Crop Profile for Grapes in Missouri

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General Production Information

(French-American hybrids,*V. aestivalis, Vitus labrusca*)

In Missouri, approximately 1,000 acres of grapes are grown primarily for wine production. Acreage is expanding with the largest concentration of production acres is in a region bordered by the Missouri River to the north, primarily from Hermann to St. Charles, and the Ozarks plateau in the St. James area and in southwest Missouri near Mountain Grove. The largest vineyards in Missouri contain approximately 100 - 120 acres of grapes and are located in the central portion of the state. Average vineyard size is 11 acres.

- Missouri ranks 10th in US for all grape production and 6th in US for processed Concord, not counting fresh market Concord grapes.
- Average total production from 1994-1998 was 2,210 million pounds with an average seasonal price of $491 per ton.
- Ninety percent of Missouri production is for wine. Average yields for wine grapes range from 3.5 tons/A for Norton (*V. aestivalis*) to 6-8 tons per acre for the French-American hybrids. Average prices received for Norton are $900 per ton to $700 per ton for the French-American hybrids.
- Ten percent of Missouri production is for juice & table cultivars; primarily Catawba and Concord (*V. labrusca*). Average yields are 3 to 5 tons per acre with average prices received estimated at $450 per ton.
- Missouri wine production in 1999 was 380,000 gallons.
- Economic data on the contribution of the grape industry in Missouri from wine production indicates that wine production generates, directly and indirectly, about $26 million in wine sales, about 256 jobs, over $6.0 million in income and almost $2.0 million in tax revenue for the state.

Cultural Practices

To produce high quality grapes for wine production and obtain yields between 6 to 8 tons per acre, vineyards require the following management decisions and production inputs:

- vineyard location planted to cold hardy, adapted wine grape varieties

- appropriate trellis system for site and vine vigor
- proper pruning and canopy management for proper fruit load and ripening
- proper fertilization; overuse of N fertilizer promotes excessive vine growth
- irrigation and a tile system if soils are poorly drained
- excellent disease, insect and weed management

Location of vineyards and varieties:

The best sites for grape production have full sun exposure, mild winter temperatures, freedom from frost, good soil drainage, and a reliable water source. Cultivars vary in their cold-hardiness and disease tolerance; selection of the best-adapted varieties for the site takes these factors into consideration as well as market demand. In the hilly Ozark region, finding enough good, flat ground with adequate frost protection can be a problem.

Maximum sunlight is captured when rows are oriented from north to south but vineyards on sloping land should be planted on the contour, ideally with rows of equal length for ease of spraying. High winds can contribute to breakage of shoots and may topple trellises. The latter situation can be minimized by orienting rows so prevailing winds blow parallel to rows rather than perpendicular to them. Grapes are very sensitive to 2,4-D drift, a factor which should be considered when making decisions on locating a vineyard near agricultural areas.

In Missouri the majority of the varieties grown commercially are derived from the hybrids of native American species crossed with *V. vinifera, V. labrusca* and *V. aestivalis*. French-American hybrids grown in Missouri for red wine are Chambourcin, Chancellor, and Rougeon. French-American hybrids for white wine are Cayuga White, Seyval, Vidal blanc, and Vignoles. The principal *V. labrusca* varieties grown in Missouri are Concord, Catawba, Delaware and Niagara. Acreage of Concord and Catawba exceeds that of other American varieties. Norton (*V. aestivalis*), a native American variety that is highly disease resistant, is increasingly grown due to its excellent red wine. Lack of cold-hardiness and little inherent resistance to several pests and diseases are the major reasons that *V. vinifera* acreage is severely limited in Missouri.

Trellis systems:

Grapevines need support to hold up the vine and to increase the light intercepting the canopy. Trellis systems provide this support and enhance air flow through the canopy. The most common systems used in Missouri are Kniffen, bilateral cordon and Geneva double curtain.

The Kniffen and bilateral cordon trellis systems are vertical trellis systems that work well for the upright or semi-upright French-American hybrids and Catawba. Shoot-positioning is often necessary with these trellis systems but they lend themselves to a high degree of mechanization: mechanical pruning, suckering, combing, and mechanical harvesting.

Geneva double curtain trellis system features a horizontally divided trellis with shoots trained downwards. It was specifically designed to allow more light into the fruiting zone while, at the same time, increasing the surface area of the canopy. This combination increases yield and enhances uniform ripening. All shoots should be positioned downward so this trellis is ideally suited to "droopy" cultivars (for example, Norton and Concord). This system fits well with mechanical pruning, shoot positioning, and harvesting. An added advantage is that fruiting wood is held high off the ground and less susceptible to frost damage in the spring.

Pruning and canopy management:

Pruning is mechanically done in the late winter and early spring prior to budbreak. Skilled vineyard managers and laborers are required to train the appropriate grape varieties for maximum fruit loads. Most varieties require some combinations of shoot positioning, leaf removal, and canopy management for production of high quality grapes suitable for wine production.

Vineyard fertilization, tile systems and irrigation:

Grapes grow best in well drained soils of moderate fertility. In Missouri, vineyard sites located along the Missouri river tend to be highly fertile but well drained. Thus, nitrogen fertilization must be carefully monitored or vine growth becomes excessive. In the Ozark production regions, soils tend to be moderately fertile but poorly drained. In these vineyards, tile systems are beneficial for vineyard health and optimum production. In addition, most vineyards are equipped with drip irrigation systems because the water needs of the vines are not met by normal precipitation during the critical grape filling months of July and August.

Disease, insect and weed management:

Grapes cannot be successfully grown for wine or juice production in Missouri unless diseases, insects and weeds are controlled. The humid environment combined with fertile soils results in vigorous vine growth, heavy dews, and optimum conditions for pest outbreaks. Without a varied repertoire of crop protection tools for pest management, the grape industry in Missouri would cease to exist.

