acre (6 to 12 oz/acre) controls annual broadleaf and grass weeds. Sequential applications are most effective. An initial application in March followed by a second application when control from the initial one deteriorates will provide residual control of annual weeds through harvest. Grapes established less than 2 years must be shielded from contact with the herbicide and trellised 3 ft above the soil surface. DO NOT apply within 60 days of harvest and allow a minimum of 30 days between sequential applications. Hooded or shielded application equipment must be used in established vineyards to prevent contact of spray solution with foliage or fruit. Tank mix with glyphosate, paraquat, or glufosinate for postemergence weed control. Applications of flumioxazin after bud break should not be applied with glyphosate.

Isoxaben (Gallery 75 DF) at 0.5 to 1. lb ai/acre (0.66 to 1.33 lb/acre) controls broadleaf weeds including pigweed, lambsquarters, horseweed, ragweed, aster, smartweed, and chickweed. Apply once soil has settled after transplanting. Tank mix with oryzalin, paraquat, glyphosate, or glufosinate.

Napropamide (Devrinol 50 DF) 4 lb ai/acre controls most annual grasses and small seeded broadleaf weeds. Apply prior to weed emergence. Activation from rainfall or overhead irrigation is needed within 24 hours of application for optimum results to prevent napropamide breakdown by sunlight. DO NOT apply within 35 days of harvest. Apply once soil has settled around vines after transplanting.

Oryzalin (Surflan 4 AS, FarmSaver 4 AS) applied at 2 to 4 lb ai/acre (2 to 4 qt/acre) controls most annual grasses and annual sedge. It also controls small seeded broadleaf weeds like chickweed, purslane, carpetweed, lambsquarters, and pigweed. Rate is soil-texture dependent. Oryzalin may be used in newly planted vineyards once soil has settled around plants after transplanting. Oryzalin can be tank mixed with oxyfluorfen, simazine, glyphosate, paraquat, or glufosinate.

Oxyfluorfen (Goal 2 XL, Galligan 2EC, OxiFlo 2EC or GoalTender) 0.5 to 2 lb ai/acre (2 to 8 pt/acre for all 2EC formulations, 1 to 4 pts/acre for GoalTender). Oxyfluorfen provides both PRE and POST broadleaf weed control. It should only be applied prior to vine bud swell while the crop is dormant. DO NOT apply to grapes established less than 3 years unless vines are on a trellis wire, 3 ft above the soil surface. Oxyfluorfen may be tank-mixed with pronamide, nampropamide, simazine, oryzalin, paraquat, glyphosate, or glufosinate.

Pendimethalin (Prowl 3.3 EC or Prowl H2O) at 2 to 4 lb ai/acre (2.4 to 4.8 qt/acre of Prowl 3.3 EC or 2 to 4 qt/acre of Prowl H_2O) controls annual grasses and small seeded broadleaf weeds including chickweed, pigweed, purslane, carpetweed, and lambsquarters. The rate is soil texture dependent. Apply as a directed spray to dormant vines only. DO NOT apply pendimethalin within one year of harvest. Pendimethalin can be tank mixed with paraquat, glyphosate, or glufosinate.

Preemgence Herbicides for Established Vineyards

Diuron (Karmex 80 DF) applied at 1.6 to 2.4 lb ai/acre (2.0 to 3.0 lb/acre) controls annual broadleaf and grass weeds. Susceptible broadleaf weeds include chickweed, dogfennel, jimsonweed, lambsquarters, pigweed, and purslane. DO NOT apply in vineyards established less than 3 years. DO NOT apply to soils with less than 1 percent organic matter. Rate is soil texture dependent. Karmex may be applied in the fall or spring. It can be tank mixed with norflurazon, paraquat, glyphosate, and glufosinate.

