Crop Profile for Labrusca (Juice) Grapes in Michigan

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General Production Information

1. In 2000, Michigan growers produced a total of 87,200 tons of grapes (including juice, wine, table and non-bearing grapes). Michigan ranked 4th in total U.S. grape production in 2000, with 1.1% of the U.S. production (California, Washington and New York ranked first through third). Michigan's average production for 1997-2000 was 73,000 tons per year (average: 6 tons per acre) (31).
2. In 2001, Michigan growers only produced a total of 28,900 tons of grapes, ranking 9th in total U. S. production. This drastic decrease was due to cold weather in May that severely damaged the grapes (30).
3. There were 83,600 tons of *juice grapes* produced in 2000 in Michigan (31), and 26,000 tons in 2001 (30).
4. *Concord grapes*, used to make jams, jellies, preserves, and grape juice, are the most common grapes grown in Michigan. In 2000, Michigan ranked 3rd in the U.S. with 64,500 tons produced, totaling 16.5% of the U.S. production (31). In 2001 Michigan ranked 4th with 19,000 tons totaling 5.4% of the U.S. production (30).
5. *Niagara grapes*, used to make white grape juice, are also a common variety grown in Michigan. In 2000, Michigan ranked first in the nation with 19,100 tons produced, totaling 36.4% of the U. S. production (31). In 2001, Michigan ranked third with 7,000 tons produced totaling 16.3% of the U.S. production (30).

PRODUCTION REGIONS

Most grape vineyards are located in 2 counties in southwestern Michigan, Berrien and Van Buren. In

2000, Berrien County had 245 farms growing 7,000 acres of grapes. Van Buren County had 106 farms growing 4,850 acres of grapes. Most of the acreage is in Concord and Niagara varieties, used for grape juice under contract with the National Grape Cooperative (32).

SITE PREPARATION

Grapevines grow best in deep, well-drained soils that promote rooting to a depth of at least 36 inches. Ideal soil pH is 6.5. Vineyards are typically located on sloping sites that offer good air drainage to minimize spring/fall freeze hazards.

Site preparation should begin at least one year prior to planting. Weed control is the single most important factor in site preparation; all perennial weeds should be eradicated before planting to eliminate competition with the new vines. Because vineyards are commonly located on slopes, erosion control measures such as diversion ditches, sod waterways, standpipes, hilling under trellises and permanent sod strips should be implemented where necessary.

PRODUCTION PRACTICES

The first three years: Grapevines take three years to reach maturity, although Niagara can be harvested in the second year if conditions are favorable. It is not until the fourth year that vines reach full production. Commercially available rooted 3-node cuttings are planted in early spring after the threat of a hard freeze has passed. For ease of management and optimum yield, grapevines must be supported by a trellis. Many growers let vines grow on the ground during the first year, then put in trellises and train vines in year two (27).

Pest Control: Weed control is critical during the first years of establishment. Insect and disease management begins the first year to protect shoots from foliar diseases and leaf-eating insects. Preventive fungicide sprays are applied three to four times during the first two growing seasons. By the third year, vines are on the same pest control schedule as bearing vines. Third-year vines produce at least half of their potential yield (27).

Bearing vines: Grapevines require annual pruning to remain productive and manageable and to achieve consistent yields. Dormant vines are pruned in early spring, and pruning severity is adjusted to account for midwinter cold injury and to balance growth and fruiting. This helps achieve consistent yields. Grapevines can potentially produce 10 to 12 tons per acre (average is 5 tons). Allowing vines to overproduce reduces vigor and future yields (27).

The seasonal pest management program begins with a burndown herbicide application in early spring. A preemergence herbicide, or preemergence herbicide tank mixed with a postemergence herbicide, is applied a month later. Scouting begins in April for grape flea beetle and cutworms to prevent damage to developing buds. A protectant spray schedule for black rot, Phomopsis cane and leaf spot, downy mildew, and powdery mildew begins the first of May when shoots are 3 to 5 inches long and continues

at 7- to 14-day intervals until veraison, or berry ripening. Sprays at bloom and post bloom are the most critical for control of major fruit pathogens and some insect pests (27).

Pheromone traps are set in late April or early May to monitor the abundance of grape berry moths. An immediate post-bloom spray of insecticide is applied for control of grape berry moths and grape leafhoppers. Insecticides are applied as needed to reduce damage from rose chafers, Japanese beetles, gall makers and other insect pests (27).

An acceptable balance of sugar, acid, and pH determines the harvest date. The ratio varies somewhat, depending on the grape variety and weather during the growing season. The winemaker or juice processor works with the grower to determine the optimum time for harvest. Juice grapes are machine-picked by the grower or a contracted harvester and hauled to the juice processor. The entire grape crop is picked at one time (27).

Following harvest, a fungicide application may be made to varieties susceptible to powdery or downy mildew. These diseases cause early defoliation, which weakens the vine, reducing winter hardiness and potentially, future production. Grapevines normally drop all their leaves at the first hard frost (27).

Worker Activities

Hand labor activities in Michigan juice grapes include:

Pruning

About two thirds of Michigan's acres are pruned by hand and the rest are pruned mechanically. Vine pruning begins in early winter and continues until early spring. Workers will prune a vine in 2 to 5 minutes and continue pruning for 4 to 8 hours a day, depending on weather and day length. About 25% of the mechanically pruned vineyards receive a quick follow-up by hand. No pesticide applications occur during the pruning season.

Tying

Tying is done in the early spring (March-April) for several weeks before and during early shoot growth. Workers tie shoots and canes to the trellis wires with 2 or 3 ties per plant and work continuously all day. Tying must be done before growth of the new shoots is too far advanced, as shoots more than a half-inch long and shorter than 6 to 8 inches are easily broken off the plant. Cutworm sprays (Lorsban or Danitol) at bud swell are applied after this activity. Tying is usually finished before any insecticide or fungicide sprays are applied.

Suckering

About half the vineyards have workers walk through the vineyard in May and remove suckers arising from the base of the plant. The remaining vineyards use Gramoxone as a contact herbicide in the row and do this task chemically.

Shoot positioning

After bloom in late June and early July, some growers have crews pull the shoots off the trellis so the shoots are oriented perpendicular to the trellis rather than growing along it and shading out lower growth. Perhaps less than 5% of the growers do this by hand and about 10% do it mechanically.

IPM Scouting

Scouting is done in about 50% of the vineyards. A scout, hired by the grower, will assess the vineyard on a weekly basis for signs of pests and disease. Most scouting is done from a pickup or ATV with the scout assessing the foliage near insect traps or where he/she sees symptoms.

Mechanized labor activities in juice grapes include:

Spraying

The grower or a family member does most of the spraying at 2- to 3-week intervals. Sprays are mostly applied with ground equipment (air blast or tower sprayers).

Harvest

Harvest timing: Niagara grapes are harvested in early September, Concord grapes are harvested in mid-September to early October.

All juice grapes are mechanically harvested. This typically consists of a 4-person crew: a harvester driver, two tractor drivers and a helper who rides a trailer to guide the conveyor that is feeding grapes from the harvester into bulk boxes (three per trailer). When one trailer is full, another trailer with empty boxes takes its place and the helper changes to the new trailer. The helper is also responsible for removing trash from the bulk bins. About 15% of the acreage is harvested into large 10-ton totes and no helper is used. Mechanical harvest crews can harvest one to two acres an hour (36).

Insect Pests

Grape Berry Moth

Endopiza viteana Clemens

The grape berry moth is a key pest of Michigan grapes. This insect has 2-3 generations per year, with adult flights before bloom, during cluster expansion in mid July, and in mid-August. Larvae from this last generation may cause contamination of the fruit at harvest (28).

Life cycle: Grape berry moths overwinter as pupae in leaf litter. First generation adults emerge around bloom time. Males are sometimes monitored at this time with pheromone traps, to determine the need for and timing of insecticide applications. Male and female moths mate, and females lay eggs directly onto the grape cluster. The eggs are shiny and very small (about 1 mm in diameter). Eggs parasitized by wasps turn black. Eggs hatch in 3 to 6 days depending on temperature. The larvae feed on the young grape clusters and spin webbing for protection. In all later generations they enter the berry, feeding inside for about 4 weeks until fully developed. Last instar larvae cut two slits in the edge of a leaf and roll a tube in which they pupate. Adults emerge 4-5 days later (28, 42).

Damage: Webbing and larvae are visible in the small clusters during and after bloom. First generation larvae feed directly on developing clusters, and may remove many small berries. When berries are formed, the young larvae burrow into the fruit. Damage from redbanded leafroller can be mistaken for grape berry moth so it is important to identify the larvae to determine the appropriate management strategy. Second generation larvae feed on the expanding berries and feeding sites are visible as holes. Larvae may web together multiple berries. Berries may be hollowed out by feeding, and larvae may contaminate harvested fruit. Damage by grape berry moth at this stage of development predisposes fruit to late-season fruit rots. Typically, damage is greatest at vineyard borders, and especially adjacent to wooded areas. Scouting for damage within the vineyard ensures that hotspots are not missed (28, 42).

Control: Pheromone traps are available to detect the presence and seasonal activity of grape berry moths. Pheromone for mating disruption should be applied at the first adult emergence. Reapplication may be necessary to cover all adult flights. Large acreage vineyards with relatively low populations are

the most appropriate for mating disruption (24).

Optimal chemical control of grape berry moth is achieved through application of insecticides to provide coverage of the clusters during the post bloom period. The third week of July is a key time to scout high-risk vineyards for grape berry moth. If subsequent monitoring of clusters indicates that grape berry moth is still active, further insecticides are applied in late July or in late August, depending on the level of infestation. Removal of leaves, keeping the vineyard weed-free and removal of wild grapes may aid in grape berry moth management. Biological control agents are active in many vineyards, but are not economical as a stand-alone control tactic. Preservation of natural enemies through appropriate selection of insecticides may enhance biocontrol activity (28).

Federal inspection standards that are applied at the processor may cause rejection of juice grape loads. The effect of grape berry moth feeding on yields has not been determined, but 50-80% of clusters can be infested with grape berry moth prior to harvest at heavily infested vineyard edges. Yield losses are likely to be concentrated at the vineyard edges, and some growers do not harvest this area to reduce contamination of fruit (28).

Pest control products recommended to manage grape berry moth include: mating disruption pheromone, Diazinon, Guthion, Imidan, Lannate, Sevin, B.t., Danitol and Intrepid (24).

Leafhoppers

Erythroneura comes Say (Grape Leafhopper)
Empoasca fabae Harris (Potato Leafhopper)

Potato leafhopper

Several leafhopper species feed on grape foliage in the eastern U.S. All feed on the undersides of leaves, puncturing cells and sucking out the contents. In general, native juice grape (labrusca) varieties are much more tolerant of leafhoppers than hybrid or vinifera varieties. Wide fluctuations in leafhopper population are common from year to year. In some years *E. fabae* can be more destructive than *E. comes* (3, 42).

Life Cycle: The *grape leafhopper* has 1 or 2 generations per year. It is 1/8 inch long and orange-yellow in color with some dark spots and yellow lines on the forewings. Adults overwinter in plant debris in or

near vineyards. After mating, egg-laying begins during mid- to late June. Eggs are laid singly beneath the epidermis on the underside of the grape leaf producing a slight blister. The first flightless nymphs appear in late June and reach the adult stage by late July. The second generation of nymphs and adults are found in late August. There are five nymphal instars. Nymphs as well as adults are very active, especially on hot dry days, and are easily disturbed. During the summer, all stages and the cast nymphal skins are found on the lower leaf surface.

Potato leafhopper adults are pale to bright green and about 1/8 inch long. Adults are very active, jumping, flying or running when disturbed. The immature forms, or nymphs, are pale green and wingless. They run forward, backward or sideways when disturbed. The potato leafhopper does not overwinter north of the Gulf States. Adults migrate north each spring on southerly winds and are deposited during spring rains in May and June. Once leafhoppers arrive, adults mate but don't reproduce. They remain on the plants until new growth develops on the vines (3, 42).

Damage: Adults as well as immature leafhoppers feed on the underside of leaves by sucking out the liquid cell contents. The tissue surrounding the feeding puncture turns white and eventually dies causing a white/yellow stippling pattern on the upper leaf surface. Feeding is limited initially to the lower leaves. Heavy leafhopper feeding results in premature leaf drop, lowered sugar content, increased acid, and poor color of the fruit. Ripening fruit are often smutted or stained by the sticky excrement (honeydew) of the leafhoppers, which affects appearance and supports the growth of sooty molds. Also, severely infested vines may be unable to produce sufficient wood for the following season. Damage to the vines can be serious if infestations are allowed to persist unchecked for two or more years (3).

General Control Information: Concord grapevines can tolerate populations of up to 15 grape leafhoppers per leaf with little or no economic damage. Cold, wet weather conditions in spring, fall and winter are damaging to leafhopper populations. Fall cultivation and clean-up of weedy land eliminates favorable overwintering sites in and near a vineyard. In labrusca vines, growers can sample for grape leafhoppers in the third week of July to determine the need for management. When grape leafhoppers appear in high numbers, the application of a contact insecticide becomes necessary. If populations are only at the vineyard edges, area-specific management should be considered. It is important to obtain complete spray coverage of the undersides of the leaves for good control. Coverage of the fruit clusters is of secondary importance. The third week of July is a key time to scout high-risk vineyards and make decisions about control. Insecticides applied for grape berry moths may control grape leafhopper as well (3, 24, 42).

