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PREFACE

Approximately 135 persons attended the 1979 Ohio Grape-Wine Short Course which 
was held at the Fawcett Center for Tomorrow, The Ohio State University, Columbus, 
Ohio, on February 20-21. Those attending were from 10 states not including Ohio and 
represented many areas of the grape and wine industry. This course was sponsored by 
the Department of Horticulture, The Ohio State University, in cooperation with Ohio 
Agricultural Research and Development Center, Ohio Cooperative Extension Service and 
Ohio Wine Producers Association.

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Any discussion of the Eutypa Dieback Disease is immediately complicated by the fact that this disease has until rather recently been mistakenly associated with the wrong fungal causative agent. This further leads to a rather confused area of disease nomenclature. Therefore, before we can proceed with a discussion of Eutypa Dieback, it will be necessary for us to review some of the background which has led to the recognition and naming of this disease.

For over sixty years (8), the eastern grape industry recognized a grape disease called Dead Arm. However, by 1976 it was clear that some of the aspects of that disease had been incorrectly understood. The causative fungal agent for dead arm disease was recognized to be Phomopsis viticola Sacc. (8). However, a second fungus has rather recently become implicated (1,3,4,5,6,7,9) as the cause of part of the damage to grapevines, which previously had been attributed to dead arm disease. What has emerged from all this is the recognition of two distinctly separate diseases, each caused by a distinctly separate fungus organism. The reasons for the choice of these new disease names as well as the abandonment of other existing and proposed names such as dead arm and dying arm has been presented elsewhere (10).

While the main emphasis of this presentation will focus on one of these diseases, Eutypa Dieback, attention will first be given briefly to Phomopsis Cane and Leaf Spot, the other of these two newly named diseases.

Phomopsis Cane & Leaf Spot

This disease is caused by the fungus organism Phomopsis viticola Sacc. Spores of this disease are released from lesions found on one to three-year old wood (1) (mostly one year-old) on the grapevine. These spores have limited mobility, can infect all green parts of the vine, and are dispersed during periods of rainfall early in the spring. Infection occurs predominantly on shoots and leaves (Fig. 1). Less often a fruit rot phase has been observed. Economic concern results from: (A) possible deterioration of shoot quality as it affects fruit cane quality the following season, (B) possible reduction in leaf quality with a resulting loss in photosynthetic efficiency and (C) less frequently direct loss of crop through berry infection and rot.

Perhaps no other grape disease lends itself better to a pest management approach to control than Phomopsis Cane and Leaf Spot. The reasons for this are: (A) the presence of this disease is readily identifiable in the vineyard before the start of the growing season through lesions, which usually predominate on the basal 5-7 internodes on a cane (Fig. 2) and (B) spread of this disease is very slow, cane to shoot, vine to vine. Therefore, a grower can identify problem areas in advance of treatment, and need not treat vineyards or portions of a vineyard not showing lesions.

Treatment typically consists of early season folpet or captan sprays. Consult Cooperative Extension for materials, rates, timing, number of sprays, etc.
**Eutypa Dieback Disease**

This disease is caused by the fungus *Eutypa armeniaceae* (7). Symptoms of this disease include a general reduction in vine size and the appearance of yellow, stunted shoots around mid-to-late June (Figs. 3 & 4). Shoots showing these symptoms may regain green coloration by mid-July or later in the season. However, the basal leaves, which are malformed on these shoots will retain their abnormal outline. During the last half of the growing season, healthy shoots from the same or adjacent vines will grow over affected shoots and camouflage the extent of damage from this disease.

The ultimate cause of these shoot symptoms is the translocation of a toxin from a canker located in an arm or trunk basal to the symptomatic shoots (Fig. 5, a,b,c). It may take three years or more after infection occurs before such a canker is advanced enough to produce shoot symptoms. It may take several more years before total destruction of the vine or vine portion apical to canker.

Spores of *Eutypa armeniaceae* are produced in dead wood tissue of infected grapevines (Figs. 6 & 7). Spores are released in response to moisture availability, and can be carried by air currents for great distances. The fungus is also responsible for the Apricot Dieback disease. It was first shown in apricots (2) and more recently in grapes (7) that spores of *Eutypa armeniaceae* must gain entry into their host plant through wounds. For grapevines, the predominant wounds are obviously pruning cuts. It is reasonable, therefore, that the location of cankers of Eutypa Dieback are often basal to major pruning cuts.

Regarding control measures for this disease, no effective spray program has yet been devised. Therefore, control of this disease must rely on measures, which will minimize the spread of spores and further will minimize the influence of infection once it occurs. Activities, which will contribute toward these goals include: (A) make clean, close pruning cuts to encourage callusing and reduce possible infection sites. (B) During the shoot symptom stage in June, identify and rogue out infected vines. At a minimum mark these vines clearly for removal during the next pruning season. (C) When renewing vines, remove old trunks as close to the ground as possible. Leave no trunk stubs as possible reservoirs of this disease. (D) Remove all cut trunks from the vineyards and either burn or bury them. (E) In vineyards where Eutypa Dieback has been identified, institute a program of trunk renewal so that vines are systematically renewed every 10-15 years.

There are several aspects of Eutypa Dieback disease of grapevines, which are not yet understood. These include varietal susceptibility, relative susceptibility of different grapevine tissues, duration of susceptibility of pruning cuts, relative abundance of spores during the year, etc. Research on these topics is in progress by Dr. Roger Pearson of the Geneva Agricultural Experiment Station and others. Future developments could lead to additional control measures for Eutypa Dieback such as time of pruning, fungicide treatments on pruning wounds, etc.
LITERATURE CITED


Figure 1. A Concord grape leaf showing numerous Phomopsis Leaf Spot lesions and also two black rot lesions.

Figure 2. A Concord grape cane infected with Phomopsis Cane and Leaf Spot lesions.
Figure 3. A normal Concord grape shoot growing in a Finger Lakes vineyard on June 1, 1978.

Figure 4. Concord shoots affected by a toxin produced by the Eutypa Dieback fungus *Eutypa armeniaceae*. Photo was taken June 1, 1978 in a Finger Lakes vineyard.
Figure 5. Eutypa Dieback canker in a trunk portion of a Concord vine (dark area). The abrupt interface portion between the healthy and diseased tissue as well as the extension of the canker into the center of the trunk are clues to the canker's identification; (a) Cross section; (b) Diagonal view and (c) Surface view.
Figure 6 & 7. A general as well as close up view of the dead portion of a grape trunk. In Figure 7 razor blade cuts have exposed the "honeycomb areas" which are the tubular fruiting bodies (stroma) of *Eutypa armeniaceae*. 

-7-
Use of sulfur dioxide (SO₂) in winemaking apparently was known to the early Egyptians and Romans (2). Early use probably involved the production of SO₂ from the burning of elemental sulfur. In modern times, the use of SO₂ in commercial winemaking has increased to the point of being nearly universal.

Sulfur dioxide is the only chemical preservative approved for use in winemaking which combines both antiseptic and antioxidative properties. Pretreatment of grape musts with SO₂ in the range of 25 to 250 ppm followed by inoculation with a proven wine yeast greatly increases the chances for a complete alcoholic fermentation and for the production of a sound young wine free from off-flavors and odors.

Sources of Sulfur Dioxide for Use in Winemaking

Sulfur dioxide is a nonflammable, readily condensible colorless gas which possess a pungent odor. It is easily liquefied under moderate pressure (7). The cheapest source is liquid SO₂ held under pressure in steel cylinders. Another source is sulfite salts which yield SO₂ when dissolved in musts or wines. Solutions of SO₂ in water can be made from either liquid SO₂ or from the sulfite salts. Another source of SO₂ is the burning of elemental sulfur which is still used in the preparation of cooperage for fermentation and storage of wines.

Wineries may use liquid SO₂ directly from the storage cylinder by metering it through a control device directly into the must as it is pumped from the stemmer-crusher into the fermentation tank. Liquid SO₂ could also be introduced directly into a filled tank followed by pumping over or mixing the contents of the tank in order to distribute the SO₂ uniformly throughout the mass. For small operations, a concentrated sulfurous acid solution can be made by passing SO₂ from the storage cylinder into a container of cold water (ca. 40°F or less). A 5% or 6% solution (by weight) of SO₂ in water can easily be made by this method and the concentration of the solution can be accurately estimated by the increase in weight. For example, if SO₂ from cylinder were dissolved in a gallon of a cold water (8.33 lbs) to give a 5% solution, the total weight of the liquid would be increased to 8.77 lbs (8.33 lbs water + 0.44 pounds SO₂). The concentration of SO₂ can also be measured chemically by titration with iodine solution.

The following sulfite salts are a convenient form of SO₂ available to small wineries and the home winemaker: Na₂SO₃ (sodium sulfite); NaHSO₃ (sodium bisulfite); Na₂S₂O₅ (sodium metabisulfite); K₂SO₃ (potassium sulfite); K₂S₂O₅ (potassium metabisulfite). The dry salts decrease in SO₂ strength during storage, especially under humid conditions, so store them in a cool, dry place. The metabisulfites are more stable than the bisulfites and the sulfites are the least stable (6). It is probably a good practice to replace the dry salts every other year to insure full strength. If aqueous solutions of SO₂ are used they should be freshly prepared and used immediately. The various sulfite salts in theory should yield somewhat more than 50% by weight of SO₂. For practical use however, consider the yield to be 50% by weight, e.g., 2 grams of K₂S₂O₅ would yield the equivalent of about 1 gram of SO₂ when dissolved in must or wine. In practice, 0.75 grams of potassium metabisulfite dissolved in one gallon of must or wine ≈ 100 ppm of SO₂.
Reasons for the Use of Sulfur Dioxide

There are many advantages attributed to the use of SO₂ in winemaking, such as SO₂:

1. Destroys or inhibits undesirable bacteria, yeasts and molds
2. Protects musts and wines from excessive oxidation
3. Inhibits certain enzymatic and non-enzymatic browning reactions
4. Can aid in color extraction and settling of musts prior to fermentation.
5. Can aid in color extraction and stabilization in making red wines
6. Can be used as a sanitizing agent for barrels and other equipment

Use of SO₂ is especially valuable in making white wines in order to prevent oxidation and browning. However, the use of an excessive amount of SO₂ should be avoided because it can:

1. Cause the legal limit (USA) of 350 ppm total SO₂ to be exceeded
2. Interfere with normal fermentation and aging of the wine
3. Bleach the color of red wines
4. Significantly degrade the sensory quality of the finished wine

The general rule is to use the minimum amount of SO₂ needed to get the job done.