Insect Pests

Grape berry moth (*Endopiza viteana*)
This insect is the primary insect pest of grapes in the eastern United States. This native pest overwinters as pupae in cocoons housed within small, folded semi-circular sections of grape leaves, both on wild and cultivated varieties. This pest is most problematic in vineyards in close proximity to woodlands with wild grapes, a common situation in Missouri grape-growing regions. Very few grape berry moth adults are found in vineyards before the clusters bloom although they will soon move into the vineyard from neighboring woods. Spring generation moths emerge from cocoons typically in early to mid-May in Missouri, mate and lay single eggs on grape berries and cluster stems. Because the berries are small at this time of the season, newly hatched first-generation larvae will spin a web around several berries and feed on them externally. Infested berries appear shriveled with fine webbing. Pupation occurs on the vine within a section of folded leaf held together with silk.

Adult moths emerge and again lay eggs on the berries. Larvae of this generation (second) enter berries and feed internally. Damage at this growth stage of the berries is easily detected because a red spot ("sting") appears on the berry at the larva's entry hole. After veraison, the red spot is much more difficult to detect on red grape varieties but it is still easily seen on white varieties. Due to their direct feeding damage on berries, larvae are the economically important life stage. Wounds on damaged berries also provide entry ports for fungal pathogens, especially late in the season.

Grape Flea Beetle (*Altica chalybea*)
Adult beetles emerge in early spring and attack grape buds as they are beginning to swell. Destruction of primary buds can cause considerable yield loss because damaged buds won't develop into primary canes. Vines can compensate for the loss of the primary bud through the production of secondary buds although shoots from these secondary buds are less fruitful than the primary buds. After the grape shoots have grown over one half-inch long, flea beetles are not an economic threat. Larvae of the flea beetles skeletonize leaves but this feeding doesn't affect yield. Damage is usually restricted to vineyard borders, particularly near wooded areas. A single spray of Imidan (Phosmet) timed for bud swell provides control.

Secondary Insect Pests

Climbing cutworms (Various genera in *Lepidoptera: Noctuidae*)
Several generations of cutworms will occur during the season, but only the larvae present at bud swell are potentially damaging. Twelve species have been reported attacking grapes in the eastern United States. An occasional early season pest, climbing cutworms only attack the buds at bud swell. Significant damage can occur if populations are high and/or cool weather delays bud growth so the buds remain in the susceptible stage for an extended period. Feeding on the buds results in the loss of the primary and in some instances the secondary and tertiary buds as well.

Damage to the buds by climbing cutworms is similar to that caused by adult grape flea beetles but in general, flea beetles attack buds earlier in the beginning of bud swell. Determining the true cause of bud damage can be challenging in part because climbing cutworms hide by day under loose trunk bark or under the debris beneath trellis and feed at night. Flea beetles, on the other hand are visible during the day and may be blamed for all the damage. Climbing cutworms are often more of a problem in vineyards with light-textured soil and vineyard areas with weeds and grasses under the vines which provide daytime cover.

Grape phylloxera (*Daktullosphaira vitifoliae*)
This tiny insect has a more complex life cycle than other grape pests and is considered the most serious grape pest worldwide. The aerial form of these tiny insects is easily recognized by warty galls on leaves. The leaf galls may be unsightly but they don't cause much damage. The only opening in the leaf gall is to the upper surface of the leaf , therefore the phylloxera are protected inside their gall. The root form of phylloxera is not considered an economic problem in Missouri. Not all grape cultivars are susceptible to phylloxera and many can withstand extensive galling without damage. On susceptible cultivars, examine the foliage weekly before and after bloom. Apply Thiodan (endosulfan) just before blossoms start to open or as soon as galls are noticed on leaves. Thiodan may be phytotoxic to Norton, Concord, Chambourcin and Chancellor cultivars.

Grape root borer (*Vitacea polistiformis*)
Larvae tunnel into larger roots and frequently go unnoticed until vines decline from the root pruning and girdling. Adults are clear-wing moths that have bodies with brown and yellow marking similar to wasps. Adult moths emerge during July and August and lay eggs on grape leaves or dropped onto the ground. Larvae hatch, burrow into the soil and commence feeding on grape roots. Larvae remain in the roots of the same vine until just before pupation when they migrate to just under the soil surface.

Insect Pest Management

Insect pests in grape are managed primarily through suppression strategies. The use of insecticides dominates the IPM tactics employed by Missouri growers. An average 2 insecticide applications are applied to 95 percent of the acreage each season. The use of pheromones or attractants to monitor for key insect pests is used on less than 10% of the acreage.

Prevention Strategy:
Cleaning up or burying leaf litter under vines in winter may help reduce number of overwintering pupae of grape berry moth. Eliminating the alternate host, wild grapes, would be difficult because they grow rampantly in Missouri and most vineyards in Missouri are located near wooded areas. Removal of damaged berries is impractical.

Avoidance Strategy:
No avoidance tactics are used for insect control in Missouri grapes.

Monitoring Strategy:
Pheromone traps are used on less than 5% of the acreage to monitor for grape berry moth. The grape berry moth pheromone is effective and there are few non-target species in traps. They can be used to time insecticide applications or deploy mating disruption ties. Mating disruption is particularly useful for second generation grape berry moths because the extended flight period of the moths make it more difficult to time insecticide applications. Recommended rate is 200 to 250 ties/acre. Ties are effective for about 10 to 12 weeks and should not be used on late maturing cultivars.

Suppression Strategy:
Insecticides are applied generally at bloom and 2-3 weeks later. On average, two insecticide applications are necessary and are tank-mixed with fungicide applications.