Pest control products recommended to control leafhoppers in Michigan include: Diazinon, Guthion, Imidan, Lannate, Provado, Sevin, Danitol, Pyrmite, Surround and Assail (24).

Climbing Cutworm

Amathes spp. Linnaeus

The name cutworm is applied to a large number of larvae of lepidopterous species in the family Noctuidae. The moths are night flyers and the larvae are night feeders. Both stages hide during the day. Several species of climbing cutworms can be found in vineyards (4).

Life Cycle: The adults are medium sized moths with a heavy body and a wing spread of 1 to 1.5 inches. The eggs are laid on the leaves of the host plants. Eggs are spherical and off-white in color changing to almost black before hatching. Fully-grown larvae are 1 to 1.4 inch long caterpillars with dark heads and dull gray/brown bodies with dots or stripes. Larvae feed at night on young buds and hide during the day in the soil beneath the vines. When fully grown the larvae pupate in an earthen cell below the soil surface. The pupae are about 0.7 inch long, smooth, and reddish brown. There are four long spines on the tip of the abdomen to aid the pupa in working its way out of the soil (4, 42).

Damage: The greatest economic injury occurs during bud enlargement in the spring. Larvae feed on the buds from early bud swell through bud break and until the shoots are 4 to 6 inches long. They also feed on the young leaves. This feeding results in the loss of primary, and in some instances, loss of secondary and tertiary buds. Grapevines compensate, at least to some extent, for primary bud loss through production of secondary buds. However, shoots from such buds are less fruitful than those from primary buds. When both primary and secondary buds are damaged the tertiary buds produce a shoot but no fruit. Cutworms are mainly a pest in areas with sandy soil and in vineyards with weeds under the vines. Bud injury due to cutworm feeding is very similar to that caused by adult flea beetles in the spring, though the feeding by cutworms creates a longer feeding site. However, attack by flea beetles begins earlier, at the beginning of bud swell. Presence of either species in the vineyard should help in identifying the cause of bud injury (4, 42).

General Control Information: Timing of spray treatments is very important since cutworm larvae can cause significant bud damage in a short amount of time in the spring. Vineyards with a history of cutworm damage should be scouted regularly during bud expansion, particularly after warm nights. Once shoot expansion begins, vines are no longer at risk. If bud damage reaches 1 to 2%, application of one or more insecticide treatments is justifiable (4, 42).

Pest control products recommended to manage climbing cutworms include Lorsban and Danitol (24).

Japanese Beetle

Popillia japonica Newman

Life Cycle: Japanese beetles begin to emerge in early July and can be found through September. Beetles leave their tunnels during the morning of clear days for feeding and mating. They return to the soil in the late afternoon or evening to spend the night and also remain in the soil on cold wet days. The beetles lay their eggs underground in grassy areas in mid summer. The eggs hatch in late July and the larvae go through three molts before fall. They are less than 1/15 of an inch long when they first hatch and may be as large as 1 inch at third stage larvae. The white, C-shaped larvae (grubs) feed on grass and weed roots and overwinter further underground in these areas. Grubs move up into the root zone during April and May to feed and reach maturity (5, 42).

Damage: Adults feed on the upper surface of the foliage between the veins, leaving a lace-like skeleton. Leaves turn brown and die if feeding is severe, but berry clusters are not attacked. Japanese beetles can be a problem particularly in new vineyards using grow tubes (5, 42).

General Control Information: Labrusca vines are naturally resistant to feeding by Japanese beetles and tolerate some damage, but vinifera vines and hybrids are more susceptible. Monitoring is required to reduce the risk of damage. Traps are not recommended because they attract more beetles to the vineyard. Birds and mammals reduce Japanese beetle grub populations considerably by feeding on large numbers of grubs during the early spring and fall. Chemical controls include: Imidan, Sevin, Danitol and Surround (24).

Rose Chafer

Macrodactylus subspinosus

This general feeder is related to the Japanese beetle, sharing a similar life cycle (6).

Life Cycle: Larvae (grubs) overwinter in the soil, resuming development in the spring. Adult beetles emerge in late May or early June, near the time of grape bloom and live for 3- to 4 weeks. They are about 0.5 inch long with a tan body, dark brown head and long legs. Males and females congregate on plants to mate and feed on blossoms, newly set fruit and leaves. Mating and egg-laying occur continuously for about two weeks with each female depositing eggs just below the surface of sandy soil. In about two weeks, eggs hatch and the grubs remain in the soil until they pupate in the spring. This pest is more common in areas with light sandy soils. There is only one generation per year (6).

Damage: Rose chafers feed on green tissue. Feeding damage is most obvious on the leaves though the greatest impact can be on young clusters when adult beetles remove the developing berries (42).

General Control Information: Vigilance must be maintained early in the season in case of high rose chafer populations. In severe cases, blossom buds are completely destroyed, resulting in little or no grape production. Bloom-time sprays for grape berry moth will control rose chafers (6). Chemical controls include: Guthion, Imidan, Lannate, Sevin, and Danitol (24).

Grape Cane Gallmaker

Ampeloglypter sesostris LeConte

The grape cane gallmaker is one of two *Ampeloglypter* species that can damage new shoot growth in the spring. This small beetle is a sporadic pest throughout eastern North America (7).

Life Cycle: The grape cane gallmaker, a 1/8 inch long, dark brown, snout-nosed beetle, looks like the grape cane girdler. The legless larva (grub) is white with a brown head. The girdler overwinters in the adult stage in debris on the ground. Egg-laying begins in May or June. The female hollows out a small cavity just above a node and places a single egg in it. Then she hollows out from 8 to 14 additional cavities in a straight line up the cane. Only the first hole contains an egg. The cane swells in the area of the oviposition injury and noticeable red galls form. The young larvae feed on tissue in the egg cavity and, later, feed along the center of the shoots in the pith above or below the gall. The larvae pupate within the galls. The pupa resembles the adult beetle with legs and snout clearly discernible. In mid-summer adults begin to emerge from infested canes and emergence continues through September (7, 42).

Damage: Galls are usually twice as thick as the cane and 1 to 2 inches long. They are found just above the nodes and are of uniform shape except for a deep longitudinal scar on the side of the gall where the female made the egg cavity. On galls where beetles successfully completed development and emerged, a round exit hole can be found near the scar. The majority of galls are beyond the fruit clusters and cause no serious yield loss. Canes with galls can produce a crop the following year. Galls apparently have little effect on vigor and growth of the vine but they can weaken the mechanical strength of the cane and cause breakage (7, 42).

General Control Information: The grape cane gallmaker is usually a minor problem. It is possible to prune out galls without affecting the crop. This reduces the overwintering population provided galls are pruned out and destroyed before the adults emerge in August. In heavy infestations, it is necessary to spray for the adults before they begin laying eggs in the spring. Materials used for control of the grape cane girdler are also effective against the grape cane gallmaker. Timing of sprays is similar for both species since adults are active at about the same time in the spring (7, 42).

Grape Cane Girdler

Ampeloglypter ater LeConte

The grape cane girdler is the second of two *Ampeloglypter* species that can attack spring shoot growth in the Midwestern and Eastern United States. Like the grape cane gallmaker, it has only one generation per year (8). Also like the gallmaker, the cane girdler is either a sporadic pest in Michigan juice grapes or does not cause economic damage worth control effort (33).

Life Cycle: The adults are black, snout-nosed beetles that emerge from infested canes during August and subsequently overwinter in trash on the ground. In late May, before bloom, females begin to lay their eggs and girdle new canes. They encircle the cane with holes in which the eggs are laid. Afterward, another set of punctures is made encircling the cane a few inches from the first set of holes bearing the eggs. Egg-laying continues for about one month. The legless grub is white with a brown head, similar in appearance to the closely related grape cane gallmaker. Grubs feed in the cane pith between the girdles. Larval development takes over a month. The pupa forms within the dead shoot on the vine or on the ground and develops into the adult in approximately 2 weeks. Adults hibernate over the winter and reappear in the spring (8, 42).

Damage: Girdling causes the terminal growth of the new shoots to bend over and drop to the ground.

Vines pruned by the grape cane girdler have a ragged appearance, suggesting serious injury to the plant but the actual damage is usually minor (8, 42).

General Control Information: Injury from this pest has the greatest impact on vines during establishment. Injured shoots are conspicuous early in the season and should be cut off below the lower girdle before the adults emerge in the summer. Destroying infested shoots helps reduce the overwintering population. In severe infestations grape cane girdler adults are controlled with sprays targeted before they begin laying eggs in the spring. Sprays may also be applied when the buds are swelling (8, 42).

Grape Flea Beetle

Altica chalybea Illiger

The grape flea beetle (or steely beetle) attacks buds of wild and cultivated grapevines. It is one of the first insect pests to appear in vineyards in the spring. Infestations are usually localized in border row plantings near favorable hibernating quarters such as wasteland, woodland, and abandoned vineyards (9).

Life Cycle: The grape flea beetle overwinters as a shiny metallic dark blue adult. Eggs are laid on the bud scales and under the loose bark of the canes near buds. As foliage develops, eggs are laid on the upper side of the leaves. Newly hatched larvae are dark brown, turning light brown with spots by the time they reach maturity. The pupal stage of development occurs in the soil (9, 42).

Damage: Overwintering adults feed on the swelling buds when weather warms in the spring. They bore into the buds and hollow out the inside. In contrast, the larvae and summer adults feed on the tender leaf tissues but avoid the leaf veins. Spring feeding on the primary buds is by far the more serious damage, causing yield loss and stunted growth from secondary or tertiary buds. No fruit develops on canes where the primary and secondary buds were destroyed. The amount of injury varies from year to year and is worse when cool temperatures slow bud development. The damage may be confused with cutworm damage because both feed during bud swell (9, 42).

General Control Information: Wasteland and woodland located near cultivated vineyards should be cleared to eliminate or reduce hibernation sites. Frequent disking to control weeds between grape rows also breaks the pupal cells in the soil. However, some adults can still emerge from the undisturbed band of soil beneath the trellis that was not touched by the disking operation. To prevent bud feeding, broad-

spectrum insecticides are effective against adults migrating to grapevines from their hibernation sites, but timing is critical. The insecticide treatments applied postbloom against grape berry moths also reduce grape flea beetle populations (9). The pest control product recommended for grape flea beetle is Danitol (24).

Grape Rootworm

Fidia viticida Walsh

Life Cycle: Adult grape rootworms are light brown with yellow hairs and about 6 mm long. They begin to appear in mid- to late May and lay eggs on the vine trunks. Larvae later crawl into the soil and attach themselves to grape roots, remaining there for one to two years while completing their development. Larvae eat small roots and bore into larger ones. (42).

While actively feeding on roots, most grape rootworms remain in the upper 12 inches of soil. In late fall, they move deeper into the soil and form overwintering cells. The following spring, they move back toward the surface to pupate or to complete larval development. After overwintering, 5^{th} instar larvae construct a chamber in which pupation takes place. Pupation occurs in the upper 6 inches of soil and is complete in about 14 days. The newly hatched adults remain in the pupal cell several days before emerging from the soil (10).

Damage: The most serious damage is caused by larvae feeding on the roots. The most noticeable damage is the characteristic chain-like feeding pattern on the leaves caused by the adults. Vine damage by adults is relatively inconsequential. The damage to the grape root system can stunt, and in some cases, even kill grapevines. In some vineyards, marked reductions in vigor and production have been observed in as little as 3 years. Because dispersal of grape rootworm is generally slow, infestations are often spotty within a region and within a particular vineyard (10). Grape rootworm is either a sporadic pest of Michigan juice grapes or does not cause economic damage worth control effort (33).

General Control Information: Control of the grape rootworm is most easily accomplished through treatments directed at the adult stage. Proper timing is key. Treatments applied too early do not persist long enough to kill rootworm adults during the 3 to 4 week period when most emerge from the soil. Treatments applied too late allow some eggs to hatch and the larvae to enter the soil unharmed. Treatments must be made when the first beetles are observed in vineyards -from late May to mid-July, depending upon location. Growers should carefully check their vineyards each week. A second

application may be needed if more adult rootworms are detected (10).

Tumid Gallmaker

Janetiella brevicauda Felt

Tumid gallmaker galls

Grape tumid galls (previously called grape tomato galls) are caused by larvae of a small cecidomyid fly, the grape tumid gallmaker. It infests wild and cultivated grapes in Michigan. Infestations are generally sporadic both within vineyards and within infested vines (11).

Life Cycle: Adults developing from overwintered larvae begin to emerge in early to mid-May, peaking around mid-June. Emergence does not occur if the air temperature is below 66° F. The adults only live for one day. Females lay eggs from early May to mid-September on grape shoots close to the ground. The eggs hatch within four to six days and the larvae bore into the tissue at the shoot tip. The boring leaves a whitish circular scar on the vine that is still visible after the gall forms. When maturity is reached within the gall, larvae exit through the same hole formed upon entering the plant tissue. They drop to the ground and form a cocoon just below the soil surface. Early and mid-season larvae pupate immediately and emerge as adults to continue the life cycle. Late season larvae overwinter in the cocoons to continue their development and pupate the following spring (11).