Chemistry of Sulfur Dioxide in Winemaking

Definitions pertaining to SO₂ in wine:

"Free SO₂" - All the forms of SO₂ not chemically bound to other constituents
"Bound SO₂" - SO₂ chemically bound to other molecules such as acetaldehyde
"Total SO₂" - The total of free SO₂ and bound SO₂

When SO₂ (gas) is dissolved in wine or must, most of it is transformed into other forms such as sulfurous acid (H₂SO₃), bisulfite ions (HSO₃⁻) and sulfite ions (SO₃²⁻). An equilibrium is established between these various forms of SO₂ which can be depicted as follows:

\[
\text{SO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{SO}_3 \rightleftharpoons \text{H}^+ + \text{HSO}_3^- \rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}
\]

and

\[
2\text{HSO}_3^- \rightleftharpoons \text{S}_2\text{O}_5^{2-} \quad \text{(Pyrosulfite ion)}
\]

All forms of SO₂ in this equilibrium are considered free SO₂. Sulfurous acid (H₂SO₃) per se is probably present only in minute concentrations (2). In practice, the term "sulfurous acid" refers to an aqueous solution of SO₂ (SO₂⁺ H₂O) rather than to the undisassociated acid (H₂SO₃).

In wines, bisulfite ions can chemically combine with acetaldehyde, sugars such as glucose, certain phenolic compounds and other substances. Binding with the carbonyl group of acetaldehyde is a good example:
Free (unbound) SO₂ has greater antiseptic and antioxidative properties than does bound SO₂. Thus enough SO₂ should be added to a given wine to satisfy the requirement for "binding" and to allow free SO₂ to exist at the desired level. However, an excessive amount of free SO₂ should be avoided as it can give a wine a "sulfur" odor and taste.

The addition of SO₂ to musts is known to result in an increase in the production of both acetaldehyde and glycerol but it is not known if the accumulation of acetaldehyde is due to the direct formation of acetaldehyde sulfonate or to interference by SO₂ in the reduction of acetaldehyde to ethanol (2). Because of its volatility, a large percentage of the acetaldehyde produced is lost during fermentation unless it is bound as the sulfonate. Accumulation of excessive amounts of acetaldehyde is considered undesirable in table wines.

**Sulfur Dioxide Additions in Wine Production**

Sulfur dioxide is usually added to musts prior to initiation of fermentation. In wines, it is often added at first racking and, if needed, at intervals during cellar operations through bottling.

The amount of SO₂ to add to a given must or wine is an important consideration. In general, musts and wines having low pH values require less SO₂ addition than do musts and wines having high pH values because low pH conditions per se inhibit many spoilage organisms, less SO₂ is usually in the bound state and a high H⁺ concentration shifts the equilibrium to the left from the bisulfite ion species to SO₂ (aqueous). The condition of the grapes and the temperature of the must are also important. Cool, sound grapes yielding low pH musts require much less SO₂ than warm, unsound and overripe grapes. Amerine et al. (1) offered the following as a general guideline:

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Conditions</th>
<th>Concentration (P.P.M.)</th>
<th>Liquid SO₂ (oz/ton)</th>
<th>K₂SO₃O₅ (oz/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underripe</td>
<td>Clean, Sound</td>
<td>75</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>Mature</td>
<td>Clean, Sound</td>
<td>112</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>Overripe</td>
<td>Moldy, Low Acid</td>
<td>270</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

1 Adapted from Amerine et al. (1972)

Other factors often must be considered. For example, it might be desirable to encourage malo-lactic fermentation in the production of a red wine in order to reduce acidity. Malo-lactic bacteria are very sensitive to the presence of free SO₂. In this case, SO₂ additions should be held to a minimum or perhaps eliminated entirely. In order to encourage malo-lactic fermentation of red musts, Beelman (4)
recommended no SO₂ addition for a must of pH 3.1 or less, 20 ppm SO₂ for a must of pH 3.3 and only 50 ppm SO₂ for a must at pH 3.6.

Grapes grown in eastern United States usually yield must having normal to high acidity with comparatively low pH values and hence usually require only moderate SO₂ additions. We usually add 100 ppm SO₂ to white musts and 75 ppm to red musts. A significant percentage of the total SO₂ added prior to fermentation is lost during fermentation. As a rule, the higher the temperature of fermentation, the more SO₂ lost.

In general, a free SO₂ content of 20 to 40 ppm is considered desirable in most wines. The most accurate method of adjusting the free SO₂ content of given wine is to estimate the amount to add by trial determinations. An empirical approach is needed because the ratio of total to free SO₂ varies greatly from one wine to another. In a recent survey of six white and five red commercial wine samples the ratio of total to free SO₂ was found to range from 10.5 to 1.5 for the white wines and from 2.3 to 1.4 for the red wines (5). In trial determinations, known amounts of SO₂ are added to samples of the same wine. The treated samples should be tightly sealed and stored for about one week (to allow the concentration of free SO₂ to come to equilibrium) before determining the amount of free SO₂ in the samples. Plot the free SO₂ measured against the amounts of SO₂ added to the samples. Draw a line connecting the points. Using this figure, a fairly accurate estimate can be made of the amount of SO₂ to add in order to achieve the desired concentration of free SO₂. For example, a white wine has a free SO₂ content of 14 ppm which needs to be increased to 40 ppm. By extrapolation from the graph below, 62 ppm of SO₂ must be added in order to increase the free SO₂ content of the wine from 14 to 40 ppm.
Testing for Sulfur Dioxide

The determination of free and total SO₂ is routinely done (Ripper procedure) by titration of a wine sample with 0.02N iodine solution. The basis for this determination is the oxidation-reduction reaction:

\[ H_2SO_3 + I_2 + H_2O \rightarrow H_2SO_4 + 2HI \]

Free SO₂ can be determined directly. Total SO₂ is determined by first hydrolyzing the bound SO₂ with NaOH solution. For details see Amerine and Ough (3).

LITERATURE CITED


Grape maturation is the stage of development when the berries have reached the maximum quality for their intended purpose, such as wine or fresh consumption (1).

As we consider the different aspects of grape maturation, the first area to discuss is the vegetative growth of the vine.

Vegetative Growth (6)

The vine is a conservative plant. It does not rush into growth in early spring, as many of the fruit trees, but remains dormant until the mean daily temperature reaches about 50°F. As the temperature rises, shoot elongation accelerates from day-to-day around mid-May. This depends on the cultivar and location. We are all familiar with the earlier growth of a cultivar, such as 'Foch', grown in southern Ohio.

For the next three to four weeks, the most rapid shoot growth occurs. Here shoots of vigorous cultivars may elongate as much as an inch or more a day. This is the time when many growers believe they can actually see the vines' shoots grow.

At about bloom time, this rapid shoot elongation slackens and continues to diminish to the end of the growing season. After shoot elongation has slowed down, carbohydrates begin to accumulate in the shoots. The accumulation is slow at first while there is still shoot growth occurring and a rapid increase in berry size. The rate of sugar accumulation is affected by such factors as: crop load, time of fruit ripening, health of the vine, status of the shoot growth, the climatic conditions, and the amount of leaves exposed to adequate light. Winkler states that it is common knowledge that overcropping and continued rapid shoot growth delay the accumulation of carbohydrates in the vine reserve.

Berry Growth (6)

Berry size increases rapidly immediately after shatter which follows bloom. Berry growth then accelerates again before berry maturation. The accumulation of soluble solids in the berries changes little between the time of berry set and the beginning of ripening. But, at the onset of ripening there is an increase in soluble solids which continues until full maturity. The rate of the soluble solids increase can differ widely because of cultivar or seasonal conditions.

Once the berries have set, they rapidly enlarge. The green stage of berry development consists of a rapid increase in size. The level of sugars remains low and almost constant. Acidity is high and remains so throughout this stage. The berries are hard.

During the ripening stage the green color of white cultivars begins to fade and the white or yellow color comes into view. In red and black cultivars, the development of color in the skin also begins. Berries, which up to this time have remained hard, begin to soften. This sudden change in color and berry softening is termed veraison by the French viticulturists. At this time the berry metabolism changes drastically and the fruit changes from an acid-accumulating organ to a sugar-accumulating organ. During ripening the red or white colors become more intense, the green color fades and the texture begins to soften. Changes in sweetness, acidity and other components progress rapidly.
Fruit Maturation (1,6)

A grape is ripe when it has reached the state best suited for its use. The ripe stage is not absolute, nor does it represent the end product in the changes that are occurring in the berries.

The overripe stage in a grape is reached when the continuing changes subtract from, rather than add to, its quality. There is no further accumulation of sugars, but the acidity continues to decrease. The berries rapidly lose their resistance to handling injuries, attack of decay-causing organisms, and water loss which results in berry shriveling. Also, the tendency of the berries to shatter increases rapidly in some cultivars; pH continues to rise.

Factors Affecting Maturity (1)

The primary factor influencing maturity is the cultivar. There exists cultivars with high and low sugar and acid contents. We also have cultivars with high and low contents of color and tannin.

The second important factor in maturation is climate. Seasonal conditions, particularly temperature, influence the rate of maturation. During a cool season, the accumulation of sugar proceeds slowly. When this occurs, maturation is delayed. In a hot year the ripening changes will proceed more rapidly than normal, and harvest will be early.

Time of ripening may also be influenced by sunlight. Shaulis (5) showed that the type of trellising which increased the amount of leaves exposed to full sunlight generally enhanced fruit maturation and also increased bud fruitfulness and vine yields. The exposed leaves maximize photosynthesis and thus provide optimum photosynthates to the grapevine.

Ripe Fruit Components (1,3,4,6)

We seldom think of water as an important component of the fruit, but quantitatively it is the most important. Ripe grapes contain 70-80% water. The total amount of water in the fruit increases during ripening. Fluctuations in amounts may occur because of temporary conditions in moisture content, such as rainfall or moisture deficiency.

Most of the sugars in the grape berries are manufactured in the leaves. The main sugar translocated from the leaves to the fruit is sucrose; but small amounts of other sugars, especially raffinose, may also be involved in carbohydrate movement. Once sucrose reaches the fruit, it is hydrolyzed into glucose and fructose by the enzyme, invertase.

Another possible source of the sugars in grape berries is from transformation of organic acids. It has been shown that immature and mature grapes are capable of synthesizing carbohydrates from malic acid. However, the percentage of total sugars in grapes formed in this manner is believed to be very small and quite minor. This reinforces Pasteur's work of over 125 years ago; a decrease in acidity is not due to the conversion of acids to sugar.