Chemicals:

- **Azinphos-methyl** (Guthion 35WP, 50WP) is registered for control of grape berry moth, grape cane girdlers, grape mealybug, leafhoppers, redbanded leafroller, thrips, and grape leaf skeletonizer. Labeled rate for Guthion 35WP is 2 1/8 to 2 3/16 pounds per acre and for Guthion 50WP it is 1 ½ to 2 pounds per acre. There is a limit of three applications per crop season; allow 14 days between applications; do not apply within 10 days of harvest if using the higher rate.

- **Carbaryl** (Sevin 50WP, 80S, 4F) is applied to 40% of the grape acres in Missouri. It is registered for the control of flea beetles, grape leafroller, Japanese beetle, leafhoppers, cutworms, grape berry moth, and June beetles. Application rate per acre is 4 pounds for Sevin 50WP, 1 1/4 to 2 ½ pounds for Sevin 80S, and 1 to 2 quarts for Sevin 4F. Do not apply within 7 days of harvest.

- **Chlorpyrifos** (Lorsban 4E) is registered for control of grape root borer by application just before the pest emerges from the soil. For grape root borer mix 4 ½ pints of Lorsban 4E with 100 gallons of water and apply 2 quarts of the diluted spray mixture to the soil surface on a 15-square foot area around the base of

each vine. In Missouri, a 24C SLN registration has been obtained for Lorsban 4E against cutworms at 1 quart per acre. Use of Lorsban 4E is restricted to a single application per season regardless of the target pest; preharvest interval is 35 days; don't let spray touch fruit. Time application to just before grape root borer adults emerge from the soil; Lorsban may be more effective if soil is bare under vine.

- **Diazinon** (D*Z*N 50WP, Diazinon 50WP, DZN AG 500, DZN AG 600 WBC) is applied to 40% of the grape acres in Missouri. It is registered for the control of leafhoppers, grape berry moth, aphids, and spider mites. Application rate for D*Z*N 50WP is 1 to 2 pounds per acre with a seasonal restriction of 10 pounds per acre; rate for Diazinon 50WP is 2 pounds per acre; rate for DZN AG 500 is 1 to 2 pints per acre with a seasonal restriction of 10 pints per acre; rate for DZN AG600 WBC is 12 3/4 to 25 ½ fluid ounces per acre with a seasonal restriction of 127 ½ fluid ounces per acre. Allow 28 days between last application and harvest to avoid illegal residues.

- **Endosulfan** (Thiodan 50WP) is applied to 20% of the grape acres in Missouri. It is registered for control of grape phylloxera and grape leafhopper. Application of Thiodan 50WP is 2 to 3 pounds per acre. May be phytotoxic to sensitive cultivars such as Concord, Cascade, Baco Noir, Colobel, Chancellor, and Norton. Do not make more than three applications or exceed 6 pounds of product per year; do not apply within 7 days of harvest.

- **Malathion** (Cythion 25WP) is applied to 8% of the grape acres in Missouri. It is effective on leaf hoppers, Japanese beetle and fruit flies. It is useful for insect control as the grapes approach harvest because it can be applied up to 3 days before harvest.

- The following registered insecticides are used on less than 3% of the grape acres in Missouri: **Bt** (Bacillus thuringiensis), **Cryolite** (Kryocide), **Imidacloprid** (Provado), **Insecticidal Soap** (M-Pede), and **Phosmet** (Imidan).

Diseases

Four major diseases of grapes occur in Missouri. Almost every cultivar is infected to some degree and commercial grape and wine production are dependent on management of these diseases.

Black Rot *(Guignardia bidwelli)*
Black rot is the most serious grape disease in Missouri. It is the one disease that must be controlled before all other diseases. However, with early season sanitary viticultural practices and properly timed fungicides applied before bloom, black rot is easily managed. All grape cultivars are susceptible to some degree and all green tissues of the vine are susceptible to infection. Leaves are susceptible for about 1 week after unfolding. Infected leaves develop brown circular lesions. Black, pimple-like, fruiting bodies (pycnidia) are visible inside lesions within a few days after lesions appear. Black, elongated lesions on petioles may cause a wilting of leaves. Large, black, elliptical lesions on infected shoots may contribute to breakage by wind. The fruit infection phase may result in substantial economic loss. Berries are susceptible from bloom until sugar content reaches approximately 8%. The initial appearance of an infected berry is a light brown coloration on a portion of the berry. The entire

berry soon becomes dark brown and numerous black pycnidia develop on the surface. The final stage is a shriveled, hard, black, mummified berry.

The black rot fungus overwinters in mummified fruit on the vine and vineyard floor. Many spores within overwintering structures on the mummies are mature and ready for discharge by bud break. Spring rains trigger release of spores from mummies and air currents carry these spores to susceptible tissue. Infections continue throughout the growing season as long as plant tissue is susceptible and environmental conditions for the fungus are favorable. Removal of mummified clusters during pruning and spring cultivation to bury mummies can contribute to a reduction of inoculum. Cultural practices which open the canopy are also beneficial because of increased air circulation and improved spray coverage.

Botrytis Bunch Rot *(Botryotinia cinerea)*
Botrytis bunch rot causes the fruit to turn brown or dark purple, with fuzzy gray mycelia and spores visible on the cluster surface. Severe economic losses may occur, particularly on the tight-clustered French-American hybrids and some *V. vinifera* hybrids. Cultivars differ in susceptibility to Botrytis bunch rot based on the compactness of their clusters, the thickness and anatomy of the berry skin, and their chemical composition. The French-American hybrids Seyval, Vignoles, and Vidal, excellent white wine grapes in the region, are particularly prone to Bunch Rot.