Norflurazon (Solicam 80 DF) applied at 1 to 4 lb ai/acre (1.25 to 5 lb/acre) controls annual grasses and some broadleaf weeds. Use only on vines established at least 2 years in the field. Whitening in grape leaf veins may occur if applied within 3 months of bud break when grapes are grown in coarse-textured soils. Solicam may be tank mixed with simazine, diuron, glyphosate, and glufosinate.

Pronamide (Kerb 50W) at 1 to 4 lb ai/acre (2 to 8 lb/acre) provides POST and PRE control of winter annual broadleaf weeds, cool-season perennial grasses, and other grass weeds. DO NOT apply pronamide to vines less than one year old. Pronamide (Kerb 50W) should be applied in late fall or early winter when temperatures do not exceed 55˚F.

Simazine (various 90 WDG and 4L formulations) applied 2 to 4 lb ai/acre (2.2 to 4.4 lb/acre or 2 to 4 qt/acre). Generic formulations of simazine are available. Simazine controls some annual grasses, annual sedge, and many broadleaf weeds including ragweed and smartweed. It can be applied in fall or spring. DO NOT apply simazine in vineyards less than 3 years old or to vines planted in gravelly, sand, or loamy sand soils. It can be tank mixed with oryzalin or noflurazon to improve PRE grass control. It may be applied in combination with paraquat, glyphosate, or glufosinate for control of emerged weeds.

Postemergence Herbicides

Bentazon (Basagran) at **0.75 to 1 lb ai/**acre (1.5 to 2 pt/acre) will control some emerged broadleaf weeds like cocklebur, common ragweed, smartweed, spreading dayflower, as well as, yellow nutsedge in **non-bearing** grape vineyards. In order to control yellow nutsedge sequential Basagran applications 7 to 10 days apart must be applied to yellow nutsedge that is 6 to 8 inches. In order to maximize herbicide effectiveness, crop oil concentrate must be included in the spray solution at 1 qt/acre.

Carfentrazone-ethyl (Aim 2EC) at 0.016 to 0.031 lb ai/acre (1 to 2 oz/acre) will control certain broadleaf weeds like cocklebur, pigweed and lambsquarters. DO NOT allow spray solution to contact leaf tissues, flowers, or fruit of the crop. DO NOT use on vines established less than 1 year or apply within 3 days of harvest. Apply in a minimum spray volume of 20 gpa. Apply in combination with crop oil concentrate at 1 % v/v (1 gal per 100 gal. of spray solution) or nonionic surfactant at 0.25% v/v (1 qt/100 gal of spray solution)

Clethodim (Select 2EC or Arrow 2EC) applied at 0.09 to 0.125 lb ai/acre controls annual and most perennial grasses. Clethodim has no soil activity or activity on broadleaf weeds or sedges. The addition of nonionic surfactant at 0.25% v/v (1 qt per 100 gal of spray solution) is necessary for optimum results. Spray solution contact with grape leaves during hot, humid conditions can cause foliar burn or injury. Sequential applications will be necessary for controlling perennial grass weeds like bermudagrass or johnsongrass. DO

NOT apply to weeds stressed from drought. DO NOT apply within one year of harvest. Clethodim is for non-bearing grapes only. Apply in spray volumes of 15 to 20 gal per acre for best results.

Fluazifop (Fusilade DX) at 0.25 to 0.375 lb ai/acre (16 to 24 oz/acre) provides excellent POST control of annual and perennial grasses. Fusilade has no soil activity or activity on broadleaf weeds or sedges. For optimum results add 1 qt of a crop oil concentrate or 8 oz of nonionic surfactant for every 25 gal of spray mix. Spray solution contact with grape leaves during hot, humid conditions can cause foliar burn or injury. Sequential applications will be necessary for controlling perennial grass weeds like bermudagrass or johnsongrass. DO NOT apply to weeds stressed from drought. DO NOT apply within one year of harvest.