The principal acids of the grape are tartaric and malic, constituting 90% or more of the total acidity. Grapevines are one of the few plants in which tartaric acid is synthesized. Malic acid is almost universally found in plants.
In the growing berries there is a progressive increase in malic and tartaric
acids and total acidity following fruit set until just before ripening. Both tartaric
acid and malic acid decrease during ripening. Malic acid usually decreases much more
rapidly than tartaric acid because malic acid is more readily respired. There are
also several enzymes in grapes capable of metabolizing malic acid.

The pH level is an important factor in the cleanness of the fermentation, and in
the color, taste, and resistance to spoilage organisms of the finished wine. It has
been suggested that pH be used as a standard for harvesting. Although pH is impor-
tant, this measurement is not recommended since pH is only one quality factor of the
ripe fruit components--and not a primary one.

Another component of the ripe grape berry is color. The green color of the
grape skin fades or is masked during ripening. Generally, the pigment of the grape
is found only in the skin, where it is confined to the outer 3 or 4 layers of cells.
There are a few cultivar exceptions. The intensity of color varies with cultivar,
maturity, seasonal conditions and crop level.

Also, changes in aroma occur with the mature fruit. We all know the character­
istic smell of the 'Concord' grape. This aroma develops by the formation of methyl
anthranilate. Studies have shown that notable increases of methyl anthranilate occur
during the grape ripening process.

Maturity Determination (2)

Because the causes of variability in the composition of fruit are so various,
maturity must be tested in all parts of the vineyard. After testing many sampling
procedures, it is now believed that taking 100 to 200 berries at random from a large
number of vines is the simplest, and most accurate in determining maturity. It is
also the most economical of time and fruit.

For practical purposes, each cultivar is sampled separately. If vineyards of
the same cultivar are separated, each location needs to be sampled. Sampling should
start 2 or 3 weeks before the probable date of harvest. Berry samples should be
collected at random from vines in all parts of the vineyard. End vines and vines
near trees should be avoided. The 100 to 200-­berry sample is then pressed and solu­
able solids and total acidity should be determined. Soluble solids can be measured
by use of a refractometer, and total acidity can be determined by titration.

Criteria for Harvesting (1)

The criteria most often used for determining when to harvest is sugar content.
Although soluble solids is generally emphasized, total acidity should also receive
consideration. Maximum wine quality can occur only if the level of total acidity
is followed during maturity as an additional guide to sugar content for setting the
harvest date.

The fruit has to be sound and have the carrying quality necessary to reach the
winery or processing plant in good condition. Along with soundness, care-in-handling
should be considered. Grapes become more subject to handling injuries as they ap-
proach full maturity; the degree differs among cultivars. But, overripe grapes of
all cultivars are very susceptible to mechanical injuries. The length of the haul
to the winery should be considered. Grapes can be harvested at a more mature stage
for short hauls than for long hauls.
In summary, deciding the stage of maturity of the grapes in order to determine the harvest date should include several aspects; growth and development of the grapevine and berries, factors affecting ripening, such as weather, and the ripe fruit components of a random berry sample taken without bias.

REFERENCES


Malo-lactic fermentation (MLF) is the bacterial conversion of L-malic acid to L-lactic acid and carbon dioxide that often occurs in new wine as a result of growth of certain strains of lactic acid bacteria. It occurs at least sporadically in wines of all viticultural regions (5). The main effect of the fermentation is a decrease in acidity of the wine as a result of the decarboxylation reaction. Since malo-lactic fermentation serves as a natural means of reducing wine acidity, it is usually considered highly desirable and is often encouraged in regions that produce high-acid grapes.

Malo-lactic fermentation is sometimes encouraged even in warm viticultural regions where most wines would not benefit from the deacidification (7). In such cases the bacteriological stability which results is its main value (9). Many oenologists feel that malo-lactic fermentation improves the sensory quality, especially in red wines, by giving the wine more complexity (8). However, MLF may not be desirable in white wines made in some countries or with certain styles (e.g. semi-dry or sweet table wines) where consumers were not familiar with the taste it imparts. The high level of lactic acid is thought to destroy the fresh fruity quality of such wines (7).

The occurrence of malo-lactic fermentation in wine is often unpredictable. The fermentation takes place when a sufficient population of appropriate bacteria develop in the wine. The fermentation may take place immediately following the alcoholic fermentation or sometimes even years later, possibly even following bottling. When malo-lactic fermentation occurs following bottling, it is considered as spoilage, since the bacterial growth produces turbidity and the wine becomes inappropriately effervescent.

Numerous species of bacteria in the genera Lactobacillus, Pediococcus and Leuconostoc have been shown to cause malo-lactic fermentation in wine. Leuconostocs have been reported to be the most prevalent bacterial type associated with high-acid (low pH) wines like those of the eastern U.S. Recent classification of the leuconostocs indicate that all species of that genus isolated from wine would be named Leuconostoc oenos.

Wine is a hostile environment, even for malo-lactic bacteria. Lack of nutrients, low pH, the high concentrations of ethanol and sulfur dioxide present and normally low temperatures associated with storage all contribute to the inhibition of the bacteria to various degrees. Low pH, high concentrations of sulfur dioxide and low storage temperature are the most important factors inhibiting malo-lactic bacteria and delaying the fermentation (7). Wines with pH values below 3.2, initial sulfur dioxide concentrations above 50 ppm, or storage temperature below 10°C are not generally considered susceptible to the fermentation. White table wines are often made under these conditions; therefore, it is not surprising that the incidence of malo-lactic fermentation is much lower among white than red wines.

Winemakers wishing to stimulate the fermentation use minimal levels of sulfur dioxide and maintain cellar temperatures around 18 to 22°C. Rankine, et al. (10) indicated that sulfur dioxide concentration was the most important factor. They related that some Australian winemakers withhold the use of sulfur dioxide until
the bacterial fermentation is complete. Rice (11) demonstrated that if initial sulfur dioxide addition to New York State wines was less than 20 ppm, malo-lactic fermentation occurred at pH values as low as 3.0, even with low cellar temperatures.

Kunkee (5) suggested the possibility that wines with low pH values could be deacidified partially by some other method to increase the pH, thereby improving the susceptibility of the wine to malo-lactic fermentation. Blending acidic wines with wines with higher pH values was suggested as one possibility. The use of ion-exchange or the addition of chemicals to increase the pH was also suggested. It is common practice in some European countries to treat low pH musts with calcium carbonate to raise the pH and stimulate malo-lactic fermentation. In Switzerland, calcium carbonate is often added to raise the pH of the musts to about 3.3 for this purpose. Calcium carbonate treatment may have a secondary effect, since it has been observed that the carbon dioxide released into the wine subsequent to calcium carbonate addition was markedly stimulatory to the growth of malo-lactic bacteria. In the eastern United States, partial amelioration has been used to deacidify wines which subsequently undergo malo-lactic fermentation (11,14). Amelioration has little effect on wine pH but it might possibly dilute the concentration of substances inhibitory to malo-lactic bacteria. Thus, amelioration could possibly stimulate malo-lactic fermentation, since it might lower the concentration of inhibitors.

Other factors associated with vinification also influence malo-lactic fermentation. Leaving wine in contact with the yeast sediment following completion of the alcoholic fermentation (delayed racking) has been shown to increase the incidence of malo-lactic fermentation (4,12). Presumably nutrients stimulatory to the bacteria are released by yeast autolysis. The presence of grape skins during alcoholic fermentation has been shown to be stimulatory to malo-lactic fermentation (1). Most red table wines are made using the fermentation on the skins process to extract the anthocyanin pigments. However, hot-pressing (also called thermovinification) is currently being used more widely to extract color in red wine production. Some studies have found that wines made from hot pressed musts were more resistant to malo-lactic fermentation (1,2). Rice (11) indicated that red wines made by hot-pressing and with limited use of sulfur dioxide routinely completed malo-lactic fermentation. It may be that an interaction between sulfur dioxide and heated musts produces something inhibitory to malo-lactic bacteria.

Since wines often do not undergo natural malo-lactic fermentation, winemakers sometimes induce the fermentation by inoculation (6). Blending the resistant wine with a portion of wine which previously completed a desirable malo-lactic fermentation is one method used. Kunkee (5) indicated the large "inoculations" (15 to 50%) are employed. Castino et al. (3) reported success in inducing malo-lactic fermentation in resistant wines by the addition of wine (about 5%) which was undergoing malo-lactic fermentation. However, they cautioned that the bacterial strain added in this manner must be one that is active at the pH of the wine to be fermented. Vetsch (13) studied the fate of added bacteria (Leuconostoc oenos) transferred from wine to wine. He showed that the death rate was greater at lower pH and a large inoculum was necessary for successful stimulation at low pH. He suggested that large inoculations using a wine with high populations of bacteria (such that the resultant wine would contain more than 10 million viable Leuconostoc oenos cells/ml) would in most cases initiate the fermentation in the blended wine.

Recently, interest has developed in the use of pure culture inoculation of wine with known strains of bacteria to induce malo-lactic fermentation. Most of the recent studies concerning bacterial inoculation have been with strains of Leuconostoc oenos. Kunkee (7) discussed procedures for the preparation of pure cultures of
malo-lactic bacteria and inoculation into wine and recommended the use of pure culture inoculation only if trained personnel and adequate microbiological facilities are available. *Leuconostoc oenos* ML-34 was the organism recommended for inoculation. Beelman et al. (2) demonstrated the potential importance of selecting a malo-lactic bacterial strain adapted to local conditions for wine inoculation by their work with *Leuconostoc oenos* PSU-1.

Rankine (9) suggested that it may be necessary to prepare bacterial cultures in a central laboratory. He also related that liquid cultures are not convenient since they are at maximum viability for only a short time. Freeze-dried cultures would be attractive for this purpose and probably will be used routinely in the future. The use of such cultures is discussed in another paper in this proceedings (see pg. 39).

**LITERATURE CITED**


LITERATURE CITED (cont.)


Our knowledge of virus diseases of grapevines is far from complete in eastern North America. Their relationship to grapevine decline and to winter injury is acknowledged, but uncertain to growers, breeders and pathologists. These relationships are extremely important if we are to accurately evaluate cultivars for adaptability and fruitfulness, and to diagnose grapevine decline problems in the vineyard.