Disease development can be reduced by avoiding excessive vegetative growth with cultural practices such as controlled nitrogen fertilization, increased aeration and exposure of clusters to the sun with appropriate trellising systems, shoot positioning, and leaf removal. Controlling other diseases and insect pests capable of injuring the berries, particularly the grape berry moth, will also reduce Botrytis bunch rot. The fungus overwinters as sclerotia on or in colonized plant tissues, especially in grape mummy clusters from the previous year that have been left in the vineyard.

Downy Mildew *(Plasmopara viticola)*
Downy mildew is caused by a fungus which primarily attacks the leaves, berries, and shoots. The fungus causes direct yield losses by rotting inflorescences, clusters, and shoots, and indirect losses by prematurely defoliating vines which increases their susceptibility to winter injury and delays ripening of the fruit. Reduced carbohydrate production by infected leaves results in lower yields and reduced sugar content in the fruit. Downy mildew on the foliage may be responsible for the loss of vigor and even death of susceptible cultivars which have been cropped heavily.

The development of downy mildew is favored by wet weather. In dry seasons, downy mildew may be almost completely absent from vineyards, even on susceptible cultivars. Downy mildew can infect young green tissue anytime during the growing season, although it usually becomes noticeable about mid-season and increases as the season progresses in Missouri.

Powdery Mildew *(Uncinula necator)*
Powdery mildew has become a more important disease with the increased planting of some of the susceptible French-American hybrids. Powdery mildew is a fungal disease that affects all green tissues. Disease tissues appear to be covered with a white to grayish-white powder. Severe leaf infection can result in cupping of leaves. Cluster infection around bloom may leaf to poor fruit set while later infections can cause berry splitting. Fruit infection may also reduce wine quality on varieties intended for that use. Berries are susceptible to infection until they reach 8% sugar content while established infections produce conidia until about 15 % sugar content.

Minor Diseases

Anthracnose (*Colletotrichum gloeosporioides*)
Research in Missouri has shown that certain grape cultivars, including Cayuga White, Challenger, Glenora, Himrod, Reliance, Vidal blanc, Vignoles, Villard blanc and Vinered are highly susceptible to anthracnose. In vineyards where anthracnose has become a problem, a dormant spray of liquid lime-sulfur is essential for effective control. Protection of the rapidly growing, succulent, green shoots of susceptible cultivars with fungicides is also important. Sprays containing benomyl (Benlate) applied for the control of other diseases will also control anthracnose. Pruning out infected wood during dormancy and removal from the vineyard prior to bud break should reduce primary inoculum of the anthracnose fungus in the coming growing season.

Bitter Rot (*Melanconium fuligineum*)
Bitter rot is often mistaken for black rot because the symptoms are similar. However, bitter rot infections of the fruit occur in late season, whereas black rot infections do not occur after veraison (coloring of fruit). Warm wet weather at ripening favors the development of bitter rot which, once established, spreads rapidly throughout the clusters. Catawba seems to be very susceptible. Lack of control can result in a total crop loss. Fungicide research in Missouri indicates that ferbam (Carbamate) or benomyl (Benlate) applied for control of other diseases just before ripening will also control bitter rot.

Phomopsis Cane and Leaf Spot (*Phomopsis viticola*)
Phomopsis cane and leaf spot is most likely to become a problem when inoculum is allowed to build up on the dead canes in the vineyard and if the weather is wet during the first few weeks of shoot growth. The disease can be controlled by a combination of sanitation and fungicide applications. Diseased and dead wood should be removed and destroyed by shredding, disking or plowing into the soil, or burning. Under heavy disease pressure, a preventive spray of captan or mancozeb should begin as early as ½-inch shoot growth and alternated with azoxystrobin (Abound) through fruit set. The period from bloom through fruit set is a critical time to prevent fruit infection. Ziram may also be used during this period.

Disease Management

All aspects of viticultural practices in Missouri are configured for optimum disease management. Canopy pruning and trellis style, fertilization, shoot positioning and canopy management, vineyard floor sanitation and weed control, insect management, irrigation practices, and harvest scheduling are all intertwined with disease control. In the words one major grape producer in the region, "All of our viticultural and pest management practices are designed to maintain a clean, pest free vineyard up to the two weeks preceding harvest. Without this level of a clean crop, we can lose the entire harvest."

Cultural practices that improve air circulation in the vineyard promote drying of foliage and shorten the duration of wetting periods are beneficial in reducing disease severity. When planting the vineyard, orient rows for optimum air drainage and light interception. Proper pruning improves air circulation and penetration of the canopy by sprays. Spring cultivation around the base of the vines will control weeds and also bury leaf and vine debris that harbors overwintering spores of the major disease pathogens. Also, proper soil drainage minimizes

standing water that promotes the spread of these pathogens.

Good control of black rot and downy mildew are essential for the production of grapes in Missouri. To achieve adequate control in most cultivars, preventive fungicide sprays must be applied on a regular schedule from the beginning of shoot development through veraison. If all fruit mummies have been removed from trellises, then black rot can be controlled by bloom when all ascospores are discharged. If non-systemic fungicides are applied after the fungus has infected the fruit or leaves, disease development will not be arrested. Control with preventive non-systemic fungicide sprays is dependent upon keeping all susceptible plant parts coated with an effective fungicide. This is especially important when rain and heavy dews occur, since these two diseases initiate new infections only when the fruit and leaves are wet. Preventive sprays are applied at shorter intervals during the early part of the season in order to keep the young tissue of rapidly developing leaves and fruit coated.