Glufosinate (Rely 1L) apply at 0.75 to 1.25 lb ai/acre (3 to 5 qt/acre) for non-selective POST weed control. Apply as a directed spray to the base of plants. DO NOT allow herbicide to contact desirable foliage or green bark or apply within 14 days of harvest. Glufosinate can be used for sucker control. Apply at 4 qt/acre when sucker length does not exceed 12 inches. Two applications, 4 weeks apart are recommended—see label for directions. Glufosinate can be tank mixed with PRE herbicides for residual control.

Glyphosate (Various formulations of 5.5L or 4L) applied at 0.75 to 1 lb ai/acre (16 to 22 oz/acre of 5.5L formulations or 0.75 to 1 qt/acre of 4L formulations) will provide non-selective POST weed contro1. The rates listed above controls most weeds. Some species (woody perennial, etc.) require higher rates for control; refer to label for details. Grapes exhibit excellent tolerance to glyphosate applied in winter, spring and early summer. However, grapes become sensitive to glyphosate applied after June through late fall until grapes become dormant. Applications made in late summer and fall may be injurious. DO NOT spray green bark or foliage. DO NOT apply on first-year plantings. Glyphosate may be used as a spot treatment for controlling perennial weeds like brambles, mugwort, Virginia creeper, and poison ivy. Some glyphosate formulations may require the addition of a surfactant. See label for details. Glyphosate is most effective when applied in spray volumes of 15 to 30 gal per acre. Glyphosate can be tank mixed with PRE herbicides for residual weed control.

Paraquat (Firestorm 3.0L, Gramoxone Inteon 2.0L) applied at 0.66 to 1 lb ai/acre (1.75 to 2.7 pt/acre for 3.0L formulation, 2 to 4 pt/acre for 2.0L formulation) provides POST control of annual weeds and suppresses perennial weeds. Apply when grass and broadleaf weeds are 1 to 4 in high and actively growing for best results. Green bark of grapes must be shielded from contact with spray solution. The addition of a nonionic surfactant at 0.25% v/v (1 qt per 100 gal of spray solution) is necessary. Apply in no less than 20 gal of spray solution per acre. Paraquat can be used to suppress or control suckers, however application must be when sucker length does not exceed 8 in. Paraquat may be tank mixed with PRE herbicides for residual weed control.

Sethoxydim (Poast) applied at 0.28 to 0.47 lb ai/acre (1.5 to 2.5 pt/acre) provides excellent control of annual and some perennial grasses. Sethoxydim has no soil activity or activity on broadleaf weeds or sedges. The addition of crop oil concentrate at 1 qt/acre is recommended. Spray solution contact with grape leaves during hot, humid conditions can cause foliar burn or injury. Sequential applications will be necessary for controlling perennial grass weeds like bermudagrass or johnsongrass. DO NOT apply to weeds stressed from drought. DO NOT apply within 50 days of harvest.

Tillage/Herbicide Program

While specialty tillage equipment can be used in conjunction with herbicides to provide excellent weed control in the herbicide strip, it can result in problems. One system consists of a fall (post-harvest) tillage operation that ridges soil in the vine row. The ridge is knocked down in the spring after vines break dormancy with an in-row tiller. The freshly tilled, flat surface is then treated with a PRE herbicide for residual weed control. The combined tillage operations (fall and spring) delay the need for a spring PRE herbicide several weeks. The delay extends residual weed control into the summer.

Topography and vineyard size limits the utility of this method. Rolling terrain, where erosion is more likely, limits where tillage may be appropriate. Due to the cost associated with specialized tillage equipment, economies of scale have to be considered before purchasing such equipment. It may not be cost-effective for small vineyards.

In general, tillage is not recommended in vineyards. Tillage disrupts soil and in areas prone to erosion promotes washing. Frequent tillage injures grape roots and vines, destroys soil structure, and increases soil compaction. Tillage equipment also can easily spread perennial weeds through the vineyard.