Damage: The galls, which measure 0.12 to 0.25 inch in diameter, are typically located on leaves, petioles, and flower clusters. In heavy infestations, the galls may reduce vine vigor and can cause shoot breakage, but in most instances, galling is of little economic importance. Galls on flower clusters, however, can result in poorly shaped fruit clusters or the complete loss of clusters (11).

General Control Information: Pesticide applications for grape tumid gallmaker are not economically prudent unless the infestation is heavy or the vineyard has a history of tumid gall problems. When economically justified, treatment is timed to kill adults of the overwintered generation as they emerge. It is difficult to detect the adults, so it is most feasible to base control measures on the first sign of larval

entrance into vine tissues, the small white scar, or the first indication of gall formation. There are several parasitic and predatory species of insects that attack the larvae of grape tumid gallmakers. Growers sometimes bury the pupae by mounding soil up under the vines in late April (11).

Grape Mealybug

Pseudococcus maritimus Ehorn

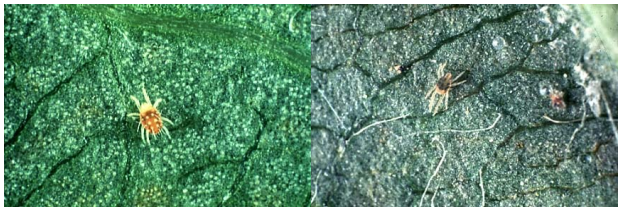
Life Cycle: Grape mealybugs overwinter as nymphs in egg sacs composed of waxy filaments. These are located under bark scales at the base of shoots or pedicles of grape clusters (13). Crawlers begin migrating from egg sacs when buds begin to swell in April, and begin feeding at the bases of the buds. Soon crawlers begin to produce the wax that gives them their characteristic appearance and makes them more difficult to control with chemicals. The adults begin appearing in late June. They are soft, oval, flat, distinctly segmented and covered with a waxy layer that extends into spines along the body margin and the posterior end. The pinkish body is visible through the powdery wax. Mealybugs are found in the crevices of foliage or where berries meet the rachis. Mating occurs and eggs are laid in late summer (12, 42).

Damage: Mealybug damage is primarily cosmetic and occurs when the honeydew (the excretory product of the insect), containing high sugar levels accumulates on fruit and foliage. The honeydew acts as a growth medium for sooty molds that can spoil fruit (42).

General Control Information: Mealybug populations often go undetected until late summer when females and egg sacs become visible. At this time it is too late for control measures and controls need to be applied the following year. The best strategy is to control the migrating crawlers early in the season before they settle down and develop their protective covering (12). Guthion and Provado are labeled for grape mealybug control.

European Red Mite

Panonychus ulmi Koch



Female Male

Life Cycle: There are 4 to 9 generations of European red mite a year, depending on the locality and the length of the growing season. The sexes of the adults are readily differentiated. The female is less than 0.5 mm long, velvety brown to brick red, has 4 rows of dorsal setae or spines borne on raised white tubercles and has eight legs. Adult males are smaller, dull green to brown in color, have a pointed abdomen and proportionately longer legs. The rate of development for both the male and female is temperature dependent, slower in the spring and fall, and becoming more rapid during the hot summer months.

The first generation requires about 3 weeks to develop, while summer generations may develop in 10 to 14 days. Reproduction can be both sexual and parthenogenetic - unfertilized eggs give rise to males only, while mated females produce eggs for both sexes. Winter egg deposition begins in August but may continue until late September. It is triggered by diminishing food supply, temperature and photoperiod. Tiny spherical eggs are laid around cane nodes and under loose bark. Egg hatch occurs in the spring when buds are swelling. There are 3 stages (larva, protonymph and deutonymph) between egg hatch and adulthood. A resting period precedes each molt to the following stage. The hatching larvae have only 6 legs, while all subsequent stages have 8 legs. The average development time to adulthood ranges from 5 to 15 days (14, 42).

Damage: Injury is caused when the bristle-like mouthparts pierce the cell walls and the mite ingests the contents, including the chlorophyll. The lower leaf surface is preferred. This results in off-color foliage, which in severe cases becomes bronzed. Heavy mite feeding early in the season (late June and early July) can not only reduce vine growth and yield but also drastically affects fruit bud formation, and thereby reduce yields the following year (14).

General Control Information: Control is achieved using an application of acaricide in response to scouting for mites. Predatory mites may impact populations of pest mites. Control of established populations in the summer requires 2 applications 10 to 14 days apart (14). Products recommended for mite control include Kelthane, Vendex, Agri-Mek, Danitol, Pyramite, and Acramite.

Grape Phylloxera

Daktulosphaira vitifoliae (Fitch)

Life Cycle: Phylloxera are small yellow, aphid-like insects that live on vine roots and leaves. The foliar form overwinters as eggs under the bark of canes. Eggs hatch when leaves have emerged in spring, and nymphs begin feeding on the leaves. The feeding elicits gall formation and the female becomes enclosed within a small spherical gall on the underside of the grape leaf. After about 15 days, nymphs, or crawlers, emerge from the gall and move to shoot tips where they begin feeding and initiate new galls. In the fall females lay a single egg that overwinters. There are three to five generations of foliar phylloxera per season in eastern North America.

Some of the foliar crawlers move to the soil surface where they eventually reach grapevine roots. The root form of phylloxera overwinters on the surfaces of root galls. When roots start growing in the spring, these sexual insects lay eggs and produce several generations resulting in galls on the roots (28, 42).

Damage: Grape phylloxera form galls on leaves and roots of grapevines. High populations of foliar phylloxera can result in premature defoliation, reduced shoot growth, and reduced yield and quality of the crop.

The root form stunts growth of susceptible vines and can kill them. Insects feed on growing rootlets, which then swell and turn yellowish. Dead areas develop at the feeding sites. Phylloxera prefer vines growing in heavy clay soils. Labrusca grapes can tolerate phylloxera feeding on roots, particularly in well-watered vineyards.

General Control Information: Phylloxera infestations may originate from wild grapevines so nearby infested wild vines should be destroyed. Phylloxera crawlers can be spread on vineyard equipment; machinery should not be moved from an infested block to a non-infested block. This pest is effectively managed by using resistant or tolerant rootstocks Few chemicals are registered for control of foliar grape phylloxera (37). Thiodan is the standard commercial treatment but it can burn the foliage of some cultivars. Danitol is also recommended (24).

ABOUT THE FORMAT OF THE PESTICIDE PROFILES

Michigan weather can be extremely variable so sprays are timed to plant or pest development rather than calendar dates. The terms used in the Juice Grape Profile for the timing of applications to grapes from

spring through fall are as follows:

Bud Swell

1. 1 to 5-Inch Shoot
2. 8 to 12- Inch Shoot
3. Immediate Pre-Bloom
4. Bloom
5. First Cover (Pea-Sized Berries)
6. Second Cover
7. Third Cover (Bunch Closing)
8. Fourth Cover
9. Fifth Cover
10. Sixth Cover (Veraison: berry ripening)
11. Pre-Harvest

General Headings for Pesticide Profiles:

Common Name (chemical class)

- **Formulations**: The most common formulation(s) used on grapes in Michigan.
- **Pests Controlled**: Pests common to Michigan on which the pesticide is effective.
- **Acres of Crop Treated**: The percent of total acres of juice grapes treated in the state per year. Total acreage = approximately 11,700.
- **Application Rate**: The formulation rate per acre (in pounds of active ingredient if available from NASS data), and the number of applications allowed or averaged per year.
- **Types of Applications**: The most common means by which the pesticide is applied in Michigan.
- **Timing**: Indicates the application timing when the pesticide may be used in the vineyard based on Michigan State University Extension spray recommendations and product label information.
- **PHI**: Pre-Harvest Interval. The minimum time between the application and the first time that fruit can be harvested.
- **REI**: Restricted Entry Interval. The time period immediately after a pesticide application when entry into the treated area is limited.
- **IPM Concerns**: Issues such as environmental hazards and other concerns.
- **Efficacy Issues**: Issues that affect the pesticide's power to produce the desired effect.

INSECTICIDE PROFILES

Acres of bearing grapes in 1999 = 11,700
Acres of bearing grapes in 2001 = 12,300

Chlorpyrifos (organophosphate)

- Formulations: Lorsban 4E.
- Pests Controlled: Climbing cutworms (24).
- Acres of Crop Treated: 22% (1999) (38).
- MI Average Rate per Application: 1 lb ai/A (1999) (38).
- Number of Applications: 1 application per season in 1999 (38).
- Types of Applications: Ground (26).
- Timing: Bud swell, 1-To 5-inch Shoot (24).
- PHI: 35 days (25).
- REI: 24 hours (25).
- IPM Concerns: Toxic to birds and wildlife and extremely toxic to fish and aquatic organisms (26).
- *Restricted Use Pesticide* (26).
- Section 24(c), Special Local Needs until 2004 (24).

Diazinon (organophosphate)

- Formulations: Diazinon 50WP.
- Pests Controlled: Grape berry moth, grape and potato leafhoppers (24).
- Acres of Crop Treated: Not available from NASS data (39).
- Application Rate (from label): 2 lbs/A (24). Do not apply more than 2 lbs/A/application and no more than 10 lbs/A/season (26).
- Types of Applications: Ground (26).
- Timing: Apply as a thorough cover spray when the pest first appears. Repeat application after seven days if necessary (26).
- PHI: 28 days (25).
- REI: 24 hours (25).
- IPM Concerns: Highly toxic to birds, fish and other wildlife (26).
- *Restricted Use Pesticide* (26).

Azinphos-methyl (organophosphate)

- Formulations: Guthion 50 WP.
- Pests Controlled: Grape berry moth, rose chafer and leafhoppers (24).
- Acres of Crop Treated: 41% in 2001, 17% in 1999 (38, 39).
- MI Average Rate per Application: 0.60 lb ai/A in 2001, 0.60 lbs ai/A in 1999 (38, 39).
- Number of Applications: 1.5 applications per year in 2001, 1.1 application per year in 1999 (38, 39).
- Types of Applications: Ground (26).
- Timing: Allow at least 14 days between applications and allow at least 21 days between last application and harvest. A total of 3 applications per season may be made per crop season regardless of rate or formulation used (26).
- PHI: 21 days (25).

- REI: 48 hours to 21 days depending on the task (see label) (26).
- IPM Concerns: Extremely toxic to fish and wildlife (26).
- *Restricted Use Pesticide* (26).

Phosmet (organophosphate)

- Formulations: Imidan 70WP.
- Pests Controlled: Grape berry moth, rose chafer, leafhoppers, and Japanese beetle (24).
- Acres of Crop Treated: 17% in 2001, 13 % in 1999 (38, 39).
- MI Average Rate per Application: 1.10 lbs ai/A. in 2001, 1.12 lbs ai/A in 1999 (38, 39).
- Number of Applications: 1.5 applications per year in 2001, 1.2 application per year in 1999 (38, 39).
- Types of Applications: Ground (26).
- Timing: Bloom through sixth cover (24).
- *Grape berry moth*: apply prebloom, post bloom, first and late cover sprays as needed. *Grape leafhopper*: apply when nymphs hatch (generally coincides with grape berry moth). Repeat as needed (26).
- PHI: 7 days (26).
- REI: 24 hours (25).
- IPM Concerns: Extremely toxic to fish (26).

Methomyl (carbamate)

- Formulations: Lannate 90SP.
- Pests Controlled: Grape berry moth, rose chafer, and leafhoppers (24).
- Acres of Crop Treated: 15% in 1999 (38).
- Michigan Average Rate Per Application: 0.5 lbs ai/A in 1999 (38).
- Number of Applications: 1.2 applications per year in 1999 (38).
- Types of Applications: Ground (26).
- Timing: Bloom through sixth cover (24).
- *Grape berry moth*: apply pre- and post-bloom and repeat at 10-14 day intervals or as needed (26). Do not apply more than 4.5 lbs ai/A/season nor make more than 5 applications per season (26).
- PHI: 1 day for fresh grapes, 14 days for juice grapes (26).
- REI: 7 days (26).
- IPM Concerns: Toxic to fish, aquatic invertebrates, mammals and bees (26). Highly toxic to mite predators (24).
- *Restricted Use Pesticide* (26).

Carbaryl (carbamate)

- Formulations: Sevin 50WP, XLR+, and 80S.
- Pests Controlled: Grape berry moth, rose chafer, Japanese beetle, and leafhoppers (24).

- Acres of Crop Treated: 7% in 2001, 60% in 1999 (38, 39).
- MI Average Rate Per Application: 1.53 lbs ai/A in 2001, 1.11 lbs ai/A in 1999 (38, 39).
- Number of Applications: 1.2 applications per year in 2001, 2.3 applications per year in 1999 (39).
- Do not apply more than 10 lbs ai/A/season (26).
- Types of Applications: Ground (25).
- Timing: Bloom through sixth cover. Repeat applications as necessary up to a total of 5 times but not more often than once every 7 days (24).
- PHI: 7 days (25).
- REI: 12 hours (25).
- IPM Concerns: Extremely toxic to bees, aquatic and estuarine invertebrates (26).
- Efficacy Issues: Highly toxic to mite predators. Reports of resistance in grape leafhoppers in some regions of Michigan (24).