The viruses of greatest concern in this region are termed nepoviruses. They share many common characteristics. The virus particles are spherical or polyhedral in outline. They are vectored by nematodes. The viruses in grapevines are common in weed hosts such as dandelion, plantain, chickweed, Indian hemp and many others that can be found in vineyards. These viruses can be transported in distance in weed seeds and in infected woody portions of the grapevine used for propagating material.

These viruses cause degeneration or grapevine decline and crop loss in infected vines just as does what we often diagnose as winter injury. The disease symptoms, which we can see on leaves, shoots and fruit clusters, vary greatly as they are influenced by the grape cultivar, the virus strain, and by environmental factors. Infected vines consistently yield less than healthy ones, and in some vineyards vine mortality is high. Other symptoms of the nepoviruses usually include delayed budbreak in the spring, followed by erratic shoot growth, mottled or malformed leaves, and reduced yields.

The most important of these virus diseases on grapes is termed the virus-induced grapevine decline disease. It occurs on cultivars of *Vitis vinifera*, and some of the French hybrids grown commercially in eastern North America. The disease is caused by the tomato ringspot virus or the tobacco ringspot virus. These viruses are spread to healthy vines in the vineyard from infected weeds or from infected vines by the dagger nematode, *Xiphinema americanum*. The viruses, the dagger nematode, and numerous infected weed species are widely distributed in eastern North America. Infected grapevines can be found in non-bearing and mature vineyards. In the vineyard, symptoms of tomato and tobacco ringspot virus infected vines are identical and I will discuss them synonymously.

Symptoms of the virus-induced grapevine decline disease usually occur over a three-year period. In the first year of visible symptoms, one or more scattered shoots appear on otherwise normal-appearing vines. The leaves on these shoots are stunted and show chlorosis between the veins and mottling. On some cultivars the leaves may be deformed and show chlorotic rings or sectors. Grape yields may or may not be affected in the first year. Virus-infected canes do not mature properly and are susceptible to cold injury. Buds on the canes often are injured or killed during the winter.

In the second year, new shoots on the diseased, winter-weakened canes show shortened internodes and greatly stunted leaves. Fruit clusters develop poorly, or not at all, and the berries may be uneven in size.

Vine growth in the third year may be limited to suckers arising from near the soil line where shoot buds were somewhat protected from damaging winter temperatures.
by snow cover. When DeChaunac vines are infected by the tomato ringspot virus, the leaves become yellow to golden brown in late summer, and their margins curl downward slightly.

The grapevine degeneration disease of 'Concord', the only other nepovirus that I will discuss, is caused by the peach rosette mosaic virus. The virus and the disease symptoms are very similar to the virus-induced grapevine decline disease caused by the tomato and tobacco ringspot viruses. All have the same nematode vector. Disease symptoms on infected vines include delayed budbreak, weakened growth, deformed leaves, poor fruit set, and eventually decline of the vines. At present, this soil-borne virus disease is limited to Michigan and southwestern Ontario.

These three viruses are disseminated by propagating vines from diseased grape cuttings, by the dagger nematode vector, and through infected weeds and weed seeds. Thus, several types of control are possible. The use of certified, virus-free planting stocks will insure that the viruses are not brought into the vineyard on propagating material. However, if the dagger nematode is present in the vineyard or nursery site and virus-infected weed seeds become established, the planting of disease-free plants may only delay the appearance of infected vines. The soil in the proposed vineyard site should be analyzed for the presence of the nematode vector, and the site fumigated with a nematicide if needed. Control of broadleafed weeds and wild brambles will reduce or prevent populations of alternate hosts of these viruses.

There are genes for resistance of the virus-induced grapevine decline disease in Vitis cultivars, and the use of these may be an important means of control in the future. Resistant genes are known to occur in V. labrusca and V. rupestris. Genes for susceptibility occur in V. vinifera and V. riparia. Thus, among the own-rooted French hybrid cultivars, virus-induced grapevine decline disease occurs in Cascade, DeChaunac and Baco Noir. Aurore and Seyval Blanc appear to show no symptoms. Own-rooted White Riesling and Mission show symptoms, but Concord, Niagara and Delaware do not. The rootstocks, Couderc 3309, 504, and Baco Noir, are susceptible.

When a resistant scion cultivar is grafted onto a susceptible rootstock, and the rootstock becomes infected with one of the grapevine decline viruses we can expect pathological conditions to occur at the graft union. This has occurred in the vineyard on Seyval Blanc/Baco Noir where deeply embedded necrotic tissues mark the graft union. In these cases the scion cultivar initially shows lighter green-colored foliage, which becomes progressively yellowed. Closer examination of the leaves show that the symptoms resemble nutritional deficiencies. These vines may live for a year or two, and then die during the summer and early fall.

To summarize, tomato and tobacco ringspot viruses are the causal agents for a serious disease known as virus-induced grapevine decline. Over a three-year period, the vines become unproductive, very susceptible to winter injury, and many may die. The viruses are soil-borne and often present in a number of weed species that may occur in the vineyard. The viruses are spread by the dagger nematode and by infected propagating material. The disease symptoms mimic winter injury. When resistant scion cultivars are grafted onto susceptible infected rootstocks, the disease symptoms mimic nutritional deficiencies in the early stages of the disorder.

Control of the virus-induced grapevine decline disease includes the use of resistant cultivars, nematode control by means of crop rotations and soil fumigation, the use of indexed, virus-free plants and propagating materials, and control of broadleafed weeds that may be symptomless carriers of the viruses.
DEACIDIFICATION OF WHITE TABLE WINES
WITH SCHIZOSACCHAROMYCES POMBE

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When grapes are grown in a relatively cool region, such as Ohio, an excessive titratable acidity often occurs and contributes to acidic wines. The main contributors to this high acidity are malic acid (a major acid in grapes) and tartaric acid.

Although there are several methods of reducing wine acidity, our studies at OARDC have been directed towards biological deacidification. These studies have involved two biological methods: bacteria and yeast fermentation of malic acid. Most of our studies in the past have been devoted to malo-lactic fermentation, which is a bacterial conversion of malic acid to lactic acid and carbon dioxide in wine. This fermentation often occurs after alcoholic fermentation and its primary effect is reducing wine acidity. Although this secondary fermentation is usually a desirable means of wine deacidification, especially for red wines, the initiation of malo-lactic fermentation is sometimes difficult.

Many factors influence this fermentation in wines, such as temperature, aeration, alcohol content, time of racking, sulfur dioxide content, and pH. In addition, most enologists feel that malo-lactic fermentation is beneficial in red wines, even in cases where wine deacidification is not necessary. They believe that this bacterial fermentation improves the quality by providing the wine with more complexity. This is in contrast to white wines, which usually do not benefit from malo-lactic fermentation due to a high level of lactic acid. Also, white wines made with minimal levels of sulfur dioxide, an important practice to stimulate malo-lactic fermentation, is not desirable, because of the greater chance of oxidation and off-flavors developing in the wines.

Because malo-lactic fermentation is not always desirable for white wines, this report summarizes the findings of a preliminary study concerning another biological deacidification method—the degradation of malic acid through fermentation by Schizosaccharomyces pombe. This yeast has the ability to metabolize malic acid to ethanol and carbon dioxide. Although the wine acidity is reduced, several studies have found that off-flavors and aromas are produced by the yeast during fermentation. This prompted a study to determine the effects of various yeast strains on malic acid degradation and wine quality.

PROCEDURE

Juice from two varieties, Vidal 256 and Delaware, were obtained in 1977 from a commercial winery in northern Ohio. The grapes were immediately destemmed, crushed, and pressed after harvesting. The juice was then treated with 100 ppm of sulfur dioxide in the form of potassium metabisulfite. From the soluble solids readings, the juices were ameliorated with sucrose to bring the soluble solids content of each variety to 21%. After amelioration, the juices were transported to OARDC for further vinification.

The juice of each variety was divided into four lots (15 l each) and transfer-
red to glass carboys. Twelve hours after the sulfur dioxide treatment, one lot of each varietal juice was inoculated with 2% v/v active yeast culture of *Saccharomyces cerevisiae* (control) and the other three lots with strains of *Schizosaccharomyces pombe*. All carboys were equipped with water seals and were placed in 18°C storage for fermentation. When the wines reached dryness, they were racked and treated with sulfur dioxide. After additional rackings (during a 6-month period), the wines were clarified with bentonite and filtered. The wines were then cold stabilized, bottled, and analyzed for composition and quality.

Yeast cultures: The *Saccharomyces cerevisiae* was the "Montrachet" strain and the *Schizosaccharomyces pombe* strains were 105, 106, and 0-77. The Schiz. pombe strains were obtained from Bayerische Landesanstalt fur Weinbau und Gartenbau, Wurzburg, Germany, and the Institute for Wine and Food Technology, Kofu City, Japan. The yeasts were grown in pre-sterilized grape juice for 48 hours prior to juice inoculation.

Chemical analysis: Total acidity, pH, soluble solids, alcohol, volatile acidity, and tartaric acid were determined as described by Amerine and Ough (1). The L-malic acid content of the wines was determined enzymatically with malic dehydrogenase (2).

**RESULTS AND DISCUSSION**

The results of the chemical analyses for the various musts are shown in Table 1. The soluble solids were highest for Vidal 256, 19.8%. All pH values were relatively low, Vidal 256, 3.26, and Delaware, 3.35. Results of the total acidity indicated that the varieties were above the acceptable level for table wines. Vidal 256 was highest at 1.29%.

**TABLE 1.-- Chemical analysis of musts from Vidal 256 and Delaware grapes.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Soluble Solids (%)</th>
<th>pH</th>
<th>Total Acidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vidal 256</td>
<td>19.8</td>
<td>3.26</td>
<td>1.29</td>
</tr>
<tr>
<td>Delaware</td>
<td>19.0</td>
<td>3.35</td>
<td>1.25</td>
</tr>
</tbody>
</table>

a Titratable acidity as g tartaric acid per 100 ml.

The analytical data of the wine composition indicated that the Schiz.-fermented wines were lower in total acidity than the Sac.-fermented wines (Table 2). For example, the Sac.-fermented wines of the variety Vidal 256 contained 0.86% total acidity, while the Schiz.-fermented wines ranged between 0.80% and 0.45%. This lowering of total acidity was due to the malic acid fermentation by Schiz. pombe. This study showed that the decomposition of L-malic acid was influenced by the strain of Schiz. pombe. Vidal 256 wines fermented with 106 and 0-77 Schiz. pombe contained 0.02% malic acid while wines of strain 105 were 0.38%. The level of malic acid degradation was also affected by variety. For example, strain 106 fermented most of the malic acid in Vidal 256 while Delaware wines contained 0.24%. Results also showed that the Schiz. fermentation brought about an increase in pH through the loss of malic acid. Since the pH level of 3.6 was not obtained, the tartrate concentrations
were nearly identical for all the wines. In addition, the volatile acids of the Schiz.-fermented wines were about the same as the Sac. wines. All values were below the U. S. legal limit.