Systemic fungicides such as azoxystrobin (Abound), benomyl (Benlate), myclobutanil (Nova), and triadimefon (Bayleton) are effective for up to seven days early in the season during rapid growth and up to 14 days after vine and fruit growth has slowed later in the season. Myclobutanil and triadimefon not only protect plant tissues from infection, but also kill or inhibit the growth of the black rot fungus after it has penetrated susceptible grape tissue. Because of this unique property, myclobutanil and triadimefon are said to have curative or "kick-back" action against black rot. Either myclobutanil or triadimefon can be applied up to 72 hours after the beginning of a black rot infection period for control of black rot. The sooner that myclobutanil or triadimefon is applied after the infection period, the greater the black rot control is achieved. However, in instances where scheduled preventive sprays have been delayed due to wet weather and an infection period has occurred, either myclobutanil or triadimefon can be used as a curative spray. When myclobutanil or triadimefon are used for black rot control, powdery mildew is also controlled. However, neither fungicide is effective against downy mildew or Botrytis bunch rot.

In vineyards where powdery mildew has been difficult to control in previous years, a dormant spray of liquid lime-sulfur to the trunks and canes will reduce the amount of overwintering inoculum of this fungus. During the growing season, preventive sprays of fungicides may be used on highly susceptible cultivars to prevent an outbreak of powdery mildew. Only 0.1" rain and temperatures above 55 F are required for infection. Ascospores are discharged from budbreak on throughout the season. Sulfur, which is by far the cheapest fungicide, should be considered for use as a protective fungicide on those cultivars not normally injured by sulfur. Should an outbreak of powdery mildew occur, higher rates of JMS Stylet Oil, azoxystrobin (Abound), myclobutanil (Nova), or triadimefon (Bayleton) can be applied as an eradicant at 14-day intervals to bring the disease under control.

The potential exists for the powdery mildew fungus to develop resistance to triadimefon, benomyl (Benlate), myclobutanil, fenarimol (Rubigan) and azoxystrobin. To reduce the chances of developing resistance, several precautionary measures should be taken. First, use the higher recommended rates of these fungicides where longer intervals between application of these fungicides are expected. Secondly, where feasible, triadimefon, myclobutanil, and fenarimol should be alternated with azoxystrobin or sulfur.

Botrytis bunch rot is best managed through a combination of canopy management and preventive fungicides. A minimum of two applications of iprodione (Rovral) or benomyl (Benlate) has given moderate control of the disease: first, at early mid bloom; second, just before berry touch. A third spay may be necessary on late varieties (e.g. White Riesling) if the interval between the second spray and harvest is greater than 4 weeks. Field experience suggests that effectiveness of the fungicide is reduced following a heavy, prolonged rainfall. If such conditions occur after the last intended spray has been made, an additional fourth application may be necessary.

If only one application can be made, wait until the grapes average 5% sugar content and direct the fungicide toward the fruit, and use a minimum of 100 gal/A of water. Proper timing and consistently good penetration and coverage of clusters is essential for satisfactory control. Leaf removal in the fruiting zone improves spray coverage and drying of clusters after periods of dew and rain thus reducing the incidence of Botrytis.

Prevention Strategy:

Virus indexing for disease-free germplasm:
Missouri is one of three states where grape germplasm can be imported and screened for viruses and susceptibility to other diseases. Currently, grape cultivars from Eastern Europe are being evaluated for cold hardiness, disease resistance and wine quality under mid-western conditions. The cultivars Bianca, Kozma 55 and Kozma 525 are promising disease resistant cultivars from this program. Although initial indexing of some vineyards in Missouri indicate that certain viruses are present, they are not considered a threat to production in the state.

The xylem-limited bacterium that causes Pierce's disease does not survive the winter temperatures in Missouri.

Avoidance Strategy:

Resistant Varieties:
Grape cultivars differ in their susceptibility to disease. Norton is only slightly susceptible to black rot, powdery mildew, Botrytis and anthracnose, and only moderately susceptible to downy mildew. Catawba is extremely susceptible to black rot and downy mildew and only slightly susceptible to powdery mildew; whereas, Chancellor is moderately susceptible to black rot and highly susceptible to downy mildew and powdery mildew. Because of these differences the fungicides that should be used in a spray program will depend upon the cultivar. Some cultivars are sensitive to sulfur or copper sprays. Observations in Missouri indicate that Norton, Chancellor, Concord, Marechal Foch and Rougeon are sensitive to sulfur and Aurore, Catawba, Chancellor, and Rougeon are sensitive to copper.

Monitoring Strategy:
Currently, several of the largest wineries have disease forecasting systems installed in their vineyards. Disease forecasting can be used to determine when to apply fungicides for control of certain grape diseases. These computerized instruments collect environmental data and make the determination of when the infection period for a particular disease has occurred. In order to use infection period information to control diseases, fungicides must be applied which will kill or inhibit the growth of the fungal pathogen after the infection process is initiated.

Research and on-farm use has demonstrated that grape disease forecasting systems in Missouri should have black rot, downy and powdery mildew, and bunch rot models running. The weather stations should be located in a vineyard block planted to a highly disease susceptible cultivar and situated in an area most conducive to disease infection and development. Experience has shown that in a dry year, fungicide use can be reduced 30% to 50%, whereas in a normal to wet year the number of fungicide applications will equal those applied under a calendar spray schedule.

Suppression Strategy:
Grapes in Missouri receive an average 7 fungicide applications for suppression of diseases. Disease control on

resistant varieties such as Norton can be achieved with an average of 3 fungicide applications whereas the susceptible varieties will require an average 10 applications per season. Disease control within the season is achieved through regularly timed fungicide applications that begin with budbreak and continue on a 7 to 10 day schedule depending upon weather conditions. All applications are made by ground.