Endosulfan (organophosphate)

- Formulations: Thiodan 50WP, 3EC.
- Pests Controlled: Grape phylloxera (24).
- Acres of Crop Treated: No information in the NASS data (39).
- Application Rate (label): 2 lbs/A (24). Do not use on Concord variety, as severe plant injury is likely to occur. Do not exceed more than 3 applications per year and do not exceed more than 3 lbs ai (4 qts) per acre per year (26).
- Types of Applications: Ground (25).
- Timing: Bloom and second cover (24).
- PHI: 7 days (25).
- REI: 24 hours (25).
- IPM Concerns: Toxic to fish, birds, bees and other wildlife (26).

Imidacloprid (nicotinoid)

- Formulations: Provado SoluPak 75WP.
- Pests Controlled: leafhoppers (24).
- Acres of Crop Treated: 32% in 1999 (38).
- MI Average Rate per Application: 0.03 lbs ai/A in 1999 (38).
- Number of Applications: 1.3 applications per year (38). Do not apply more than a total of 2.0 oz/A/season. Allow at least 14 days between applications (26).
- Types of Applications: Ground (25).
- Timing: First cover through third cover (24).
- PHI: Applications may be applied up to and including day of harvest (24).
- REI: 12 hours (25).
- IPM Concerns: Highly toxic to bees and aquatic invertebrates (24).

Dicofol (chlorinated hydrocarbon)

- Formulations: Kelthane 35WP
- Pests Controlled: Mites (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 1 ½ to 3 ½ lbs/A (24).
- Types of Applications: Ground (26).
- Timing: Third cover and fourth cover (24).
- PHI: 7 days (25).
- REI: 12 hours (25).
- IPM Concerns: Moderately toxic to mite predators. To avoid resistance, use only 1 to 2 times a season and only once against the same generation of mites (24).
- Toxic to fish (26).
- Efficacy Issues: Temperature does not affect its activity against pest mites (24).

Fenbutatin-oxide (organotin)

- Formulations: Vendex 50WP.
- Pests Controlled: Mites (European red and twospotted spider mite) (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 1 to 2 ½ lbs/A (24).
- Types of Applications: Ground (air assisted tree and vine sprayers) (26).
- Timing: Third and fourth cover (24). Make no more than 2 applications per year; apply no more than 4 lbs/A/season. Do not spray in less than 21 day intervals (26).
- PHI: 28 days (25).
- REI: 48 hours (25).
- IPM Concerns: Toxic to birds, mammals, fish and aquatic invertebrates (26). Low toxicity to predaceous mites and can be utilized to adjust predator-prey ratios (24).
- Efficacy Issues: Control is temperature dependent and is more effective in warm weather (26).
- *Restricted Use Pesticide* (26).

Fenpropathrin (pyrethroid)

- Formulations: Danitol 2.4EC (24).
- Pests Controlled: Grape flea beetle, climbing cutworms, grape berry moth, rose chafer, grape phyloxera, leafhopper, mites, Japanese beetle (24).
- Acres of Crop Treated: 52 % in 2001(39).
- MI Average Rate per Application: 0.16 lb ai/A (39).
- Number of Applications: Michigan averages 1.7 applications per year (39).
- Types of Applications: Ground (air assisted/air blast applications) (26).
- Timing: Bud swell, 1-to 5-inch shoot, bloom through sixth cover (24). Start sprays when pest activity begins and repeat as needed maintain control but not more often than every seven days (26).
- PHI: 21 days (26).

- REI: 24 hours (26).
- IPM Concerns: Extremely toxic to bees, fish, aquatic organisms and wildlife (26). To reduce risk of resistance developing, post bloom sprays are restricted to one spray (24).
- *Restricted Use Pesticide* (26).

Bacillus thuringiensis (biological)

- Formulations: Dipel DF.
- Pests Controlled: Grape berry moth (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 1 lb/A (24).
- Types of Application: ground (26).
- Timing: Bloom (24).
- PHI: Up to the day of harvest (26).
- REI: 4 hours (26).
- Efficacy Issues: Pest mortality varies by larval size and dose consumed. Most effective when applied when day temperatures are in the 70s (26).

Pyridaben (pyridazinone)

- Formulations: Pyramite 60W.
- Pests Controlled: Grape leafhopper and mites (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 6.6 to 13.2 ozs/A (24). Maximum rate per acre per application is 13.2 ozs. Maximum rate per acre per season is 26.4 ounces (26).
- Types of Application: Ground (26).
- Timing: First cover through fourth cover (24).
- PHI: 7 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to bees. Should be used on an alternate schedule with another insecticide (26).
- Efficacy Issues: Higher rates are used to ensure adequate concentration in mature vineyards with dense foliage (26).

Abamectin (antibiotic)

- Formulations: Agrimek 0.15 EC.
- Pests Controlled: Mites (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 16 ozs/A (24).
- Types of Application: Ground (26).
- Timing: Third and fourth cover. Applications are made immediately after egg hatch for best

control of mites (24, 26). Do not exceed 16 fl. oz. per application or 32 fl. oz. per season. Do not make more than 2 applications per season (26).
- PHI: 28 days (24).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish, mammals and aquatic organisms (26).
- Efficacy Issues: A nonionic surfactant should be added to the tank mix (24).
- *Restricted Use Pesticide* (26).

Methoxyfenozide (diacylhydrazine)

- Formulations: Intrepid 2F (insect growth regulator)
- Pests Controlled: Grape berry moth (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 8-16 oz./A (24).
- Types of Application: Ground (26).
- Timing: Apply at beginning of egg hatch for each generation. Reapply within 10-18 days to ensure complete coverage of rapidly expanding fruits or foliage. Do not apply more than 48 fl oz (0.75 lbs. ai) per acre per season (26).
- PHI: 30 days (26).
- REI: 4 hours (26).
- IPM Concerns: Upon ingestion, larval stages of Lepidoptera undergo an incomplete and premature molt that is ultimately lethal. Feeding ceases within hours and death occurs within days. No other insect or arthropod orders are affected. Avoid drift and runoff, as the product may be toxic to sensitive aquatic invertebrates. See label for endangered species restrictions in Michigan.
- Efficacy Issues: Addition of an adjuvant will maximize coverage and weatherability.

Kaolin (clay)

- Formulations: Surround WP
- Pests Controlled: Rose chafer, grape leafhopper, Japanese beetle (24).
- Acres of Crop Treated: Not listed in the NASS data (38).
- Application Rate (label): 25 lbs/A (24).
- Types of Application: Ground (26).
- Timing: Start as infestation occurs, applying a minimum of 2-3 applications at 7-14 day intervals (26).
- PHI: May be applied up to the day of harvest (26).
- REI: 4 hours (26).
- IPM Concerns: Forms a mineral-based film that suppresses pests but supplemental methods may be needed to enhance the level of control (26).
- Efficacy Issues: Coverage must be maintained for adequate performance (24).

Acetamiprid (neonicotinoid)

- Formulations: Assail WSP.
- Pests Controlled: grape leafhopper (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1.1 ozs/A (24). Do not make more than 2 applications per season and do not apply more than once every 14 days. Do notliexceed 1 lb. ai (2.3 fl ozs of product) per acre per crop (26).
- Types of Application: Ground (26)
- Timing: First through third cover (24).
- PHI: 7 days (26).
- REI: 12 hours (24).
- IPM Concerns: Toxic to bees and wildlife (26).

Bifenazate (carbazate)

- Formulations: Acramite 50W
- Pests Controlled: Mites.
- Acres of Crop Treated: No information available.
- Application Rate (label): 0.75-1.0 lb/A (24). Do not make more than one application per crop per year (26).
- Types of Application: Ground (26).
- Timing: Third or fourth cover (24).
- PHI: 14 days (26).
- REI: In addition to the early entry exceptions allowed by WPS, you may enter or allow workers to enter to perform all tasks other than tying, turning and girdling after 12 hours following application, as long as at least long pants, long-sleeve shirt, shoes and socks are worn. REI is 5 days for cane tying, turning or girdling. (26).
- IPM Concerns: Toxic to fish and bees (26).
- Efficacy: For best performance, maintain spray tank water at or near pH 7.0 (24).

Spinosad (antibiotic)

- Formulations: SpinTor 2SC
- Pests Controlled: grape berry moth, red banded leafroller, thrips.
- Acres of Crop Treated: None as of 6/03.
- Application Rate (label): 4-8 fl ozs/A
    - Types of Application: Ground
    - Timing: For egg hatch of grape berry moth and red banded leafroller. Apply at first sign of thrips feeding (26).
    - PHI: 7 days (26).
    - REI: 4 hours (26).

- IPM Concerns: Residues are safe to bees only when dry. Toxic to aquatic organisms (26).

Nematodes

Northern Root-Knot Nematode
Meloidogyne hapla (Neal) Chitwood

Life Cycle: The northern root-knot nematode overwinters as eggs in the soil. As soil temperatures increase in the spring, second-stage juveniles emerge and locate and penetrate grape roots. These nematodes establish feeding sites in pro-vascular tissue in an area behind the root cap. As the infected root continues to grow, the vascular tissue differentiates in the area where the nematodes have established their feeding sites. Therefore, the northern root-knot nematode disrupts the vascular tissue. Shortly after successfully establishing a feeding site, the second-stage juvenile begins to swell. The nematode soon molts to a third-stage juvenile. Eventually, following two additional molts, it matures to become an adult female or male nematode. Female northern root-knot nematodes are round and are incapable of movement. Males are worm-like and generally exit the root because they do not feed. Females produce large numbers of eggs, potentially up to 1000, in a gelatinous matrix secreted by the anus. The northern root-knot nematode can complete its life cycle in a month at optimal soil temperatures. Therefore, the nematode can complete multiple generations per growing season (34).

Damage: The northern root-knot nematode, like all other nematode species that feed on grapes, does not cause characteristic damage on aboveground portions of the vines. Typical damage consists of stunting, chlorosis and reduced yields. Severely infested plants may wilt during periods of hot, dry weather. Invasion of roots by northern root-knot nematodes will result in the production of small swellings on the roots called galls. Galls will vary in size depending on the numbers of nematodes feeding within them. Due to the fact that parasitism by the northern root-knot nematodes results in the production of very small galls, they are often difficult to discern on woody hosts. The northern root-knot nematode appears to be the most virulent of the plant-parasitic nematodes that feeds on grapes in Michigan. Young plants are often unthrifty and usually have poorly developed root systems. Feeder roots are often destroyed (34).

General Control Information: Once established, root-knot nematodes are virtually impossible to eradicate. Therefore, attempts are made to keep sites free from northern root-knot nematode for as long as possible. This is primarily accomplished by using nematode-free rootstocks and by not contaminating fields with northern root-knot nematode-infested soil.

Cultural Controls: Vineyards with histories of root-knot nematode problems are kept out of grape production for a period of 2-4 years before they are replanted. Non-host crops for northern root-knot nematode such as small grains are grown to reduce population densities of these important pathogens. Weed control is imperative. Many weeds serve as hosts for

the northern root-knot nematode.

Genetic Controls: Resistant rootstocks have potential for control of the northern root-knot nematode. However, in a recent study conducted in Michigan, of 10 French-American grapevine cultivars tested against northern root-knot nematode, none were considered resistant and only two were rated as tolerant. One tolerant cultivar, Couderc 1202 is typically used as a rootstock, whereas, Seyval is grown as a scion (40).

Chemical Controls: Old vineyard sites are routinely sampled for plant-parasitic nematodes. If nematode population densities are recovered at damage threshold levels, a nematicide is used. Soil fumigation with 1, 3-Dichloropropene (Telone II), 1, 3-Dichloropropene + Chloropicrin (Telone C-17) or metam-sodium (Busan, Nemasol or Vapam) provides effective control of northern root-knot nematode. However, particularly in old vineyard sites, deep and shallow fumigation is necessary to achieve good control. In Michigan, fumigation is used in the fall, prior to vineyard establishment. The non-fumigant nematicide, fenamiphos, is registered for use on grapes in Michigan. It is sometimes applied prior to planting or as a post-plant treatment. However, as a post-plant material, it is not very effective against northern root-knot nematode once they are established within grape roots (34).

Michigan Grape Root-Knot Nematode

Meloidogyne nataliei Golden, Rose and Bird

Life Cycle: The biology of the Michigan grape root-knot nematode is believed to be very similar to that of the northern root-knot nematode. However, the Michigan grape root-knot nematode has not been as intensively studied. Its worldwide distribution is currently 2 townships in western Michigan (34).

Damage: Feeding by the Michigan grape root-knot nematode does not result in the production of galls. This nematode has only been recovered from extremely stunted and unthrifty grapevines in Michigan. However, because it has never been isolated as the sole causal agent in any vineyard, its virulence has not been estimated (34).

General Control Information: See the section on the northern root-knot nematode (34).