Table 2.--Chemical analysis of wines fermented with strains of Schizosaccharomyces pombe and Saccharomyces cerevisiae.

<table>
<thead>
<tr>
<th>Yeast</th>
<th>pH</th>
<th>Total a acidity</th>
<th>Volatile b acidity</th>
<th>Total tartrates g/100 ml</th>
<th>Total malates g/100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacch.</td>
<td>3.10</td>
<td>0.96</td>
<td>0.023</td>
<td>0.21</td>
<td>0.51</td>
</tr>
<tr>
<td>Schiz. 105</td>
<td>3.21</td>
<td>0.80</td>
<td>0.027</td>
<td>0.21</td>
<td>0.38</td>
</tr>
<tr>
<td>Schiz. 106</td>
<td>3.48</td>
<td>0.45</td>
<td>0.034</td>
<td>0.22</td>
<td>0.02</td>
</tr>
<tr>
<td>Schiz. 0-77</td>
<td>3.41</td>
<td>0.49</td>
<td>0.023</td>
<td>0.21</td>
<td>0.02</td>
</tr>
</tbody>
</table>

a Titratable acidity as g tartaric acid per 100 ml.
b Volatile acidity as g acetic acid per 100 ml.

Studies have shown that Schiz.-fermented wines often possess off-aromas. For this reason, our sensory tests were designed to determine if any aroma differences existed between the Sac.- and Schiz.-fermented wines. Results of triangle tests demonstrated that the Vidal wines produced with strains of Schiz. pombe were significantly different from the Sac.-fermented wines (Table 3). Although the panelists were able to differentiate the wines fermented by 105, the results of the aroma rankings indicated that the 105 wines were not objectionable. The score of the Sac.-fermented wines was 5.0, while the 105 Schiz.-fermented wines were slightly lower, 4.7. The other two Schiz.-fermented wines, 106 and 0-77 were ranked lowest with off-aromas.

For the Delaware wines, the panelists were able to differentiate the wines fermented with 105 and 0-77 strains from the Sac.-fermented wines (Table 3). Although the aroma of the 105 wines was significantly different, the panelists ranked their aroma similar to the aroma produced by Sac. cerevisiae. The wines produced with strain 0-77 were scored lowest, 4.1, and were considered atypical in aroma. The results of the aroma evaluation also indicated that the panelists were unable to differentiate the wines fermented with strain 106. However, the aroma score for the 106 wines was lower than the Sac.-fermented wines, 4.3 and 4.8, respectively.
TABLE 3.-- Aroma evaluation of wines fermented with strains of *Schizosaccharomyces pombe* and *Saccharomyces cerevisiae*.

<table>
<thead>
<tr>
<th>Yeast</th>
<th>Triangle Test</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>No.</td>
<td>Significance level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tasters</td>
<td>correct</td>
<td></td>
</tr>
<tr>
<td>Schiz. 105</td>
<td>Vidal 256</td>
<td>18</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>Schiz. 106</td>
<td></td>
<td>18</td>
<td>17</td>
<td>.1%</td>
</tr>
<tr>
<td>Schiz. 0-77</td>
<td>Delaware</td>
<td>18</td>
<td>14</td>
<td>5%</td>
</tr>
<tr>
<td>Sac. cerevisiae</td>
<td></td>
<td>18</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>11</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>14</td>
<td>5%</td>
</tr>
</tbody>
</table>

a 7-point hedonic scale, 7 being the most acceptable.

In general, results of this preliminary study indicate that strain 105 was the only *Schiz. pombe* to have no adverse influence on wine aroma. However, this strain was only able to metabolize a portion of the malic acid in both varietal wines.

LITERATURE CITED


MARKETING TABLE GRAPES

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Marketing for most of the grape growers in the Finger Lakes Grape Region, which I serve, involves potential opportunities with a relatively few processing outlets. In recent years actual marketing options have become even more limited. For most of my growers, the marketing situation became acute in 1976 when grapes sold for as little as $100 per ton and thousands of tons of grapes went without any market at all.

Many growers approached me that year for last minute information regarding details of fresh grape marketing. Potential market outlets, sources of packaging, etc. In our area like yours, fresh grape marketing has been a minor market constituent, about 2-3% of total sales. I doubt that this will change drastically in the coming years. However, it was with the philosophy that any expansion of fresh grape marketing would be better than no new market development at all, that a group of 20 growers and I began an experimental project in the fall of 1976. Most of my following comments are based on experiences in that project.

This talk won't involve a discussion of varieties. In our project we utilized what we had available, Concord grapes. The Concord variety has several faults when used as a table grape. It handles poorly, cracks easily, stores well for only relatively short periods, etc. Nevertheless, there are still a large number of consumers who recognize and will purchase Concord grapes when given the opportunity. There are numerous promising table grape varieties superior to Concord. If you're interested in this topic, I've brought copies of a recent presentation on this topic, which I'd be glad to share with you.

Fresh grape marketing can be divided into two general categories, local and distant marketing. I define "local marketing" as sales within a 150-200 mile radius of the farm. Many growers get involved with this type of activity. Typical characteristics of this marketing approach are growers acting individually; transportation varying from station wagons to stake body trucks; packing utilizing 2, 4, 8 qt. baskets, 1/2 bushel hoppers, etc.; market outlets include roadside stands, farmers' markets, regional markets, sales to grocery stores and occasionally sales to food chains. In a good situation, a grower can make more profit on his grapes through local marketing than any other marketing channel. Problems, however, can include: numerous competitors with associated price cutting; large market fluctuations in supply and demand; and limited sales opportunity.

For some of my growers, local marketing could not provide sufficient volume to fulfill their desires to market fresh grapes. Growers in this project produce from 25 to 1,000 tons of grapes per year. Their fresh market goals range from 3 to 20 tons of grapes per year on a semi-permanent basis. To accomplish these goals, a distant marketing project was organized. Our experiences thus far are as follows:

(1) Sales - an experienced marketing agent is desirable. It's difficult to have a farmer follow market trends, make contacts, arrange transportation, insure payment, etc. at the same time he's deeply involved with the hectic harvest period. Our grapes were sold in along the east coast from Boston to Washington by the Country Foods Division of Agway, Inc.
(2) Transportation - involved refrigerated tractor trailers. We found a tractor trailer could handle 20 pallets, each with about a half ton of grapes (Fig. 1) or about 10 tons of grapes in total.

(3) Packaging - this was one of the most difficult problems we encountered. Packaging requirements for distant markets became more demanding than local marketing. Packaging for distant markets must be durable and capable of being palletized for shipment. Additional packaging factors included weather resistance, product utilization, appearance, packaging regulations, assembly costs, and actual picking and packing complications. We found only one source of packaging, which could possibly have sufficed, and that we rejected for several reasons. I think anyone getting into this activity would similarly be forced to undergo the cost and complication of designing and ordering custom made packaging. For distant markets eastern grapes usually sell in bulk containers or in master containers holding 6, 8, or 12, 2 qt. containers other than bulk containers. The 12-2 qt. container has been the standard, while more recently 8-2 and 6-2 containers have been introduced. Ours is the 6-2 qt. container, which can also be utilized as a bulk grape container (Fig. 2). To obtain a good packaging price we found it necessary to place an order for about $5,000 (Fig. 3). In addition, we had about $600 of initial printing dye costs.

(4) Quality Control - we found it helpful to have the Dept. of Ag & Markets inspect most of the loads of grapes (Fig. 4). All growers in the project were committed to a quality image. The purpose of the inspection, therefore, was not to penalize growers but rather to provide them with information that would permit improvement in the consistency of pack among the 20 growers. Although many shipments could have been shipped "U.S. #1", there appeared to be no market advantage to this practice. Therefore, for ease of operation, most cartons were standardly stamped with an "unclassified" grade.

(5) Market Structure - types of market outlets we dealt with in this project included jobbers, direct sales to supermarket chains, and sales at terminal markets. Regarding the latter, I've summarized some data on Table 1. They indicate that the sales period in 1978 generally ended by mid-October. This is closely related to the onset of fall freezes. There is about a 4 week marketing period in total. It appears from the data in Table 1 that: (A) grapes generally don't travel beyond neighboring states, (B) prices received range from $.62 to 1.31 per 2 qt. container, and (C) the average price for these markets was just about $1.00/2 qt. container.

<table>
<thead>
<tr>
<th>TABLE 1. Market factors for Concord grape sales in 2 qt. containers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Sources Listed</td>
</tr>
<tr>
<td>Price Range per 2 qt.</td>
</tr>
<tr>
<td>Avg. price</td>
</tr>
</tbody>
</table>

Five eastern markets in 1978.
(6) Economic Factors - If this type of marketing is successful, a grower should anticipate a profit less than he might obtain by direct, local marketing, and more than that typical of the processing market.

(7) Costs - our experience on costs has been as follows: (A) Packaging - approximately 16¢ for each 2 qt. container sold. This is divided about equally between the cost of the 2 qt. container itself (8¢), and the additional cost of the master container, taping materials, labeling materials, etc. (another 8¢). Therefore, we had about 96¢ into each 6-2 qt. container. (B) Labor - this factor is highly variable, depending upon the labor management practices of the grower, the packing system used, etc. Our most efficient grower maintained his labor cost at about $.75 per 6-2 qt. container. However, our costs generally ran about $1.65 per 6-2 qt. container. This labor involves box assembly, picking, packing, and delivery to a central point. (C) Shipping - costs averaged approximately 50¢ per 6-2 qt. container. (D) Marketing Expense - our marketing agent's commission was approximately 10% of the gross price minus shipping costs. This amounted to about $.53 per 6-2 qt. container.

In total, therefore, our costs for the above four items amounted to $3.64 per 6-2 qt. container.

(8) Prices - our prices received for these grapes in 1978 ranged from $5.10 to $7.25 per 6-2 qt. container. The average price was $5.85 per container.