Chemical:

- **Azoxystrobin** (Abound), registered in 1997, is used on less than 5% of the grape acreage in Missouri. There were reports of some grower use in 1999 but a major constraint to use of Abound is minimum purchase requirements for dealers and distributors and the relatively small acreage in the region cannot cover dealer purchases. Abound has been shown to effectively control black rot, downy mildew, powdery mildew, and Phomopsis leaf and cane spot. Control of Botrytis bunch rot has been inconsistent. Abound is applied at 0.18 to 0.25 lb a.i. per acre and cannot be applied within 14 days of harvest. Because its mode of action is inhibition of spore germination, Abound is most effective when applied as a protectant fungicide. It disease control spectrum positions Abound as a Captan "replacement" but concerns about the development of disease resistance to Abound dictates that its use is more appropriate when alternated with other fungicides such as Captan, Nova, or Mancozeb for control of the major grape diseases. Use recommendations are for no more than two sequential sprays of Abound alternated with other fungicides with a different mode of action. No more than 1.5 lb a.i. of Abound can be applied in one season.

- **Benomyl** (Benlate) is used on approximately 65% of grape acres. It is applied at 0.38 to 0.75 lb a.i. per application for a maximum of 3 lb a.i. per season. Benlate can be applied every 10 to 21 days from 1 inch shoot growth until 70 days before harvest. Because of rapid development of resistance to Benlate, this fungicide is almost always applied with other fungicides.

- **Calcium Polysulfide** (Liquid Lime-Sulfur, Lime Sulfur) is used on approximately 12% of grape acres. It is applied at up to 36 gallons per acre as a dormant spray for control of anthracnose and powdery mildew.

- **Captan** (Captan, Captec) is the number one fungicide used on grapes in Missouri; almost 100% of the acreage receives at least one application per season. On all except the more disease-resistant grape cultivars such as Norton, captan is applied 3 to 4 times per season. It is almost always tank-mixed with another fungicide (Nova, Benlate, Mancozeb). Captan is applied 1 to 2 lb a.i. per application with a maximum of 12 lbs a.i. per season. It can be applied beginning at 1 inch shoot growth and every 10-14 days after up to the day of harvest. Captan carries a 96-hour restricted entry interval.

- **Copper Hydroxide + hydrated lime** (Agtrol, Kocide, Microflo) can be applied beginning at bud break and continue up to harvest at 1 to 2 lbs a.i. per application depending on disease severity. Some formulations of Kocide should not be applied during bloom. If applied under cool, slow drying conditions, copper may cause injury to grape foliage. Grape varieties vary in their sensitivity to copper. Catawba is moderately sensitive.

- **Metalaxyl + Mancozeb** (Ridomil GoldMZ) is applied at 0.01lb a.i. metalaxyl + 1.6 lb a.i. mancozeb as an preventive or eradicant for downy mildew. Because of its expense and 66-day PHI restrictions, Ridomil GoldMZ is used only to stop a downy mildew outbreak that was not controlled with a grower's conventional fungicide program. In Missouri, we recorded its use only once over a 4- year period.

- **Myclobutanil** (Nova) is used on approximately 40% of the grape acres in Missouri. Nova is applied 3 to 4 times in a season and is almost always tank-mixed with another fungicide (captan, mancozeb) because of concerns over resistance development. A sterol inhibitor with localized systemic activity, it is a very important fungicide because of it's "kick-back" activity. Nova can be applied within 72 hours after the beginning of an infection period for disease control. It is extremely useful with disease predictors in an integrated pest management program. Nova is applied at 1.2 to 2.0 oz a.i. per application. Nova can be applied every 10 to 14 days from 1 inch shoot growth up till 14 days before harvest for a maximum of 9.6 oz a.i. in a season.

- **Mancozeb** (Mancozeb, Dithane M45, Penncozeb) and **Maneb** (Maneb, Manex, Maneb plus Zinc F4) are the second most important fungicides used on grapes. Applied to approximately 94% of grape acres, they are extremely useful for early season disease control and for resistance management. They are applied at 1.125 to 3.0 lb a.i. per application from 1 inch shoot growth through fruit set. All formulations have a 66-day pre-harvest interval and thus are not recommended fungicides for late season control of black rot or downy mildew.

- **Iprodione** (Rovral) is used on approximately 33% of grape acres. Its use is generally limited to French-American hybrids such as Seyval, Vignoles, and Vidal. These are premium white wine grapes that are tight clustered and thus prone to bunch rot. Unless conditions are conducive to bunch rot, Rovral is usually applied only once or twice in a season. Rovral is applied at 0.5 to 1 lb a.i. per acre for a maximum of 4 applications per season. Iprodione can be applied at early mid-bloom, prior to bunch closing, at the beginning of fruit ripening, and 7 days prior to harvest.

- **Sulfur** (many formulations of wettable sulfur) is used on approximately 85% of grape acres. Sulfur is one of the most important fungicides for disease management. It is highly effective against powdery mildew and can be applied up to the day of harvest. It is applied at 2 to 10 lbs a.i. depending on formulation. Some grape cultivars are sensitive to injury from sulfur, especially if applications are made when ambient temperatures exceed 85 F.

- The following registered fungicides are used on less than 3% of the grape acres in Missouri: **Carbamate** (Ferbam), **Kresoxim-methyl** (Sovran), **Tebuconazole** (Elite), **Triadimefon** (Bayleton), **Trifloxystrobin** (Flint), **Triflumizole** (Procure), and **Ziram** (Ziram).

Weeds

In general, weeds are managed in the vineyard through grass sod middles, mowing, and application of a pre-emergence herbicide followed by spot treatments with either glyphosate or Paraquat. About 80% of Missouri's vineyards are treated with an average 1.2 herbicide applications per season.