Lesion Nematodes

Pratylenchus penetrans and *P. neglectus* Cobb

Life Cycle: Lesion nematodes overwinter as juveniles and adults within roots or in the soil. These nematodes penetrate young roots and invade the cortex. Once they enter roots, they migrate between and through cells, often killing them. Lesion nematode females lay eggs singly in root tissue or in soil. Females typically produce less than 100 eggs. Life cycles can be completed in 3 to 4 weeks depending on soil temperatures. Like root-knot nematodes, they can complete multiple generations in a growing

season (34).

Damage: Aboveground symptoms are virtually the same as those produced by the northern root-knot nematode. Penetration of roots by lesion nematodes results in minute wounds. These wounds are often invaded by other soil pathogens. Therefore, lesion nematodes commonly predispose plants to invasion by pathogenic fungi. Lesion nematode-infected plants typically have reduced root volumes and weights. Feeding and migration by these organisms results in cell death. Feeder roots are usually destroyed (34).

General Control Information: Lesion nematode-free rootstocks are planted.

Cultural Controls: Lesion nematodes feed on virtually all species of cultivated plants, so they are difficult to manage with rotation. Vineyards with histories of lesion nematode problems are kept fallow before replanting. Maintaining a clean fallow is important because many weeds serve as hosts (34).

Genetic Controls: In a recent study, 8 of 10 French-American grapevine cultivars evaluated against lesion nematodes in Michigan appeared tolerant (40).

Chemical Controls: See the information on the northern root-knot nematode. Nematicides, particularly post-plant materials, are more effective against lesion than root-knot nematodes probably due to the lower fecundity of lesion nematodes (34).

Dagger Nematodes

Xiphinema americanum Thorne and Allen

Life Cycle: Dagger nematodes overwinter as eggs, juveniles and adults. Eggs are laid in the soil but little is known about the developmental biology of these organisms. They appear to have rather long life cycles (a year or more) and very low reproductive rates. Unlike root-knot and lesion nematodes, dagger nematodes do not penetrate roots. They feed as ectoparasites, typically in the area just behind root tips. Dagger nematodes are potential vectors of nepo (nematode-transmitted polyhedral-shaped) viruses. Although feeding by the nematodes can result in the production of symptoms, characteristic aboveground symptoms are often caused by the viruses transmitted by these organisms (34).

Damage: Root tips are often enlarged when plants are infested with dagger nematodes. These swollen root tips resemble the galls caused by northern root-knot nematodes. Feeding by dagger nematodes often results in decay or death of these root tips so that root growth stops. Sometimes lateral root growth is stimulated (34).

Viruses that affect grapes often produce characteristic symptoms. Those transmitted by dagger nematodes in Michigan are listed below.

Tomato Ringspot Virus (TmRSV): During the first year of infection, plants may produce

normal growth except for a few leaves that appear mottled and possess distinct oak leaf patterns. Symptoms are much more evident the second year. Infected plants are much more susceptible to winter injury. Shoots are short, with shortened internodes, distorted leaves and a leaf area about one-third the normal size. Berries on clusters are sparse and develop unevenly. Symptoms are typically more severe the third and subsequent years. New growth is very stunted and usually limited to suckers that arise near the base of the trunk where shoot buds are less susceptible to winter injury (34).

Tobacco Ringspot Virus (TRSV): The symptoms are indistinguishable from those caused by TmRSV (34).

Peach Rosette Mosaic Virus (PRMV): Infected vines typically exhibit an umbrella-like growth habit due to shortened and crooked shoot internodes. Leaves are often deformed. Clusters are uneven and berries shell off. In older vineyards, dead vines are often evident in a circular or elliptical pattern. This pattern is typical of diseases caused by nepoviruses (34).

General Control Information: Vineyards are always established with virus-free cuttings.

Cultural Control: Dagger nematode population densities are reduced with rotation to nonhost crops. However, when removing an old vineyard, care is taken to remove as many of the roots as possible. Dagger nematodes survive and feed on roots that remain deep in the soil profile after vineyard removal. Some weed species are hosts for *X. americanum*. Many weeds harbor the nepoviruses that are transmitted by these nematodes. Therefore, weed control is very important in vineyards. Grapevines exhibiting symptoms caused by viruses are sampled and tested to confirm the presence of these pathogens. If viruses are present, infected vines are removed and destroyed. Roots are also removed as well as neighboring plants. These sites are spot fumigated before the establishment of other grapevines (41).

Genetic Control: Of the 10 French-American grapevine hybrids recently tested in Michigan, none were regarded as susceptible to *X. americanum (40)*. *Vitis labrusca* cultivars are resistant to TmRSV and TRSV, but are susceptible to PRMV. Sites are always sampled and tested for viruses. Proper identification of these pathogens is imperative for implementation of sound management tactics (34).

Chemical Control: See information on other nematodes (34).

Ring Nematodes

Criconemella xenoplax (Raski) Luc & Raski

Life Cycle: Ring nematodes overwinter in all life stages. They feed as ectoparasites on roots, often

remaining attached at the same point for several days. The life cycle can be completed in roughly 35 days. These nematodes are not known to produce large quantities of eggs, but females are reported to lay 8-15 eggs over a 2-3 day period (34).

Damage: Grapevines fed upon by ring nematodes typically lack feeder roots. These plants are often more susceptible to winter injury (34).

General Control Information: See information on other nematodes. Some French-American grapevine cultivars investigated in Michigan are resistant to or tolerate *C. xenoplax* (40).

NEMATICIDE PROFILES

1,3-D (chlorinated hydrocarbon)

- Formulations: Telone II
- Pests Controlled: Nematodes.
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): Broadcast: 30 gal/A (24).
- Types of Application: Shank injection (24).
- Timing: Apply as a preplant treatment into well-prepared soil at least 21 days prior to planting. Soil temperatures should be between 50° and 80° F. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60° F or if the soil is very wet (24).
- PHI: None applicable.
- REI: 5 days (25).
- IPM Concerns: Do not apply within 100 feet of any well used for potable water (26).
- *Restricted Use Pesticide* (26).

1,3-D and Chloropicrin (chlorinated hydrocarbon)

- Formulations: Telone C-17
- Pests Controlled: Nematodes.
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): Broadcast: 35 gal/A (24).
- Types of Application: Injection (24).
- Timing: Apply as a preplant treatment into well-prepared soil at least 21 days prior to planting. Soil temperatures should be between 50° and 80° F. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60° F or if the soil is very wet (24).
- PHI: None applicable.
- REI: 5 days (25).
- IPM Concerns: Do not apply within 100 feet of any well used for potable water (26).

Restricted Use Pesticide (26).

- Formulations: Telone C-35.
- Pests Controlled: Nematodes.
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): Broadcast: 39-50 gal/A (24).
- Types of Application: Injection (24).
- Timing: Apply as a preplant treatment into well-prepared soil at least 21 days prior to planting. Soil temperatures should be between 50° and 80° F. Inject to an 8-inch depth with shanks spaced 12 to 24 inches apart. Seal soil immediately after application. Allow additional time before planting if temperatures are below 60° F or if the soil is very wet (24).
- PHI: None applicable.
- REI: 5 days (25).
- IPM Concerns: Do not apply within 100 feet of any well used for potable water (26).

Restricted Use Pesticide **(26).**

Metham (carbamate)

- Formulations: Busan 1020 and Vapam
- Pests Controlled: Nematodes.
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): Broadcast: 50 to 100 gal/A (24).
- Types of Application: Injected 4 inches deep (24).
- Timing: Apply as a preplant treatment at least 21 days prior to planting into moist soil. Soil temperatures should be between 40° and 70° F (24). Inject to a soil depth of 4 inches with blades spaced 5 inches apart. Follow immediately with a roller to smooth and compact surface. Light watering or a tarp after rolling helps prevent gas escape. Fumigant should be applied with equal parts water or in a 2 to 1, water to fumigant, ratio (24).
- PHI: None applicable.
- REI: 48 hours (26).
- IPM Concerns: Toxic to fish (26).

Fenamiphos (organophosphate)

- Formulations: Nemacur 3.
- Pests Controlled: Nematodes.
- Acres of Crop Treated: Not listed in the NASS data (38. 39).
- Application Rate (label): Band: 3 gal/A (24).
- Types of Application: Ground (banded) (24).
- Timing: Pre-plant or post-plant application. Incorporate immediately after application (24).

- PHI: 2 days (26).
- REI: 48 hrs (25).
- IPM Concerns: Toxic to fish and wildlife (26).
- Efficacy Issues: Apply in not less than 10 gallons of water per acre and incorporate immediately either mechanically or with sufficient irrigation. The band width should be 50% of the total area. On bearing grapes, the last application may be made up to 2 days of harvest. Do not use the site for feed or grazing (24).
- *Restricted Use Pesticide* (26).

Diseases

Black Rot

Guignardia bidwellii (Ellis) Viala & Ravaz

Symptoms: Small, circular reddish-brown spots 1/8 to 1/4 inch in diameter appear on the leaves in mid to late June. Lesions develop a dark border, and small black, pimple-like pycnidia are found in a circular pattern in the lesion. The herbicide Gramoxone, often used in vineyards for weed control, can cause similar-appearing leaf spots, but these do not show the black pycnidia. Berries can be infected from bloom until 3 to 5 weeks after bloom, at which time they become naturally resistant. Berry symptoms are visible about 10 to 14 days after infection as a whitish dot within a rapidly expanding brown area. Within a few days, the berry shrivels and looks like a hard bluish raisin (mummy). These eventually fall to the ground and are an inoculum source for the next season. American varieties such as Concord and Niagara are quite susceptible to the pathogen (15,42).

Method of Transmission: The fungus overwinters in mummies within the vines or on the ground. The leaf lesions result from the spring release of ascospores that are dispersed from the mummies by wind and rain. Leaf spots and infected berries produce conidia, also dispersed by rain splash, resulting in secondary infections (15, 24).

Conditions Favoring Disease: Ascospores and conidia infect the blossom and developing fruit during periods of rain. The optimum temperature for disease development is 80°F when a wetting period of only six hours is required for infection (15, 42).

Management Practices: Early-season sprays specifically for black rot are not necessary. Instead, protection of the vines against black rot is emphasized during the period of fruit susceptibility - from immediately pre-bloom to 4-5 weeks after bloom - for Concord and Niagara. EBDC or SI fungicides applied at early shoot growth will be sufficient to suppress foliar black rot infections. Fungicide control is very effective, especially when good spray coverage is obtained. Chemical controls include: Abound, Bayleton, Captan, Ferbam, Dithane, Elite, Nova, Rubigan, Flint, Penncozeb, Sovran and Ziram (24, 42).

Botrytis Bunch Rot and Blight

Botrytis cinerea (de Bary) Whetzel

Symptoms: *Botrytis* infection of leaves begins as a dull, green spot usually surrounding a vein, and the tissue rapidly turns brown. The fungus may also cause blossom blight or shoot blight, which can result in significant crop losses. Dead blossom parts may be colonized by the fungus. Botrytis then moves from berry to berry and initiates development of an early season rot. However, the most common phase of this disease is the infection and rot of ripening berries. This will spread rapidly throughout the cluster. The berries of white cultivars become brown and shriveled and those of purple cultivars develop a reddish color. Under damp weather conditions, the fungus produces a fluffy, gray-brown growth containing spores (17, 42).

Method of Transmission: *Botrytis* overwinters in mummified fruit and other infected plant parts. The fungus produces small, dark, hard resting structures called sclerotia. Sclerotia are resistant to adverse weather conditions and usually germinate in spring. The fungus then produces conidia, which spread the disease. Sporulation may also occur on debris left on the vine during the previous growing season, such as cluster stems remaining after mechanical harvest or mummified fruit. The fungus usually gains a foothold by colonizing dead tissue prior to infection of healthy tissue. Tissue injured by hail, wind, birds, or insects is readily colonized by *Botrytis*. Ripe berries that split because of internal pressure or because of early season infection by powdery mildew, are especially susceptible to infection by *Botrytis* (17).

Conditions Favoring Disease: Moisture in the form of fog or dew and temperatures of 59° to 77° F are ideal for conidia production and infection. Rainfall is not required for disease development, although periods of rainfall are highly conducive to disease development. Cultivars with tight clusters are more prone to Botrytis bunch rot then cultivars with loose clusters (17, 42).

Management Practices: Early fruit ripening (veraison) and pre-harvest are important timings for Botrytis bunch rot control, especially in susceptible cultivars (24). Chemical controls include: Elevate, Rovral, Topsin M and Vangard (24).

Crown Gall

Agrobacterium vitis (E.F. Smith and Townsend) Conn

Symptoms: Galls form on the roots, crowns and/or trunks. Crown gall is usually introduced into a vineyard with the planting material. Once established, the bacteria can live in the soil for many years. The vines can become weakened and stunted if severely infected (15).

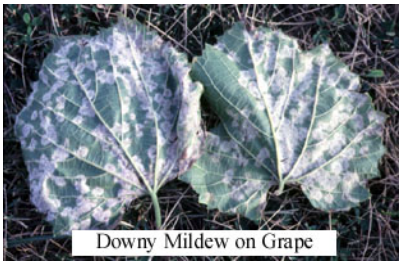
Method of Transmission: Infection of grapevines can occur directly through root wounds or as the result of bacteria being rain-splashed onto upper portions of the plant. The bacteria can also be spread by shears during the pruning process. Sometimes nursery stock will arrive already infected with crown gall, thus inoculating the soil into which it is planted (15).