(9) Returns - from the above figures, one can calculate the net return for a 6-2 qt. container was $2.21. There are about 18 lbs. of grapes per container or a return of 12.3¢ per pound of fruit. This translates to about $245 per ton of grapes. To compare this with processing prices, however, one must remember that the harvesting and trucking costs of these table grapes have already been expensed out. Therefore, a similar subtraction must be made for a processing price before comparison. In our Finger Lakes area, the highest price for Concord grapes in 1978 was $220 per ton. Conservatively, estimating a combined harvesting and trucking cost of $35 per ton, we get a comparison price of $185 per ton. The $60 per ton difference between these comparable processing and fresh market prices ($185 per ton for processing vs. $245 per ton for fresh market) is admittedly not large. Nevertheless, our experimental project was able to return to a grower a processing price plus an additional amount for the labor management involved with fresh fruit marketing.

One major learning experience we had this year was that this type of operation is not suited to all growers. It is often difficult for a large grower to organize and give priority to 1/2 to 1 ton of grapes for fresh market on a day when he is also harvesting up to 50 tons of grapes for processing. Therefore, this activity is likely suited to small to medium-sized farm operations.

In conclusion, two factors will likely prevent a sizeable resurgence of fresh grape marketing in our eastern grape industry. The first is the unpredictable and sometimes totally devastating weather during the harvest period. The second factor is the relative difficulty in finding suitable temporary hand labor. Nevertheless, our Finger Lakes experience suggests that there is some opportunity for expansion in the fresh grape market.
Fig. 1. A pallet of 48 master containers is being loaded on a refrigerated truck. Each of these master containers measures 6" x 16" x 20" and contains 6-2 qt. containers of grapes.

Fig. 2. These are the two container types used in the Finger Lakes project. The master (l) is 6" x 16" x 20". It is assembled with tape, and six of them fit perfectly on a standard 40" x 48" pallet. The 2 qt. container (r) has a wire handle and will hold about three pounds of grapes.
Fig. 3. This is a portion of the approximately two truckload shipments of packing ordered for the first order.

Fig. 4. Dept. of Ag & Markets inspectors are weighing grapes to determine the percentage by weight of grapes that did not meet standards for soundness, freedom from rot, etc.
CROP CONTROL IN GRAPES

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Ohio Agricultural Research and Development Center

Definition of Crop Control: "Any cultural practice that can be used to manipulate the grape crop in order to produce a more favorable impact on yield, vigor and/or quality."

Producing the largest and best quality grape crop, year after year is the goal of every grower. Therefore, within the scope of this topic, almost anything you do in your vineyard can be considered as related to crop control. For example, proper fertilization or weed control stands a good chance of developing a larger, healthier and more vigorous vine. This in turn will generally result in greater productivity that year or in future years. The average grower, within the limits of his ability, is already doing many of the cultural practices listed in Table 1. The items I desire to emphasize most are those the average grower is not now using, or not using as well as he could with more timely application and a better understanding of the response that can be obtained.

Within the subject of crop control I would like to deal both with factors that can reduce a potential over-crop situation during any given year as well as increase the crop. The long range goal, however, is for increased production, quality and vigor.

Over-production of French-American hybrids, as has been emphasized many times in our previous Grape-Wine Short Courses, is a threat almost any production year in which frost or winter kill is not a principal factor. In order to be a successful producer year after year, it will not suffice to take whatever mother nature decides to give you. Apple growers, for example, would suffer very adversely if they did not practice crop control (fruit thinning). Over-bearing frequently exists in both apples and peaches and in order to obtain size and keep the trees from breaking, thinning must be done at an appropriate time. Alternate bearing is also the result of improper thinning in apple cultivars.

When favorable climatic conditions prevail, especially following a low production year, excessive crops will be set. The urge to leave too large a crop is sometimes overwhelming, especially if the previous crop failed or was abnormally small. Many times the grower does just not realize the size crop he has until it is too late to do anything about it.

First of all what are the components that make up yield? They are berry number, berry size (which makes up cluster weight), and cluster number. For the sake of understanding the problem, let us make a few mathematical calculations to illustrate some of the factors involved.

Example 1. (Cluster Number)

2 lbs/vine average pruning weight
30 buds retained on vine (20 + 10)
2 clusters/bud = 60 clusters
.20 lb/cluster = 12 lbs of fruit/vine = 3.6 tons/acre
<table>
<thead>
<tr>
<th></th>
<th>Cultural Factors Involved in Crop Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Balanced Pruning</td>
</tr>
<tr>
<td>2</td>
<td>Cluster Thinning</td>
</tr>
<tr>
<td>3</td>
<td>Fertilization</td>
</tr>
<tr>
<td>4</td>
<td>Pest Control (insects, disease and weeds)</td>
</tr>
<tr>
<td>5</td>
<td>Shoot positioning, leaf exposure to sunlight</td>
</tr>
<tr>
<td>6</td>
<td>Trellising and training systems</td>
</tr>
<tr>
<td>7</td>
<td>Irrigation or moisture addition</td>
</tr>
<tr>
<td>8</td>
<td>Rootstocks</td>
</tr>
<tr>
<td>9</td>
<td>Vine spacing to regulate competition</td>
</tr>
<tr>
<td>10</td>
<td>Chemical growth regulators (to increase and decrease crop)</td>
</tr>
<tr>
<td>11</td>
<td>Shoot tipping or thinning</td>
</tr>
</tbody>
</table>
Example 2. (Cluster Number)
2 lbs/vine average pruning weight
30 buds retained on vine (20 + 10)
4 clusters/bud = 120 clusters
.20 lb/cluster = 24 lbs of fruit/vine = 7.2 tons/acre

Example 3. (Cluster Weight)
2 lbs/vine average pruning weight
30 buds retained on vine (20 + 10)
2 clusters/bud = 60 clusters
.40 lb/cluster = 24 lbs of fruit/vine = 7.2 tons/acre

Example 4. (Cluster Weight and Number)
2 lbs/vine average pruning weight
30 buds retained on vine (20 + 10)
4 clusters/bud = 120 clusters
.40 lb/cluster = 48 lbs of fruit/vine = 14.4 tons/acre

Example 5. (Vigor)
4 lbs/vine average pruning weight
50 buds retained on vine (20 + 10)
4 clusters/bud = 200 clusters
.20 lb/cluster = 40 lbs of fruit/vine = 12.0 tons/acre

Thus, even though a grower is conscious of his potential crop he can fall into several traps. To avoid general over-production, the number of clusters on a vine can be determined by simply counting. However, cluster weight (which is made up of berry weight and number of berries) can be greater or less than he anticipates.

If it appears as though undue emphasis is being placed on the over-production aspects, it is not without personal experience that I do it nor without a well documented goal in mind. After all, maximum production with quality is also our primary goal. The key to having good production year after year is vigor; you must have the framework on which to grow the grapes.

As previously mentioned, one of the areas of competence that an apple or peach grower has to develop is proper fruit thinning. In contrast to apple or peach production, a grape grower will lose his major yield advantage if he waits until the fruit is set. He must remove the clusters before flowering.

To examine the various aspects of cluster thinning let's first go through a calculated response situation (Table 2); then an actual case (Table 3). Let us start with vines of similar vigor, pruning severity and cluster number (Table 2, Year 1). In general we will find that, although thinning to one cluster per shoot reduces the total number of fruiting clusters, their size is significantly increased (.20 to .25 lb.). As vines are thinned in subsequent years, vigor (pruning weight) increases allowing more buds to be retained, producing more shoots and clusters and thus increasing yield (Years 2 and 3). The theory is that by thinning to one cluster per shoot this can all be done without sacrificing vigor, yield or quality. In fact all 3 should be enhanced.

In Table 3, we have an actual case whereby cluster thinning was carried out for three consecutive years on Villard noir. The result was to significantly increase vigor, cluster weight, cluster number and thus, yield.
TABLE 2.--Hypothetical Response of a Grapevine Due to Cluster Thinning to 1 Cluster/shoot.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. Thin</th>
<th>Thin</th>
<th>Year</th>
<th>No. Thin</th>
<th>Thin</th>
<th>Year</th>
<th>No. Thin</th>
<th>Thin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>2.0</td>
<td>2.5</td>
<td>Year 2</td>
<td>3.0</td>
<td>3.5</td>
<td>Year 3</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Pruning Wt.-lbs</td>
<td>1.0</td>
<td>1.0</td>
<td>Clusters/node</td>
<td>4.0</td>
<td>4.0</td>
<td>Clusters/node</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Nodes retained</td>
<td>20</td>
<td>20</td>
<td>Total Cluster No.</td>
<td>80</td>
<td>80</td>
<td>Total Cluster No.</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Shoots/vine</td>
<td>40</td>
<td>40</td>
<td>Fruit clusters</td>
<td>80</td>
<td>80</td>
<td>Fruit clusters</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Fruit clusters</td>
<td>.20</td>
<td>.25</td>
<td>Weight/cluster</td>
<td>.30</td>
<td>.35</td>
<td>Weight/cluster</td>
<td>.20</td>
<td>.25</td>
</tr>
<tr>
<td>Yield/vine - lbs.</td>
<td>16.0</td>
<td>10.0</td>
<td>Yield/vine - lbs.</td>
<td>18.0</td>
<td>24.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3.--Actual Response of Villard Noir (S.V. 18-315) Grapevines to Cluster Thinning to 1 Cluster/shoot

<table>
<thead>
<tr>
<th>Year</th>
<th>No thin</th>
<th>Thin</th>
<th>Year</th>
<th>No thin</th>
<th>Thin</th>
<th>Year</th>
<th>No thin</th>
<th>Thin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>77</td>
<td>.12</td>
<td>Year 2</td>
<td>107</td>
<td>3.7</td>
<td>Year 3</td>
<td>84</td>
<td>63</td>
</tr>
<tr>
<td>Pruning Wt.-lbs</td>
<td>.14</td>
<td>.14</td>
<td>Clusters/node</td>
<td>1.21</td>
<td>1.41</td>
<td>Clusters/node</td>
<td>1.21</td>
<td>1.41</td>
</tr>
<tr>
<td>Nodes retained</td>
<td>44</td>
<td>54</td>
<td>Total Cluster No.</td>
<td>24</td>
<td>23</td>
<td>Total Cluster No.</td>
<td>44</td>
<td>54</td>
</tr>
<tr>
<td>Shoots/vine</td>
<td>.24</td>
<td>.29</td>
<td>Fruit clusters</td>
<td>2.3</td>
<td>3.6</td>
<td>Fruit clusters</td>
<td>2.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Fruit clusters</td>
<td>11.9</td>
<td>24.0</td>
<td>Weight/cluster</td>
<td>.25</td>
<td>.29</td>
<td>Weight/cluster</td>
<td>.25</td>
<td>.29</td>
</tr>
<tr>
<td>Yield/vine - lbs.</td>
<td>6.3</td>
<td>26.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thus, the key to good production and quality as previously stated involves the retention of vigor. Without adequate vigor the vine cannot continue to support an economic fruit load, maintain winter hardiness, or have good berry and cluster size. Producing better vigor, cluster size, and fruitfulness by cluster thinning appears to be one of the best methods presently available for the culture of French-American hybrids.