Herbicide Mixing, Application, and Sprayer Calibration

Before applying any pesticide it is the responsibility of the applicator to read the label. The label is a legal document that outlines specific conditions and restrictions for which that particular pesticide is to be used. It contains information on re-entry interval, personal protective equipment needed, and preharvest intervals among other important issues pertaining to proper use of the pesticide in question. Any use of a pesticide inconsistent with label direction is a violation of the law. Any grower who intends to use pesticides should contact his or her local Cooperative Extension Service agent to get information on a private applicator pesticide license.

Herbicides are often tank mixed to broaden the control spectrum. There could be as many as three to four products included in a single tank. To ensure proper mixing follow the mixing order given below.

1. Wettable powders (W) or water dispersable granules (WDG or DG) or dry flowables (DF)
2. Flowables (F)
3. Emulsifiable Concentrates (EC)
4. Oils
5. Surfactants (fill tank before adding to avoid foaming)

Herbicides are applied using water as a carrier, although there are circumstances in certain crops when herbicides are applied using liquid fertilizer as carrier. The amount of carrier containing the herbicide applied on acre is known as the spray volume. The optimum spray volume for applying herbicides can vary from one herbicide to another but most herbicides generally perform very well when applied in a spray volume ranging from 20 to 25 gallons per acre (GPM). In order to correctly and safely apply herbicides, the sprayer must be calibrated properly. Over- as well as under-application can be costly. Procedures for herbicide calibration are given at the end of this chapter.

Herbicide Alternatives

Tillage can effectively reduce weed competition in the weed-free strip. A grower choosing to use tillage must be timely. Waiting until weeds are large will limit the effectiveness of the tillage operation. Furthermore, specialty tillage equipment used in vineyards is designed to control small, seedling weeds. Large weeds with well-developed root systems are very difficult to remove by tillage. Growers must also be aware of soil moisture conditions when using tillage equipment in the vineyard. Tillage when soil is wet will result in clod development and lead to poor soil structure. Tilling has negative effects on organic matter because it increases

Table 8.10 Herbicide Efficacy Table[1]

Weeds	Aim	Basagran	Casoron	Chateau	Clethodim	Devrinol	Diuron	Fusilade	Gramoxone	Glyphosate	Kerb	Oryzalin	Oxyflruorfen	Poast	Prowl	Rely	Simazine
Barnyardgrass	N	N	E	E	E	G	G	G	G	E	E	G	E	E	G	G	E
Large Crabgrass	N	N	E	E	E	E	G	G	G	E	E	E	E	E	E	G	E
Crowfootgrass	N	N	E	-	E	E	G	G	G	E	E	E	F	E	E	G	G
Fall Panicum	N	N	N	G	E	G	F	G	G	E	E	E	F	E	G	G	E
Foxtail species	N	N	E	G	E	E	G	G	G	E	E	E	F	E	E	G	G
Goosegrass	N	N	E	E	E	E	G	G	G	E	E	E	E	G	E	G	G
Johnsongrass(es)	N	N	E	-	E	P	P	G	F-G	E	P	G	F	E	G	G	P
Signalgrass	N	N	G	G	E	G	P	G	G	E	G	G	F	E	G	G	P
Texas Panicum	N	N	E	G	E	P	F	G	G	E	P	G	F	E	G	G	P
Carpetweed	E	-	E	E	N	G	-	N	E	E	G	G	E	N	G	E	E
Chickweed	P	-	E	E	N	E	G	N	E	E	E	G	E	N	G	E	E
Cocklebur	E	E	-	G	N	P	F	N	E	E	P	P	-	N	N	E	F
Dodder	-	-	N	-	N	-	-	N	E	E	E	N	-	N	N	-	N
Dogfennel	-	-	E	-	N	-	E	N	-	E	-	N	-	N	N	-	N
Eveningprimrose	F	-	E	G	N	G	-	N	G	F	G	P	-	N	G	-	G
Galinsoga	-	F	-	G	N	E	-	N	G	E	F	P	F	N	P	E	G
Horseweed	-	-	E	G	N	-	E	N	F	E	-	N	G	N	N	G	-
Jimsonweed	G	E	-	G	N	P	G	N	E	E	P	P	G	N	P	E	E
Lambsquarters	E	F-G	E	E	N	G	E	N	E	E	E	G	E	N	G	E	E
Morningglory	E	F-G	G	E	N	P	F	N	E	G	G	P	P	N	P	E	G
Pigweed	E	P	E	E	N	F	E	N	E	E	E	G	E	N	G	G	G
Prickly Sida	-	-	-	E	N	P	F	N	E	E	-	P	E	N	P	G	G
Common Ragweed	-	F	E	G	N	G	G	N	E	E	E	F	E	N	P	G	E
Smartweed	-	G	E	E	N	G	F	N	G	G	G	F	E	N	P	G	E
Velvetleaf	E	G	-	G	N	P	F	N	E	E	P	F	G	N	E	G	-
Bermudagrass	N	N	P	N	E	P	N	E	F	G	P	P	N	G	N	F	N
Bramble	N	N	N	N	N	N	N	N	P	G	N	N	N	N	N	F	N
Greenbriar	N	N	P	N	N	N	N	N	P	G	N	N	N	N	N	P	N
Johnsongrass	N	N	F	N	E	N	N	E	F	G	P	N	N	E	P	F	N
Yellow Nutsedge	N	G	E	N	N	N	N	N	F	F-G	N	N	N	N	N	F	N
Virginia Creeper	N	N	P	N	N	N	N	N	P	G	N	N	N	N	N	P	N