Conditions Favoring Disease: Temperature can influence infection by affecting pathogen growth (77° to 85° F, optimum). Wounds are necessary for the bacteria to enter the plant, so cultivation, pruning or freeze injury may predispose vines to infection (18,42).

Management Practices: Planting stock with galls or suspicious swellings should be rejected. Shears should be disinfected between cuts when pruning vines known to be infected with crown gall (15). Avoid wounding vines (15, 42).

Downy Mildew

Plasmopara viticola (Berk. & Curt.) Berle. & DeToni


Downy Mildew on Grape

Symptoms: Leaf symptoms appear in early to mid-July. Yellow or light green circular lesions 1/4 to 1/2 inch in diameter are seen first on the upper surface of the leaf. These are called "oil spots" because they often have a greasy appearance. On the underside of the leaf are corresponding areas of whitish fungus growth. The lesions eventually turn brown. Later, the leaf tissue dies in the area of the lesion. If lesions are numerous, they will coalesce, causing large areas of the leaf to turn brown. Badly damaged leaves will fall prematurely, leaving berries exposed to sunscald and reducing the winter hardiness of the vine. Infected flower clusters dry up or, under humid conditions, become covered with white fungus growth. Infected berries harden and turn reddish or yellow and fall from the cluster. Berries become resistant to infection within three weeks after bloom but the rachis remains susceptible for several weeks longer (42).

Method of Transmission: The fungus overwinters in diseased leaves on the ground. Spores are released in the spring, spread by splashing rain or wind to the leaves and berries where they require a film of water for infection. Sporangia produced on leaves and fruit clusters are also dispersed by wind and rain splash. During years with warm, extended wet periods during bloom, fruit clusters may be partially or totally killed (15, 42).

Conditions Favoring Disease: Warm weather with frequent periods of rain or dew favors disease (15, 42).

Management Practices: It is important not to delay downy mildew sprays beyond immediate pre-bloom (except for grape varieties that are resistant to downy mildew). Vineyards should be scouted for the disease throughout the summer and the foliage should be protected based on weather conditions and presence of the disease. On susceptible varieties, downy mildew has the potential for explosive spread during mid-to late- summer when conditions are warm and wet. The need to spray during sixth cover (veraison) should be based on the weather conditions and the presence of the disease as determined by scouting (24). Downy mildew is comparatively easy to control with fungicides. It is most economical to use a fungicide or combination of fungicides that will control both black rot and downy mildew (15). Chemical controls include: Abound, Basic copper Sulfate, Captan, Copper Hydroxide, Dithane, Ridomil Gold MZ, Ridomil Gold/Copper, Sovran, Flint, Penncozeb, Manzate, Prophyt, Ferbam and Ziram (24).

Eutypa Dieback

Eutypa lata (Pers.:Fr.) Tul. & C. Tul

This disease used to be called "dead-arm" until it was discovered that "dead-arm" was really the symptoms of two diseases: Eutypa dieback and Phomopsis cane spot disease. Eutypa dieback is common in older Concord vineyards in Michigan. It is a very serious and costly disease (15).

Symptoms: The most striking symptoms appear in the late spring and early summer when new shoots are 6 to 12 inches long. The shoots are stunted and the leaves are cupped upward, smaller than normal and yellow, or streaked with yellow. The symptoms are caused by a deep-seated wood rot of the arms or trunk and a toxin produced by the fungus. As the disease progresses over several years, one or both of the arms as well as the whole vine, may die (15, 42).

Method of Transmission: Careful examination of the arms or trunk will reveal that the initial infection occurs at a pruning wound. At this old wound is a black "stroma" composed partly of grape bark tissue and partly of fungus tissue. The stroma contains fungal fruiting bodies called perithecia whose ascospores are shot out from autumn through May whenever the temperature is above freezing and rainfall occurs. The spores are wind-borne and infect pruning wounds on the vines. When sawing through a diseased arm or trunk, a dark pie-shaped area of diseased wood is often present (15).

Conditions Favoring Disease: Very small amounts of rain will trigger ascospore release. Pruning wounds are susceptible to infection for a month or more (15, 42).

Management Practices: It takes two to three years after infection for symptoms to show, and four or five years for a stroma to form. Diseased arms or the entire vine are often removed and burned. Sometimes a new vine is trained from a sucker. However, these often show disease symptoms after a few years. Double-trunking has also been successfully done. If one trunk becomes diseased it is cut off, leaving the other that may remain disease-free for some time (15).

Phomopsis Cane and Leaf Spot

Phomopsis viticola (Sacc.) Sacc.

Symptoms were originally thought to be part of the "dead-arm" disease. It was not until the mid-1970s that this confusion was rectified (15).

Symptoms: Leaf symptoms appear in May as small angular brown spots, often with yellow halos. Later in the season, canes, tendrils, leaf petioles and cluster stems may show elongated, brownish or blackish lesions up to 1/2 inch long. Infected tissue becomes brittle and breaks easily. The fungus can enter the grape berries directly or through the pedicel (berry stem). Rachis and berry stem infection can lead to premature berry drop. Mechanical harvesting will often shake many berries off the vine ahead of the machine, causing considerable crop loss (15).

Method of Transmission: The fungus overwinters in bark of infected canes. Most conidia are released in the summer during rainy weather (42).

Conditions Favoring Disease: Six or more hours of leaf wetness are needed for infection. The optimum temperature range for disease development is 15-20°C (42).

Management Practices: The critical period for protection against shoot and leaf infection is during early shoot development, as young tissue is especially susceptible. Rachises are susceptible from the time the flower clusters become visible until harvest so protection is warranted from the moment the flower clusters appear. Berries are most susceptible from bloom to pea-sized berry (24). 'Niagara' grapes are very susceptible to this disease. 'Concord' is less susceptible, but where fungicidal control has been lacking, losses often occur. Fungicide coverage from the 1-inch shoot length stage, until at least pea sized berries will give good control (15, 42). Chemical controls include: Abound, Captan, Dithane, Elite, Flint, Nova, Sovran, Procure, Penncozeb and Ziram. Some processors will not accept fruit treated with Mancozeb after bloom (24).

Powdery Mildew

Uncinula necator (Schwein) Burrill

Symptoms: Leaf symptoms of powdery mildew appear in early to mid-summer as a white powdery or dusty fungus growth on the upper surfaces of the leaves and other green parts of the vine, such as berries

and cluster stems. Leaves heavily infected by powdery mildew are less able to manufacture food (photosynthesize) resulting in decreased plant vigor, lower yield or juice quality and increased chance of winter injury to the vines. Severely affected leaves turn brown and fall. Infected cluster stems can cause shelling of ripe fruit. Infected berries turn brown and crack, and fail to properly mature. Infection also predisposes berries to *Botrytis* bunch rot and sour rot. On Concord vines, powdery mildew appears first on the rachis around bloom and is rarely seen on foliage until later in summer (15, 42).

Method of Transmission: In late summer and early autumn, minute black fruiting bodies called cleistothecia form on infected vine parts. They get washed off by rain into cracks in the bark of the trunk, where they overwinter. The cleistothecia release ascospores during rains in the spring between bud break and fruit set (42).

Conditions Favoring Disease: Powdery mildew is favored by high humidity and temperatures of 68 to 81°F. Wetness is not required for infection (42).

Management Practices: Begin monitoring at immediate prebloom, checking rachis and leaves inside the canopy closest to the trunk. Sprays for powdery mildew at the 1- to 5-inch shoot stage may only be needed for highly susceptible varieties or problem areas. Fungicide sprays should be applied as indicated by monitoring and weather conditions. On highly susceptible varieties, late-season powdery mildew development may need to be controlled (24, 42). Chemical controls include: Abound, Amicarb, Bayleton, Elevate, Elite, Nova, Procure, Sulfur, Sovran, Rubigan and Flint (24).

FUNGICIDE PROFILES

Acres of bearing grapes in 1999 = 11,700
Acres of bearing grapes in 2001 = 12,300

Azoxystrobin (strobilurin)

- Formulations: Abound 2F (*a strobilurin fungicide with limited post infection activity*) (24).
- Pests Controlled: Black rot, downy mildew, powdery mildew, Phomopsis cane and leaf spot (24).
- Acres of Crop Treated: 28% in 2001, 44% in 1999 (38, 39).
- MI Average Rate per Application: 0.20 lb ai/A in 2001, 0.18 lbs ai/A in 1999 (38, 39).
- Number of applications: Michigan averaged 1.2 applications per year in 2001 and 1.3 application/ year in 1999 (38, 39).
- Types of Applications: Ground (26).
- Timing: Do not make more than 3 applications of Abound or other strobilurins per acre per year (26).
- PHI: 14 days (26).
- REI: 4 hours (26).
- IPM Concerns: Toxic to fish and aquatic invertebrates (26). Do not allow spray to drift onto apples trees or fruit. Do not use spray equipment contaminated with Abound for apples, as injury

may result (26).

Resistance Management: Abound should be integrated into an overall disease management strategy that includes canopy management through pruning and thinning, proper selection of varieties with disease tolerance and removal of plant debris in which inoculum overwinters (26).

Triadimefon (triazole)

- Formulations: Bayleton 50DF (*a systemic sterol-inhibiting fungicide with post infection activity*) (24).
- Pests Controlled: Black rot, powdery mildew (24).
- Acres of Crop Treated: 6% in 2001, 18% in 1999 (38, 39).
- MI Average Rate per Application: 0.11 lbs ai/A in 2001, 0.11 lbs ai/A in 1999 (24).
- Number of Applications: Michigan averaged 1.5 applications per year in 2001, and 1.2 applications per year in 1999 (38, 39).
- Types of Applications: Ground (26).
- Timing:
    - *Powdery mildew:* Make the first application pre-bloom and continue at 14- to 21-day intervals as needed.
    - *Black rot protective schedule*: Make the first application at 10-inch green shoot and continue applications at 7- to 14-day intervals through 5 Brix or until veraison (berry coloring) is completed. Under severe disease conditions and/or on highly susceptible varieties, make applications at 7-day intervals.
    - *Black rot post infection schedule*: During bloom apply within 72 hours after the beginning of an infection period. Do not make spray applications any closer than 7 day intervals. After bloom continue applications at 7-14 day intervals or as needed to maintain control (26).
- PHI: 14 days (24).
- REI: 12 hours (26).
- IPM Concerns: Alternating or tank mixing Bayleton with a non-sterol inhibitor is recommended (24).
- Efficacy Issues: Use the higher label rates under heavy disease pressure or when used as a post-infection application, with extended spray intervals and/or on highly disease susceptible varieties (26).

Benomyl (benzimidazole)

- Formulations: Benlate 50WP (*a systemic fungicide with post-infection activity*) (24).
- Benlate has been withdrawn by the manufacturer, but existing stocks can be used up (24).
- Pests Controlled: Black rot, powdery mildew, Botrytis bunch rot, Phomopsis cane and leaf spot (24).
- Acres of Crop Treated: 11% in 1999 (38).

- MI Average Rate per Application: 0.31 lbs ai/A in 1999 (38).
- Number of Applications: 1.0 per season in 1999 (38).
- Types of Applications: Ground (26).
- Timing:
    - *Botrytis bunch rot*: apply at first bloom and repeat 14 days after first bloom. If conditions favor disease, repeat again 14 days later.
    - *Powdery mildew*: apply at leaf emergence and repeat at 14 to 21 day intervals (24, 26).
- PHI: 50 days (26).
- REI: 24 hours (26).
- IPM Concerns: Toxic to fish (26).
- *Resistance Management*: Do not use Benlate alone in a spray program, use only in combination or in an alternating application program with a labeled non-benzimidazole fungicide (26).

Captan (dicarboximide)

- Formulations: Captan 50WP or Captec 4L (*a protectant fungicide with a broad spectrum of activity*) (24).
- Pests Controlled: Black rot (suppression only), downy mildew, Phomopsis cane and leaf spot and Botrytis rot (24).
- Acres of Crop Treated: 3% in 2001, 8% in 1999 (38, 39).
- MI Average Rate per Application: 1.66 lbs ai/A in 2001, 1.65 lbs ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 2.2 applications per year in 2001 and 2.2 applications per year in 1999 (38, 39). Do not apply more than 24 lbs per acre per crop cycle (26).
- Types of Applications: Ground (26).
- Timing: Apply when shoots are ½ to 1½ inches long, when shoots are 3 to 5 inches long and when shoots are 9 to 12 inches long. Repeat just before bloom, immediately after bloom and continue at 10- to 14-day intervals as long as disease conditions persist (24, 26).
- PHI: May be applied up to the day of harvest (26).
- REI: 4 days (26).
- IPM Concerns: Toxic to fish. Many processors will not accept grapes sprayed at any time during the season with Captan (24).