WEED CONTROL

To illustrate the effects and importance of weed competition on vine productivity I would like to refer to the work of Byrne and Howell, Michigan State University (1). Table 4.

TABLE 4.--Effect of Weed Control on Yield and Quality of Baco Noir Grapevines in 1975.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield Clusters/ Lbs/ Clusters/ Pruning Wts/1bs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs/vine vine cluster node 1975 1976</td>
</tr>
<tr>
<td>Weed Cover</td>
<td>14.96 77 .12 3.2 1.21 1.01</td>
</tr>
<tr>
<td>Weed Control</td>
<td>19.96 107 .14 3.7 1.41 3.17</td>
</tr>
</tbody>
</table>

It can be seen that productivity and vigor decreases significantly in the face of competition from weeds. The same applies to other forms of competition: insects, diseases, insufficient moisture, nutrient deficiencies, etc.

Productivity Following Stress

Not only does productivity suffer when the vine is stressed during a normal year but when winter damage and spring frosts occur then the fruitfulness of secondary and tertiary buds can mean the difference between an acceptable crop and near crop failure. For example, after three years of cluster thinning treatment at the Southern Branch, Ripley, a spring frost occurred that essentially killed all the primary buds. Table 5 shows the collective effect of cluster thinning on 8 French-American hybrid cultivars.

TABLE 5.--Effects of Cluster Thinning for 3 Years (73-75) On Yield and Quality of 8 French-American Hybrids Following a Severe Frost in May 1976.

<table>
<thead>
<tr>
<th></th>
<th>1 Cluster/Shoot</th>
<th>2 Cluster/Shoot</th>
<th>No Thinning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prune. Wt.-lbs</td>
<td>1.93</td>
<td>1.25</td>
<td>.83</td>
</tr>
<tr>
<td>Nodes Retained</td>
<td>28</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Yield/vine-lbs</td>
<td>16.3</td>
<td>11.8</td>
<td>10.3</td>
</tr>
<tr>
<td>Cluster No.</td>
<td>63</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>Cluster Wt.-lbs</td>
<td>.26</td>
<td>.27</td>
<td>.27</td>
</tr>
<tr>
<td>% Soluble Solids</td>
<td>18.6</td>
<td>18.5</td>
<td>18.6</td>
</tr>
<tr>
<td>% Total Acid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clusters/Node</td>
<td>2.36</td>
<td>1.78</td>
<td>1.68</td>
</tr>
<tr>
<td>Yield/Node - lbs</td>
<td>.58</td>
<td>.49</td>
<td>.43</td>
</tr>
</tbody>
</table>

PRUNING AND TRAINING SYSTEMS IN RELATION TO VINE PRODUCTIVITY

Pruning and training systems have much to do with the long range productivity of a grape vine. For example, a system (not necessarily just a trellis) can expose the vines to greater sunlight, allow more room for growth, regulate pruning severity, and, therefore, result in less vine competition.

In an 8-year experiment (1968-75) on Concord grapevines at OARDRC, Wooster, yield differences between Umbrella Kniffin and Single Curtain systems were not significant (2). Pruning weight differences usually were different; Umbrella Kniffin having higher brush weight than Single Curtain. Comparisons from 1975-78 with Umbrella Kniffin, Single Curtain (hand pruned) and Single Curtain (machine + hand pruned) and Geneva Double Curtain (hand pruned) have produced some significant results (Table 6). For example, pruning weights for Umbrella Kniffin still remained the highest of all systems. Single Curtain (hand pruned) and GDC (hand pruned) had about the same level of vigor (pruning wt) while the Single Curtain (machine + hand pruned) were less vigorous in 3 out of 4 years as compared to the Single Curtain (hand pruned) vines. Yield, cluster number, soluble solids, clusters per node and fruitfulness (yield/node) have been higher under GDC every year with one exception: in 1977 a severe spring frost reduced yields, cluster number, weight/cluster and fruitfulness more than the other systems. Two out of 4 years the GDC system produced 41.0 lbs of fruit/vine. On Umbrella Kniffin trained vines a reduction in yield and fruitfulness (yield/node) occurred in 3 out of the 4 years. This is a contrast to the previous 8-year period in which there were yield differences favor-
ing Single Curtain system, only 1 year in 8.

We have dealt with balanced pruning concepts throughout the discussion thus far, but little has been said about selection of fruiting wood. If good sound canes are selected at pruning time that have been well exposed to sunlight and not overfruited, there will be more productive than canes grown in the shade. Training and trellising systems that expose most of the shoots on the vine to good sunlight will not only be more productive during the current season as we have already shown, but will produce more fruitful, winter hardy canes for the following year. Thus, a well trained vine increases the probability that wood selected by the pruner will be more productive.

TABLE 6.--Comparison of Four Vineyard Training Systems on Concord Grapes, Wooster, Ohio (4 Year Average, 1975-78)

<table>
<thead>
<tr>
<th></th>
<th>Umbrella Kniffin</th>
<th>Single Curtain</th>
<th>GOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prune wt-lbs</td>
<td>3.6</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Nodes Retained</td>
<td>52</td>
<td>44</td>
<td>42</td>
</tr>
<tr>
<td>Yield/Vine-lbs</td>
<td>17.9</td>
<td>22.2</td>
<td>20.1</td>
</tr>
<tr>
<td>Cluster No.</td>
<td>93</td>
<td>125</td>
<td>114</td>
</tr>
<tr>
<td>Cluster Wt.-lbs</td>
<td>.20</td>
<td>.19</td>
<td>.18</td>
</tr>
<tr>
<td>% Soluble Solids</td>
<td>14.9</td>
<td>15.1</td>
<td>14.8</td>
</tr>
<tr>
<td>% Total Acid</td>
<td>.56</td>
<td>.56</td>
<td>.56</td>
</tr>
<tr>
<td>Clusters/Node</td>
<td>1.79</td>
<td>2.85</td>
<td>2.73</td>
</tr>
<tr>
<td>Yield/Node- lbs</td>
<td>.34</td>
<td>.50</td>
<td>.48</td>
</tr>
</tbody>
</table>

UNDER-PRODUCTION IN RELATION TO VINE VIGOR

There are many instances in grape vineyards where the capability of a vine to produce is less than it should be. In other words, the vine has sufficient vigor, but will not set an adequate crop of fruit. This can be due to the inherent genetics of the variety or to some relationship with the cultural practices, soil, etc. Balanced pruning is aimed at reducing this problem along with many of the cultural practices previously mentioned such as avoiding over-fertilization, shoot positioning and pest control.

There are also times when modern technology can give mother nature a boost. With cultivars such as Himrod, Concord and Catawba the use of growth regulators have been very useful tools. Alar (Succinic acid-2,2-dimethylhydrazide) as a bloom time spray has been shown to increase yields 1.5 tons per acre and more. However, yield increases of around 1 ton per acre are more typical. In the higher yield increases, soluble solids content is frequently decreased as well as berry size. It is believed that this relationship is more related to the physical relationships of yield increase rather than Alar by itself. However, within reason, Alar at 500-1000 ppm can be used to increase yield and in the process decrease vigor. In fact, it is on the overly vigorous vine that the greatest advantage lies. Increases in yield are accomplished by setting just a few more berries per cluster. Shaulis (3) states that an average increase of 1 berry per cluster will increase yield about 400 lbs. per acre.

Some seedless cultivars, Himrod being the most notable in this area, respond to bloom time Alar sprays by setting more berries and, in contrast to Concord, in-
creasing fruit size (Fig. 1). The application of Gibberellic Acid at shatter has been shown to be beneficial in further increasing berry, and thus, cluster size. Commercial applications of both these materials is approved for use and should be used under appropriate conditions.

CHEMICAL THINNING

Crop thinning chemicals such as Ethephon have not yet proven to be reliable enough for commercial use. Three years of data in Ohio indicate that, depending on temperature and concentration, over-thinning or under-thinning may frequently result. Hopefully, some time in the near future a chemical will be available, as it is on apples, whereby, fruit thinning can be as simple as spraying your vines for insects or disease.

LITERATURE CITED


Malo-lactic fermentation (MLF) is the conversion of malic acid to lactic acid and carbon dioxide caused by the metabolic activity of certain strains of bacteria. The bacteria most often responsible for this fermentation in wine are strains of *Leuconostoc oenos* (4). The main effects of this fermentation are a natural reduction in the acidity, an increase in the biological stability and an apparent improvement in the sensory quality.

Malo-lactic bacteria are most likely always naturally associated with new wines but usually in relatively low populations. If conditions are favorable, the bacteria may grow in the new wine and eventually cause a "natural" malo-lactic fermentation. However, this natural occurrence can be considerably delayed—sometimes indefinitely. In some cases, MLF occurs following bottling. When this occurs, it is considered as spoilage, since unwanted turbidity and effervescence results from the bacterial growth (3).

In order to stimulate malo-lactic fermentation in wines rapidly and predictably, the use of pure culture inoculations of wines with selected strains of bacteria has become a new trend in winemaking (4). Pure culture inoculation has an additional advantage over reliance on the natural microflora in that it provides reasonable assurance that proven beneficial strains dominate the fermentation. Thus, possible "off" odors and flavors associated with some "wild" strains can be prevented.

Methods used to inoculate wines with pure cultures of malo-lactic bacteria and the factors affecting their growth in wine were discussed in a paper presented earlier (pg. 17-20 this Proceedings). The major problems associated with inducing malo-lactic fermentation in commercial wines is that most wineries do not have the personnel and facilities necessary to maintain and prepare the necessary cultures. We have attempted to develop freeze-dried cultures of malo-lactic bacteria that could overcome some of the problems associated with the preparation of cultures for inoculating wines. Fortunately, this work was completed (2) and such cultures are now available commercially. The purpose of this paper will be to discuss the utilization of these cultures to induce MLF in the vinification of red table wines.