E = Excellent; G = Good; F = Fair; P = Poor, N = No effect

[1]Weed response to herbicide is based upon proper herbicide activation for preemergence herbicides and timely application for postemergence herbicides.

decomposition. It may also be destructive to grape roots.

Organic and inorganic mulches can be used to reduce weed competition in vineyards. Sources of organic mulch include wood chips, pine straw, straw, hay, grass clippings, or leaves. In order to be effective, organic mulches need to be 4" thick and have to be replenished annually as decomposition occurs. Mulches should not be used in vineyards with poorly drained soils. Plastic mulches (like that used in annual strawberry production) can be used as a barrier to weeds, but rodents tend to be more problematic where plastic mulches are used. The use of mulch largely depends on the sources that are readily available near your vineyard. Application of mulch is labor intensive and use of organic mulches can introduce additional weeds into a vineyard if the mulch has not been composted.

Another nonchemical means of managing weeds in a vineyard is flame cultivation. Specialized equipment is required to flame weeds. Young vines must be shielded from the heat from the flame cultivator's burners. Mature vines can also be injured if too much heat contacts the vine bark. For optimum control, flaming must be done when weeds are small.

References

Pearson, R. C., and A. C. Goheen. 1988. Compendium of Grape Diseases. St. Paul, MN: APS Press. 93 p.

West Virginia University (WVU) Cooperative Extension offers a series of excellent publications on deer and deer control strategies, including electric fence design and construction. Information on these publications can be obtained by contacting WVU Cooperative Extension in Morgantown, West Virginia.

Consult your county Cooperative Extension Service agent for current pesticide recommendations.

Supplies and Services

Suppliers of fencing and electric fence charging materials include:

Gallagher Power Fence, Inc.
18940 Redland Road
PO Box 708900
San Antonio, TX 78270
(512) 494-5211

West Virginia Fence Corp.
U.S. Rt. 219
Lindside, WV 24591
(304) 753-4387

Kiwi Fence Systems, Inc.
RD 2 Box 51A
Waynesburg, PA 15370
(412) 627-8158

Kencove Farm Fence
111 Kendall Lane
Blairsville, PA 15717
(800) 536-2683

Laboratories offering disease testing services for viruses and Pierce's Disease:

AgDia
30380 County Rd. 6
Elkhart, IN 46514
(219) 264-2014

Agri-Analysis Associates
45133 County Rd. 32-B
Davis, CA 95616
(916) 757-4656