Ferbam (dithiocarbamate)

- Formulations: Ferbam Granuflo (*a* b*road-spectrum protectant fungicide*) (24).
- Pests Controlled: Black rot and downy mildew (suppression only) (24).
- Acres of Crop Treated: 8% in 1999 (38).
- MI Average Rate per Application: 2.53 lbs ai/acre in 1999 (38).
- Number of Applications: Michigan averaged 1.4 applications per year in 1999 (38). Do not make more than 3 applications per season (26).
- Types of Applications: Ground (26).

- Timing: Applications are made at 1- to 5-inch shoot through 4th cover as needed (24).
    - *Black rot:* Apply just before bloom, just after bloom and as disease conditions warrant.
- PHI: 7 days (26).
- REI: 24 hours (26).
- IPM Concerns: Toxic to fish (26).

Copper

- Formulations: Copper compounds (copper hydroxide, copper oxychloride, copper sulfate [COCS], tribasic copper sulfate, and copper salts of fatty & rosin acids). Bordeaux mixture is 6 lbs. copper sulfate and 6 lbs. hydrated lime in 100 gal of water (*protectant fungicides*) (24).
- Pests Controlled: Downy mildew.
- Acres of Crop Treated: 12% in 2001(39).
- MI Average Rate per Application: 0.66 lbs ai/A in 2001 (39).
- Number of Applications: Michigan averaged 1 application per year in 2001(39).
- Types of Applications: Ground (26).
- Timing: Begin application at 8-12 inch shoot with subsequent applications throughout the season depending upon disease severity (24, 26).
- PHI: Copper/lime mixtures are exempt if used as recommended (24).
- REI: 24 hours (26).
- IPM Concerns: Copper has a negative effect on earthworm populations (24).
- Foliage injury may occur on copper-sensitive varieties such as Concord, Niagara, Delaware, and Rosette. All sensitive cultivars are listed in the Michigan Fruit Management Guide (24).

Mancozeb (elethylene bis-dithiocarbamate)

- Formulations: Dithane 75 DF, Penncozeb 75DF, Manzate 200 DF (*all are protectant EBDCs*) (24).
- Pests Controlled: Downy mildew, Phomopsis, black rot and bunch rot (24).
- Acres of Crop Treated: 95% in 2001, 90% in 1999 (38, 39).
- MI Average Rate per Application: 2.24 lbs ai/A in 2001, 2.25 lbs ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 3 applications per year in 2001 and 2.3 applications per year in 1999 (38, 39). Do not exceed 25.6 lbs. per season (26).
- Types of Applications: Ground (26).
- Timing: Make first application when shoots are ½ to 1 ½ inches long. Repeat when shoots are 3 to 5 inches long, when shoots are 8 to 10 inches long and then at 7- to 10-day intervals until fruit is set (24, 26).
- PHI: 66 days (26).
- REI: 24 hours (26).
- IPM Concerns: Toxic to fish (26). Many processors will not accept grapes sprayed with mancozeb after the onset of bloom (24).

Tebuconazole (triazole)

- Formulations: Elite 45DF (*a systemic sterol-inhibiting fungicide with post-infection activity*) (24).
- Pests Controlled: Black rot and powdery mildew (24).
- Acres of Crop Treated: 55% in 2001, 37 % in 1999 (38, 39).
- MI Average Rate per Application: 0.11 lb ai/A in 2001, 0.11 lb ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 2 applications per year in 2001 and 3.1 applications in 1999 (38, 39).
- Types of Applications: Ground (26).
- Timing: *Powdery mildew*: apply in a preventative spray schedule. Make the first application before bloom and continue applications at intervals up to 21 days in low to moderate disease pressure.
- *Black rot preventative schedule*: Make the first application at 1 to 3 inches of new shoot growth and continue at 7- to 14-day internals through 5 Brix stage or until veraison (berry coloring) is complete. Apply at 1-inch new shoot growth and at 7- to10-day intervals on highly susceptible varieties or under severe disease conditions.
- *Black rot post infection schedule*: Apply from 1-inch new shoot growth through 5 Brix stage. Apply within 72 hours after the beginning of an infection period. Applications should not be closer than 7 days apart. Continue Elite applications using the preventative schedule if the post infection schedule is discontinued (26).
- PHI: 14 days (26).
- REI: 12 hours (26).
- IPM Concerns: Elite enhances control of Botrytis bunch rot by other fungicides (26).
- *Resistance management*: Should be alternated or tank mixed with a non-sterol inhibiting fungicide for resistance management purposes (24).

Myclobutanil (triazole)

- Formulations: Nova 40WP (*a systemic sterol-inhibiting fungicide with post-infection activity*) (24).
- Pests Controlled: Black rot, powdery mildew, Phomopsis cane and leaf spot suppression (24).
- Acres of Crop Treated: 33% in 2001, 48% in 1999 (38, 39).
- MI Average Rate per Application: 0.09 lb ai/A in 2001, 0.09 lb ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 1.9 applications per year in 2001 and 2.7 applications in 1999 (38, 39). Maximum application rate per season is 1.5 lbs (24).
- Types of Applications: Ground (26).
- Timing: *Black rot preventative schedule*: begin application when new shoots are 1 to 3 inches in length and continue applications on a schedule that does not exceed 14 days. Use higher rate under heavy disease pressure.
- *Black rot post infection schedule*: apply within 72 hours after the beginning of an infection period.
- *Powdery mildew*: begin applications at prebloom (12- to 18-inch shoots) and do not extend applications beyond a 21-day interval. Use higher rate or shorter spray interval on susceptible

varieties or under heavy disease pressure (24, 26).
- PHI: 14 days (26).
- REI: 24 hours (26).
- IPM Concerns: *Resistance management strategy*: alternate Nova with fungicides of a different mode of action (24).

Triflumizole (triazole)

- Formulations: Procure 50WP (*a systemic sterol-inhibiting fungicide with post-infection activity*) (24).
- Pests Controlled: Powdery mildew, black rot, Phomopsis cane and leaf spot (suppression only) (24).
- Acres of Crop Treated: Not listed in the NASS data (39).
- Application Rate (label): 4 to 6 ozs/A (24). Do not exceed 32 oz/A per season (26).
- Types of Applications: Ground (26).
- Timing: One- to 5-inch shoot through fifth cover (24). Start applications before bloom and continue on a 14- to 21-day interval. Use higher rates or shorter intervals on susceptible varieties or under heavy disease pressure (26).
- PHI: 7 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish (26).

Mefenoxam (phenylamide)

- Formulations: Found in Ridomil Gold MZ and Ridomil Gold Copper (*systemic fungicides with post-infection activity*) (24).
- Pests Controlled: Downy mildew. Ridomil Gold MZ provides some black rot control but no powdery mildew control. Ridomil Gold/Copper will not control black rot but provides some control of powdery mildew (24).
- Acres of Crop Treated: 16% in 2001, 9% in 1999 (38, 39).
- MI Average Rate per Application: 0.14 lb ai/A in 2001, 0.21 lb ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 1.2 applications per year in 2001 and 1.5 applications in 1999 (38, 39). If, in addition to Ridomil Gold/MZ, other fungicides containing EBDC active ingredients are used during the growing season, do not exceed a total of 19.2 lbs of EBDC ai per acre (26).
- Types of Applications: Ground (26).
- Timing: Bloom and post-bloom (24).
- *Downy mildew*: Use as a preventative. Make up to 4 applications beginning before bloom; do not make an application within 66 days of harvest. For late season downy mildew control, use other registered fungicides (26).
- PHI: 66 days (26).
- REI: 48 hours (26).
- IPM Concerns: Toxic to fish (26).

Iprodione (dicarboximide/imidazole)

- Formulations: Rovral 50WP (*a protectant fungicide*) (24).
- Pests Controlled: Botrytis bunch rot (24).
- Acres of Crop Treated: 3% in 2001, 4% in 1999 (38, 39).
- MI Average Rate per Application: 0.84 lbs ai/A in 2001, 0.97 lb ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 2.1 applications per year in 2001 and 1.5 applications in 1999 (38, 39). A maximum of 4 applications are allowed on grapes per year (24).
- Types of Applications: Ground (26).
- Timing: Bloom, third cover (bunch closing), sixth cover (veraison) and pre-harvest (24, 26).
- PHI: 7 days (26).
- REI: 48 hours (26).
- IPM Concerns: Toxic to invertebrates (26).
- *Resistance management*: Alternating Rovral with fungicides with a different mode of action may delay the buildup of resistant strains.

Kresoxim methyl (strobilurin)

- Formulations: Sovran (*a protectant fungicide with surface-systemic activity and limited post-infection activity)* (24).
- Pests Controlled: Powdery mildew, downy mildew, black rot, Phomopsis cane and leaf spot (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 3.2 to 5.6 oz/A. Do not use more than 25.6 oz. of product per acre per season and allow a minimum of 7 days between sequential sprays of Sovran (24). No more than 3 treatments per season can be applied to juice grapes (26).
- Types of Applications: Ground spray equipment (26).
- Timing: *For black rot and Phomopsis cane and leaf spot*: begin application at bud break and continue at 14-day intervals.
- *Powdery mildew*: begin at prebloom and continue on at 14-day intervals; under low disease pressure, the interval may be extended up to 21 days.
- *Downy mildew*: begin at prebloom and continue at 7- to 10-day intervals (24, 26).
- PHI: 14 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish and invertebrates (26).
- *Resistance management*: Alternating with non-strobilurin fungicides is recommended (24).

Cyprodinil (anilinopyrimidine)

- Formulations: Vangard 75WG (*a systemic fungicide with post-infection activity*) (24).
- Pests Controlled: Botrytis bunch rot (24).
- Acres of Crop Treated: 2% in 2001 (39).

- MI Average Rate per Application: 0.46 lbs ai/A in 2001 (39).
- Number of Applications: Michigan averaged 1.2 applications per year in 2001 (39). A maximum of 2 applications is allowed per season (24).
- Types of Applications: Ground (26).
- Timing: Begin application at early bloom. Make an additional application at berry touch, veraison, or preharvest (24, 26).
- PHI: 7 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish and aquatic invertebrates (26).
- *Resistance management*: Vangard shows no cross- resistance to other currently available fungicides (24).

Ziram (dithiocarbamate)

- Formulations: Ziram 76DF or Ziram Granuflo (*broad spectrum protectant fungicides*) (24).
- Pests Controlled: Phomopsis cane and leaf spot, downy mildew, black rot and suppression of Botrytis bunch rot (24).
- Acres of Crop Treated: 85% in 2001, 71% in 1999 (38, 39).
- MI Average Rate per Application: 2.51 lbs ai/A in 2001, 2.43 lbs ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 2.5 applications per year in 2001 and 2.4 applications in 1999 (38, 39). Do not apply more than 28 lbs. per acre per crop cycle (26).
- Types of Applications: Ground (26).
- Timing: One- to 5-inch shoot through fifth cover (24).
- Begin when shoots are one inch long and continue at 7-14 day intervals as needed.
- PHI: 21 days (24).
- REI: 48 hours (26).
- IPM Concerns: toxic to fish (26).

Fenhexamid (hydroxyanilide)

- Formulations: Elevate 50 WDG (*a surface- systemic fungicide with limited post-infection activity)* (24).
- Pests Controlled: Botrytis bunch rot (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1 lb/A (24). Do not apply more than 3 times per season. Avoid making more than 2 sequential applications (24).
- Types of Application: Ground (26).
- Timing: Apply when conditions favor disease development at early bloom, bunch pre-close and veraison (beginning of fruit ripening) (26).
- PHI: 0 days (24).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish and aquatic invertebrates.
- *Resistance management*: Has a unique chemistry, making it useful for fungicide resistance

management (24).

Trifloxystrobin (strobilurin)

- Formulations: Flint (*a surface- systemic fungicide with limited post infection activity*) (24).
- Pests Controlled: Black rot, downy mildew (suppression onl), powdery mildew and Phomopsis blight (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1.5 to 4 ozs/A (24). Do not make more than 3 applications of Flint or other strobilurin fungicides per season. Do not apply more than 8 oz of Flint per acre per season.
- Types of Application: Ground (26).
- Timing:
    - *Powdery mildew control and suppression of Botrytis bunch rot, downy mildew*: Begin applications preventively and continue as needed at 14- to 21-day intervals.
    - *Phomopsis cane and leaf spot*: applications should begin at bud break and continue on 14-21 day intervals and before 0.5 inch shoot length and again when shoots are 5- to 6 inches long (26).
    - *Black rot*: Begin applications when shoots are 1 to 3 inches long and continue as needed at 10-14 day intervals.
- PHI: 14 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish and aquatic invertebrates (26).
- *Resistance management*: Rotation with non-strobilurin fungicides is recommended (24).

Fenarimol (pyrimidine)

- Formulations: Rubigan 1EC (*a locally systemic SI fungicide with protectant and curative properties)* (24).
- Pests Controlled: Powdery mildew (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 4 ozs/A (24).
- Types of Application: Ground only (26).
- Timing: Apply pre-bloom, post-bloom and during the summer as needed (26).
- PHI: 30 days (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish (26).
- *Resistance management*: Rubigan should not be tank-mixed or alternated with a non-sterol inhibiting fungicide to reduce the risk of resistance development (24).