Prevention Strategy:
Mowing and tillage provide significant weed control during the season.

Avoidance Strategy:
Being a perennial crop, avoidance strategies for weeds are not practical on grapes.

Monitoring Strategy:
Fields are scouted by producers for weed infestations and post-emergence herbicide applications are timed accordingly.

Suppression Strategy:
Herbicides are routinely used for economical weed control in Midwestern grape vineyards. Because all established vineyards have a grass or sod middle between trellis rows, typically only a 3-4ft band within the row is treated with herbicides to maintain a weed-free area. Rates listed below are for the amount of active ingredient for a broadcast application per acre. The actual area treated will depend on row spacing and herbicide strip width. For most established vineyards in Missouri approximately 40% of an actual acre is treated.

Chemical:

- **Diuron** (Karmex, Diuron) is the most widely used herbicide used on grapes in Missouri with an estimated 45% of acreage treated each year. Karmex is registered on bearing vineyards 3 years of age or older. It is applied pre-emergence at 2-6 lb per acre for control of germinating broadleaf weeds and some grasses, and some perennial weeds. Grape vines cannot be replanted within 2 years where Karmex has been applied. The potential for crop injury or off site movement of Karmex is greatest on soils low in organic matter or clay content; soils atypical in Midwestern grape vineyards.

- **Oryzalin** (Surflan) applied to 20% of the grape acres in Missouri. It is registered for bearing, nonbearing and newly planted vineyards. Surflan is applied at 2 to 6 qt per acre for control of germinating grass and broadleaf weeds. The rate applied depends on desired length of control. One-half to one inch rainfall or irrigation is needed within 3 weeks of application.

- **Simazine** (Princep, Simazine) applied to 10% of the grape acres in Missouri. It is registered for bearing vineyards 3 years or older. Princep is applied at 2 to 4.8 qt per acre for control of germinating broadleaf weeds and some grasses. It should not be applied to gravelly, sand or sandy loam soils. Efficacy is reduced if soil surface is acidic. Limit irrigation to one-half inch after application. Make on ly one application per season.

- **Norflurazon** (Solicam) applied to 10% of the grape acres in Missouri. It is registered from application to vineyards at least 2 years old. Solicam is applied at 1.25 to 5 lb per acre for control of germinating grass and broadleaf weeds and some perennial weeds. The rate applied depends on soil texture. Rainfall or irrigation is needed within 4 weeks of application. Do not apply more than 5 lbs per year.

- **Glyphosate** (Roundup, Roundup Ultra, various generic formulations) applied to 20% of the grape acres in Missouri. It is a non-selective herbicide registered for bearing and nonbearing vineyards. Roundup is applied post-emergence at 1-5 qt per acre for control of annual and perennial grasses and broadleaf weeds. Herbicide contact with green stems, shoots or foliage must be avoided. A shielded sprayer must be used to protect young vines and replacement trunks. Do not apply within 14 days of harvest. Do not apply more than 10.6 qt per season.

- **Paraquat** (Gramoxone Extra) applied to 15% of the grape acres in Missouri. It is a non-selective herbicide registered for bearing and nonbearing vineyards. Paraquat is applied post-emergence at 2 to 3 pt per acre for control of annual grasses and broadleaf weeds. Herbicide contact with green stems, shoots or foliage must be avoided. A shielded sprayer must be used to protect young vines and replacement trunks. Spray when suckers are less than 8 inches. Restricted Use Pesticide.

- The following registered herbicides are used on less than 3% of the grape acres in Missouri. **Dichlobenil** (Casoran, Norosac), **Napropamide** (Devrinol), **Trifluralin** (Trilin, Trific, Trifluralin), **Oxyfluorfen** (Goal), **Pronamide** (Kerb), **Sethoxydim** (Poast) and **Glufosinate** (Rely) are registered for bearing and nonbearing vineyards. **Isoxaben** (Gallery), **Pendimethalin** (Prowl, Pentagon), **Clethodim** (Prism), **Fluazifop** (Fusilade DX), **Sulfosate** (Touchdown) and **MSMA** (120 Herbicide, 912 Herbicide) are registered for nonbearing vineyards only.

New Trends and Technologies in Missouri Grape Production

Organic Grape Production:
A few vineyards are attempting to produce organically grown Norton due to its high disease resistance. This specialized production system will require careful integration of the following pest management strategies.

- cover crops (clovers) and organic mulches to promote beneficial insects, suppress weeds in the row and supply nitrogen
- mating disruption for grape berry moth
- use of sulfur and copper for disease suppression
- vineyard sanitation to prevent disease inoculum from building up in the vineyard
- use of the Geneva double curtain trellis system, shoot positioning and canopy management for disease management

New sprayer technologies:
Research is being conducted on Rotary Atomizer sprayers that give improved coverage of both leaf surfaces, reduce drift, and achieve a 30-40% reduction in pesticide applied per acre.

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References

1. Geneva Double Curtain Trellis System. Sanliang Gu. 1995. Vineyard and Vintage View newsletter. Vol. 10(6). Southwest Missouri State University, Dept. of Fruit Science Research Campus, Mountain Grove.

2. Grape Insects. 1997. Ric Bessin. University of Kentucky Cooperative Extension Service.

3. Grape IPM in the Northeast. 1995. T. Weigle and J. Kovach. New York State Integrated Pest Management Program, Cornell University Cooperative Extension Publication 211.

4. Grapevine Species and Varieties Grown in Missouri. Sanliang Gu. 1995. Vineyard and Vintage View newsletter. Vol. 10(5). Southwest Missouri State University, Dept. of Fruit Science Research Campus, Mountain Grove.

5. Missouri Commercial Grape Pest Control Guide 2000. Southwest Missouri State University, Dept. of Fruit Science Research Campus, Mountain Grove. MS 19.

6. New York and Pennsylvania Pest Management Recommendations for Grapes. 1994. T. Weigle (Cornell) and A. Muza (Penn State). Cornell and Penn State Cooperative Extension Publication.

7. Pest Control in Grapes. 1999. B. Bordelon, C. Janssen and F. Whitford. PPP102. Purdue Pesticide Programs, Purdue Cooperative Extension Service.

8. Pesticide Use Surveys Missouri, Apples, Peaches & Grapes. 1990. Pesticide Impact Assessment Program, USDA ES 9 EPIX-1-0018, University of Missouri.

9. Vineyard Establishment in the Ozarks (part 1). 1996. W. Keith Patterson. Vineyard and Vintage View newsletter. Vol. 11(5). Southwest Missouri State University, Dept. of Fruit Science Research Campus, Mountain Grove.

10. Wine growing in Eastern America: An Illustrated Guide to Viticulture East of the Rockies. Lucie Morton. 1985. 216 pp.

The Missouri Grape Crop Profile was developed from interviews and surveys of key grape growers who manage approximately 25% of the production acreage in the state. Other information was gleaned from grape specialists located at the Mountain Grove Fruit Research Station, administered through Southwest Missouri State University. The third key information source was from census data and pesticide usage data obtained from USDA and the Pesticide Impact Assessment Program.

Appendices

Table 1. Pre-harvest and Restricted Entry Intervals, and Strengths and Weaknesses of Critical Pesticides on Grapes in Missouri

Insecticides (I) Fungicides (F) Herbicides (H)	PHI (days)	REI (hrs)	Strengths	Weaknesses
Diazinon (I)	28	24	Effective for grape berry moth and leaf hopper	28 day PHI
Carbaryl (I)	7	12	Effective on many insect pests of grape	Hard on bees and can promote aphid outbreaks
Endosulfan (I)	7	24	Effective for phylloxera	Phytotoxic to Norton
Captan (F)	0	96	Cheap and highly effective for black rot and downy mildew. 0 day PHI.	96 hr re-entry interval
Mancozeb Maneb (F)	66	24	Excellent early-season control of black rot and downy mildew	66 day PHI
Sulfur (F)	0	12	Cheap and effective fungicide for powdery mildew	Phytotoxic to many cultivars if temp. above 85F at application
Copper (F)	0	24	Cheap and effective fungicide for downy mildew	Phytotoxic to many cultivars
Myclobutanil (F)	14	24	Systemic fungicide: excellent for use with disease predictors	Prone to resistance
Benomyl (F)	70	24	Excellent	Prone to resistance
Azoxystrobin (F)	14	12	Excellent control of black rot, and downy and powdery mildews	Must be rotated with other modes of action to prevent resistance
Iprodione (F)	7	12	Effective fungicide for bunch rot. No stand-alone alternatives	Expensive
Diuron (H)	NA	12	Effective season-long control of many grasses & broadleaves	Vines must be 3 years old
Simazine (H)	NA	12	Effective season-long control of many broadleaves & grasses	Vines must be 3 years old
Norflurazon (H)	NA	12	Effective season-long control of many broadleaves & grasses	Expensive. Control of many weed species not as good as diuron and simazine
Glyphosate (H)	14	4	non-selective	no residual activity

Table 2. Potential Crop Protection Chemicals for IPM Systems in Grape

Chemical (Class)[1]	Mode of Action	Target Pests	Registration Status	Potential for use in Missouri
Abamectin (I,A)	avermectin	mites	registered	low
Acetamiprid (I)	chloronicotinls	aphids, phylloxera	pending	moderate
Azadiractin (I)	hormonal analog	grape berry moth	registered	high
Azafenidin (H)	ppo inhibitor	broadleaf and grass weeds	pending	moderate
Bifenazate (A)	carbazate	spider mites	pending	low
Buprofezin (I)	thiadiazone - IGR	plant & leafhoppers, scale, whiteflies	potential	low
Canola Oil (I,A)	natural product	mites	registered	low
Cinnamon Oil (I,A)	natural product	mites	potential	low
Etoxazole (I,A)	2,4-diphenyloxaline derivative	mites	potential	low
Fenpropathrin (I,A)	pyrethroid	aphids, lepidopterous insects	pending	moderate
Fenpyroximate (A)	unknown	mites	unknown	low
Flazasilfuron (H)	sulfonylurea	broadleaf and grass weeds	unknown	low
Flufenzin (A)	unknown	mites	unknown	low
Flumioxagen (H)	ppo inhibitor	broadleaf and grass weeds	unknown	moderate
Glufosinate (H)	EPSP synthase inhibitor	non-selective	registered	high
Imidacloprid (I)	chloronicotinyl	aphids, phylloxera	registered	moderate
Jojoba Oil (I,F)	natural product	whitefly, powdery mildew	registered	low
Kaolin (I,A)	biopesticide	insects & mites	potential	low
Methoxyfenozide (I)	diacylhydrazine	grape berry moth	potential	high
Pyridaben (I)	pyridazinone	aphids, leafhoppers, phylloxera?	pending	moderate
Spinosad (I)	macrocyclic lactone	grape berry moth, flea beetles, aphids, phylloxera	potential	high
Tebufenozide (I)	diacylhydrazine	grape berry moth	potential	high
Thiamethoxam (I)	neonicotinoid	aphids, leafhoppers, flea beetles?	potential	moderate
Tolylfluanid (F,A)	unknown	fungal pathogens and mites	potential	unknown

1 F = fungicide, I = insecticide, A = acaricide, H = herbicide

University. All materials may be used freely with credit to the USDA.