Potassium bicarbonate

- Formulations: Americarb 100 and Kaligreen (*protectant/contact fungicides*) (24).

- Pests Controlled: Powdery mildew, black rot (24)
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 2.5-5.0 lbs/A (24).
- Types of Application: Ground (24).
- Timing: *Powdery mildew*: begin applications at the first sign of disease and continue on a 7-14 day schedule (24).
- *Black rot*: Begin first spray at immediate pre-bloom and continue on a 7-14 day schedule until 5 weeks after bloom (24).
- PHI: 0 days (24).
- REI: 4 hours (24).
- IPM Concerns: Americarb is an environmentally friendly salt (24).

Thiophanate-methyl (carbamate)

- Formulations: Topsin-M (*a broad-spectrum systemic fungicide)* (24).
- Pests Controlled: Powdery mildew and Botrytis (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1 to 1.5 lbs per acre (26).
- Types of Application: Ground (26).
- Timing: Apply at first bloom and repeat 14 days later or as needed if severe disease conditions exist (26).
- PHI: 14 days (24).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish (26).
- *Resistance management*: Topsin-M should be tank-mixed with a non-benzimidazole fungicide (e. g. Captan or Ziram) to reduce the risk of resistance development (24*).*

Potassium phosphite

- Formulations: ProPhyt *(a systemic fungicide)* (26).
- Pests Controlled: Downy mildew (26).
- Application Rate (label): 0.3% concentration (26).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Types of Application: Ground (26).
- Timing: Applications should be initiated when environmental conditions are favorable for disease development (26).
- PHI: 0 days (26).
- REI: 4 hours (26).
- IPM Concerns: For prevention of downy mildew it is recommended to combine ProPhyt treatment with additional protective products, specifically dithiocarbamates, by tank-mix or by alternating treatments (26).

Weed Management

Weeds can be a major problem in vineyards, competing for water, nutrients, and sunlight. Weed control begins one or two years before planting grapevines to reduce perennial weeds like dock, quackgrass, poison ivy, Canada thistle, and brambles. Herbicides, or cultivation alone or in combination with cover crops, are used. Annual broadleaf weeds and grasses are easy to control once they have been identified and after the grapes have been planted. Many different means are used to control weeds in established vineyards but knowledge of the soil type, timing of a specific herbicide, use of irrigation, and equipment are several factors for successful weed control. However herbicide carry-over from field corn can be a problem in some grape vineyards (19).

Cultivation by hand hoeing is done in small vineyards. Certain types of rotary or cultivating machines, such as the grape hoe, are available but risk of trunk and root injury are high. Plastic and organic mulches are sometimes used just after planting. Although many options are available, most vineyardists use herbicides because they are usually most economical (19).

Three to four foot wide weed free strips are maintained under the vines for good growth. A permanent sod cover is established between the rows either prior to planting or immediately after planting to prevent erosion. Mulching reduces weeds, increases moisture and reduces erosion. Mulching is good on sandy or coarse soils but heavy mulching is avoided on poorly drained soils (19).

In the fall before planting, weeds are destroyed by systemic herbicide applications. Before planting, a broad-spectrum systemic herbicide is applied. After planting, a preemergence herbicide is applied to control annual weeds and weeds around plants are removed or spot treated by hand. If vines are not touching the first wire in the second year, they are treated as newly planted vines. Herbicides approved for newly transplanted grapes are also used in the second year. As vines become established and the trunk becomes mature, certain herbicides are used for persistent weeds (19).

In coarse or sandy soils with less than 2% organic matter, certain herbicides are not used; for example: Sinbar, Simazine and Karmex damage or kill young or mature vines on light soils (19).

Injury from herbicides can be confused with disease or insect injury. Volatilization of some

2,4-D compounds used in grain crops can injure grape vines. Many compounds for use around non-crop land such as forests, ditches, power lines, railway or roads may also contain harmful ingredients that injure grapes. Drift from these compounds can cause injury from 1/4 to 1/2 mile or more. If injury is not severe, normal growth will resume the following year. Severely injured vines may die or not recover for 2 years or more. Fruit ripening can be delayed or never mature and this problem may persist for several years. Concord grapes are particularly sensitive to 2,4-D injury (19).

Fall applied herbicides may be beneficial to control perennial weeds when no leaves or green tissue are present on the vines. Full rates in the fall control annual weeds until early spring. If the fall has high rainfall or the soil is coarse and sandy, a half rate in the fall and a half rate in the spring will provide weed control through mid to late summer (19).

HERBICIDE PROFILES

Acres of bearing grapes in 1999 = 11,700
Acres of bearing grapes in 2001 = 12,300

Dichlobenil (benzonitrile)

- Formulations: Casoron 4G.
- Pests Controlled: Suppresses annuals and perennials (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 150 lbs/A (24).
- Types of Application: Ground (25).
- Timing: Pre-emergence for grapes established one year or more. Apply in November prior to snowfall. Controls quackgrass and annual weeds until late summer of the following year. Other perennial weeds, such as field bindweed and Canada thistle, are also suppressed by this chemical (24).
- PHI: None (26).
- REI: 12 hours (24).
- Efficacy Issues: The granular formulation is most effective on quackgrass (24).

Diuron (phenylurea)

- Formulations: Karmex DF.
- Pests Controlled: Particularly effective on annual grasses and broadleaved weeds. At higher rates, it may also suppress quackgrass (24).
- Acres of Crop Treated: 50% in 1999 (38).
- MI Average Rate per Application: 1 lb ai/A in 1999 (38).
- Number of Applications: Michigan averaged 1 application/year in 1999(38).
- Types of Application: Ground (Band) (25).
- Timing: Pre-emergence for grapes established 3 or more years. Apply in spring before weed growth starts. Use lower rate for sandy soils. Make a single application/year (24).
- PHI: None.
- REI: 12 hours (25).

Fluazifop-butyl (aryloxyphenoxyproprionate)

- Formulations: Fusilade DX
- Pests Controlled: Grasses (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1 to 2 pts/A (24).
- Types of Application: Ground (Band applied), do not use flood type nozzles or recirculating sprayers, ropewick, or controlled droplet applicators (26).
- Timing: Postemergence for non-bearing grapes only. Apply to actively growing grasses 4 to 8 inches tall (24).
- PHI: 1 year (26).
- REI: 12 hours (26).
- IPM Concerns: Toxic to fish (26).
- Efficacy Issues: Add non-ionic surfactant or crop oil concentrate as label specifies (24).

Glufosinate (organophosphate)

- Formulations: Rely
- Pests Controlled: Controls a broad spectrum of emerged annual and perennial grass and broadleaf weeds (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 3 to 6 qts/A (24). 1 lb ai/A when weeds less than 8 inches tall and 1 1/2 lbs ai/A if taller (24).
- Types of Application: Ground only (band or spot treated) (25).
- Timing: Post emergence for grapes established 1 year or more. Apply to actively growing weeds (24).
- PHI: 14 days (24)
- REI: 12 hours (25).

Glyphosate (organophosphate)

- Formulations: Roundup Ultra
- Pests Controlled: Annuals and perennials (24).
- Acres of Crop Treated: 78% in 2001 and 77% in 1999 (38, 39).
- MI Average Application Rate: 0.56 lbs ai/A in 2001, O.62 lb ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 1.1 applications per year in 2001 and 1.2 applications per year in 1999 (38, 39).
- Types of Application: Ground (broadcast, hand-held and high volume equipment) (26).
- Timing: Postemergence from year of planting, onward: (24)
- PHI: None
- REI: 4 hours (25).

Napropamide (amide)

- Formulations: Devrinol 50DF.
- Pests Controlled: Annual grasses and some broadleaved weeds (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 8 lbs/A (24).
- Types of Application: Ground (surface applied or incorporated, applied broadcast) (26).
- Timing: Postemergence: apply to weed free ground since napropamide does not work against emerged weeds. Apply in early spring. Short residual life (24).
- PHI: 35 days (26).
- REI: 12 hours (26).

Norflurazon (pyridazinone)

- Formulations: Solicam DF.
- Pests Controlled: More effective on grasses than broadleaf weeds and does not control established weeds. Suppresses annual grasses and nutsedge (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 1.5 to 4 lbs/A (24).
- Types of Application: Ground (25).
- Timing: Pre-emergence for grapes established 2 or more years. Apply in fall or early spring before weeds emerge (24).
- PHI: 60 days (25).
- REI: 12 hours (25).

Oryzalin (dinitroaniline)

- Formulations: Surflan A.S.
- Pests Controlled: Annual grasses and many annual broadleaved weeds (24).
- Acres of Crop Treated: 4% in 1999 (38).
- MI Average Application Rate: 1.32 lb ai/A in 1999 (38).
- Number of Applications: Michigan averaged 1.0 application per year in 1999 (38).
- Types of Application: Ground (broadcast and banded) (26).
- Timing: Preemergence: Apply after planting when the soil has settled. For established plantings apply in spring before weeds emerge. Apply to weed free soil and avoid spray contact with leaves and trunks. Use the lower rate on sandy soils (24).
- PHI: No information available.
- REI: 24 hours (26).
- IPM Concerns: Toxic to fish (26).

Oxyfluorfen (diphenyl ether)

- Formulations: Goal 2XL.
- Pests Controlled: Annual broadleaves and grasses (26).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): Postemergence: 2 to 8 pt/A, pre-emergence: 5 to 8 pints/A (26).
- Types of Application: Ground (25).
- Timing: Dormant stage. Vines must be 3 years or older and trellised in order to spray (24). Pre-emergence or post-emergence (26).
- PHI: Do not apply during the period between bud swell and completion of harvest or when fruit is present (25).
- REI: 24 hours (25).
- IPM Concerns: Extremely toxic to aquatic invertebrates, aquatic plants, wildlife and fish (26).

Pendimethalin (dinitroaniline)

- Formulations: Prowl 3.3 EC.
- Pests Controlled: Most annual grasses and certain broadleaf weeds as they germinate. It will not control established weeds (26).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate: 2.4 to 4.8 qt/A (24).
- Types of Application: Ground (25).
- Timing: Pre-emergence for nonbearing grape only. Apply after planting when soil settles. Apply to established plantings before buds swell (24). Treatments are most effective in controlling weeds when adequate rainfall or irrigation is received within 21 days of application (25). Apply spray directly to the ground beneath vines since malformed plant tissue may result if applied over plants. Do not apply to newly transplanted vines until they are dormant (26).
- PHI: None.
- REI: 24 hours (25).
- IPM Concerns: Toxic to fish (26).

Pronamide (amide)

- Formulations: Kerb 50W.
- Pests Controlled: Grasses (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 2 to 4 lb/A (24).
- Types of Application: Ground.
- Timing: Use only on grapes established 1 or more years. Apply in November before soil freezes or in early spring (24). Apply pre-emergence or early postemergence for control of winter annual and perennial grasses and chickweeds. For pre-emergence control only of certain other grasses listed on the label (26).
- REI: 24 hours (26).
- *Restricted Use Pesticide*

Sethoxydim (cyclohexine oxime)

- Formulations: Poast 1.5EC.
- Pests Controlled: Grasses (24).
- Acres of Crop Treated: Not listed in the NASS data (38, 39).
- Application Rate (label): 01.5 to 3 pt/A (24).
- Types of Application: Ground (broadcast and banded) (25).
- Timing: Postemergence: apply to actively growing grasses (24). Do not cultivate 5 days before or 7 days after applying sethoxydim (26).
- PHI: 50 days (24).
- REI: 12 hours (25).
- IPM Concerns: Toxic to aquatic organisms (26).
- Repeated use of sethoxydim may lead to the selection of naturally occurring biotypes with resistance to sethoxydim (26).
- Efficacy Issues: Add non-ionic surfactant or crop oil concentrate as label specifies (24).

Simazine (triazine)

- Formulations: Princep 90WG.
- Pests Controlled: Annual and perennial grasses (does not control sedges or broadleaves) (26).
- Acres of Crop Treated: 38 % in 2001 and 30% in 1999 (38, 39).
- MI Average Application Rate: 0.81 lbs ai/A. in 2001, 1.23 lbs ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 1.2 applications per season in 2001 and 1 application per season in 1999 (38, 39).
- Types of Application: Ground (25).
- Timing: Preemergence in spring before weed growth starts for grapes established 1 or more years (24).
- REI: 12 hours (25).
- Efficacy Issues: Use lower rates on sandy soils. Do not apply in vineyards less than 3 years old (24).

Paraquat (quaternary ammonium)

- Formulations: Gramoxone Max 3L
- Pests Controlled: Kills emerged annual weeds (24).
- Acres of Crop Treated: 71 % in 2001, 80% in 1999 (38, 39).
- MI Average Application Rate: 0.35 lbs ai/A in 2001, 0.38 lbs ai/A in 1999 (38, 39).
- Number of Applications: Michigan averaged 1.4 applications per season in 2001 and 1.5 applications per season in 1999 (39).
- Types of Application: Ground (26).
- Timing: Postemergence: Apply when sucker growth is less than 8 inches long. Avoid contact with grape leaves or green foliage (24).

- REI: 12 hours (26).
- IPM Concerns: Toxic to wildlife (26).
- *Restricted Use Pesticide.*

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