The bacteria used for the freeze-dried cultures in our studies were grown by inoculating a pure culture of *Leuconostoc oenos* PSU-1 (1) into a fruit juice-based medium and allowing the culture to multiply to stationary phase of growth. The cells were harvested by centrifugation, suspended in a buffer solution containing cryo-protectants, freeze dried in serum bottles and stored under vacuum in these bottles. Most of the cultures used in our studies were 10X-concentrates meaning that the original culture in the fruit juice-based medium was concentrated 10-fold before freeze-drying. Usually 25 ml of these concentrates were freeze dried in 50 ml serum bottles. Upon rehydration with 25 ml of 0.1% peptone water prior to use,
each ml of rehydrated culture contained $1-5 \times 10^{10}$ cfu/ml. This means that each ml of rehydrated culture contained 10 to 50 billion colony forming units (abbreviated cfu's). The term cfu is employed because leuconostocs often grown in pairs, chains or clumps of cells. Upon culturing in a solid medium in order to make viable counts of bacterial populations, these units appear as only one colony and would ordinarily be counted as only one cell. Therefore, these cultures may actually contain 2 to 3 times as many cells as reported in cfu's. In the future, commercial cultures will probably be concentrated to at least $50 \times$ instead of $10 \times$. Thus, a $50 \times$ freeze-dried concentrate may contain up to $1 - 2 \times 10^{11}$ cfu/ml ($100 - 200$ billion cfu/ml).

In our research, we have employed two basic methods of using the freeze-dried cultures to induce malo-lactic fermentation in wine. The first method is direct inoculation. This is the most simple and convenient but also the most expensive method. It involves only the rehydration of the freeze-dried culture with a suitable solution followed by direct addition of it to the must or wine. The second method involves sub-culturing (expanding the volume) of the freeze-dried culture prior to the addition of it to must or wine. This method is less convenient, a little more difficult to accomplish but also less expensive, since less freeze-dried dried culture would be needed to inoculate the same amount of wine.

In our work with direct inoculation, MLF was stimulated in both fermenting musts and "finished" (year old) wines faster than uninoculated control lots which in some cases completely resisted MLF. The time required for the occurrence of a complete MLF was usually directly related to the number of bacteria present in the inoculum. In general, inoculations which resulted in bacterial populations of about $10,000,000$ cfu/ml ($10^7$ cfu/ml) were found to be adequate to produce MLF's within 2 to 6 weeks depending upon the must or wine employed.

Experiments were also conducted in our laboratory to determine a practical method for expanding the volumes of rehydrated freeze-dried cultures for subsequent inoculation into wines. Methods were sought that would be practical under winery conditions. The best results were obtained by the use of hot-pressed grape juice diluted 1:1 with water and inoculated with a 3% (v/v) active culture of the Montrachet strain of wine yeast and a sufficient volume of rehydrated freeze-dried culture of Leuconostoc oenos PSU-1 to obtain a population of about $1 \times 10^7$ cfu/ml. Yeast and bacterial growth occurred simultaneously and within a 2 to 4 days at 22°C complete malo-lactic conversion and maximum bacterial numbers (about 5-10 $\times 10^7$ cfu/ml) were observed. Observations of the complete disappearance of malic acid on paper chromatograms of the acids in these cultures was then used to determine the optimum time to use them to inoculate wines. Using this method, the addition of 5% (v/v) inoculations with these cultures were used successfully to induce malo-lactic fermentation in other wines. It was also determined that the best time to add these expanded cultures was at the beginning of the wine-making process. In fact, our results indicated that the addition of this culture might be sufficient to serve as a yeast starter culture as well as a starter for malo-lactic fermentation. This concept is now under study in our laboratory.

LITERATURE CITED

LITERATURE CITED (cont.)


Please allow me to define briefly the word "filtration". Its goal is the separation of a mixture into two or more fractions thereof, depending on the methods employed. Obviously, the emphasis is on the word "separation," therefore, filtration is a part of a rather complex separation process, in this context, whereby solids have to be removed from wine.

Today's winemaker basically has three approaches to deal with separation:

1. The settling of solids by gravity
2. By means of a decanter or centrifuge. In this case, the gravity generated by the centrifugal forces causes solids to separate from the liquid.
3. Filtration

The settling process is still widely used in small and medium sized wineries, primarily because of the cost of the equipment used today.

It is most commonly the juice that is settled for a period of 24 to 36 hours to remove solids and impurities which could influence both the taste and the development of the wine during and after fermentation.

Then again, the natural clearing process after fermentation is nothing but settlement by gravity.

It is a well established fact that wines, which are freed from solids right after fermentation, usually turn out to be cleaner and fruitier than wines which are allowed to remain on the settlings, or worse yet, where solids stay in suspension.

It is an equally well-known fact that most grape varieties vary considerably from each other when it comes to separating the solids from the liquid. Mother Nature, by providing various growing conditions, can aggravate this situation further. It is oftentimes difficult to clear wine if the weather was wet prior to or during the harvest. The partially rotten fruit yields juice with extremely high solids content, which is very difficult to clear up.

Incidentally, the natural settling process is usually a good indicator as to how the wine will behave during its development. The harder it is to achieve natural settlement, the more difficult it will be to separate the solids from the liquid by the use of either centrifuges or filters.

Centrifuges have been a vital part of winemaking for several decades in Europe, and since the early 70's they have become popular in the United States. A centrifuge works successfully if a gravity differential exists between solids and liquid, and the solids are heavier than the liquid. Centrifuges are ideal for removing large amounts of solids, as they exist in grape juice or young wines. As a general rule, it can be said that a filter should be used if high clarity is desired, however, filters cannot function economically when the percentage of solids to be removed is high.
Filtration methods employed by wineries can vary considerably. The method chosen usually is based on the experience and the philosophy of the individual winemaker, the type of wine he wants to produce and the size of the winery.

We can differentiate among these basic filtering processes: lees filtration, coarse and polish filtration of wine and sterile filtration of wine.

**Lees Filtration:**

The goal of lees filtration is to salvage the still existing liquid from heavy sediments, such as yeast or fining materials, which otherwise would be lost when the lees are disposed of. The recovered wine is not always of desirable quality, but these filtration methods usually pay for themselves in a rather short period of time, since the wine is clean and can be blended into the lesser quality brands.

Two basic systems are in use today, the traditional plate and frame lees filter and the vacuum drum filter. The decision as to which filter to use is primarily one of economics, and greatly depends on the size of the winery, and the wine-making techniques involved.

**Coarse and Polish Filtration:**

This part traditionally has been the most worrisome for the winemaker. Over the years, the wines are kept in casks for a number of years. This rendered a chemically and biologically stable wine, which through natural sedimentation finally resulted in a clarity acceptable to the consumer. It was recognized that these wines, with the exception of some reds, lost their original fruitiness and freshness.

In today's business world, the cash flow is a major factor. Therefore, methods were developed which made it possible to bottle a product which was not only stable, but also appealed to the consumer because of its clarity, without spending years waiting for the natural process.

At this time, I would like to point out that the various fining procedures and filtration are often closely related. The addition of fining materials can serve two purposes: one, to guarantee future stability of the product and two, to help precipitate existing suspensions of colloidal matter, which appear as a haze or cloudiness. On the other hand, these fining agents can themselves contribute to a haze if not used properly, or if not allowed to settle for a certain period of time. As a rule of thumb it can be stated that properly fined wine should facilitate all filtration steps that follow.

The proper procedures usually are: fermentation, malo-lactic fermentation, if desired, and then first racking. It is normally at this point that the wine undergoes stability tests to determine whether or not fining agents should be used. In any case, it should be at the time of the second racking that the first filtration takes place. This filtration will be a so-called coarse one, since the young wine still contains rather large amounts of solids of various sizes. This coarse filtration can be done by means of a filter aid or a very coarse, manufactured filter pad. Again, the size of the winery, the quantity to be filtered and certain wine-making techniques--such as using a centrifuge--will determine which method will be used. A filter aid, usually diatomaceous earth, is used when the quantity to be filtered is large and the solids content high.
The diatomaceous earth filter is either a self-contained leaf type filter whose sole purpose is filtration with a filter aid, or a regular sheet filter which can be converted into a DE filter by adding wide sludge frames.

In either case, the principle is the same. A precoat of pure diatomaceous earth or a mixture of DE and a fibrous material, such as cellulose, for example, is built up on the filter elements. After that, the actual filtration of the product begins by injecting a given amount of DE into the wine stream. The DE particles together with the solids build a cake on the support sheet. The plant solids in young wine, such as yeast, if allowed to build a film on the support sheet, would clog all pores of the filter media and the liquid flow would soon cease. The rather coarse and odd-shaped DE particles maintain the porosity of the cake by preventing the build-up of film, thus increasing the total run many times over regular sheet filtration.

Here, I would like to elaborate on the principles of absolute filtration versus deep-bed filtration. Both factors are instrumental when a polished or a sterile product is desired.

The so-called absolute filtration is a term widely used by filter membrane manufacturers. What it basically means is that all particles over a certain size are retained. It is claimed that the pore sizes in a membrane can be controlled so closely that nothing larger than the specific pore size can pass the membrane. This, of course, constitutes a pure screening effect. All particles larger than the pore size will be trapped on the surface of the filter media. These particles will clog the pores immediately, especially if they are compressible, because they will build a film over the entire surface of the media, which then closes all pores.

The deep-bed filter media almost always work on two principles: screening and adsorption. They come as felt-like mats which have a funnel-like, decreasing pore size from inlet to outlet side. The smallest pores generally determine the effectiveness of the media. Here, most particles are not trapped on the surface; rather they penetrate into the matrix and gradually fill the little channels until the sheet is plugged. This, of course, resembles the screening effect of the membrane type media, but the dirt load in this type of media exceeds that of a membrane greatly, before it is finally clogged.

Adsorption is a phenomenon which is attributed to the different electrical loading of the filter media and the solids to be removed. The differences in the loading causes the particles to cling to the millions of fibers within the matrix. Here the advantage is that much smaller particles than the actual pore size can be removed from the liquid. However, a breakthrough occurs as soon as an adsorptive equilibrium has been reached. I am sure you have all experienced this at one time or another. The wine will be perfectly clear at the beginning of filtration. Then suddenly, for no apparent reason, the wine is as cloudy coming out of the filter as it was going into it, without any build-up of differential pressure. The solution here would be either to wait a few more weeks for the colloids to coagulate into larger particles, or to use a sheet with a finer pore size.

You can see that you get higher throughput with the coarse filter pads, and that the throughput drops consistently as you approach the finest grades of sterilizing pads.

This demonstrates that total and hourly output at a given pressure will drop, as the pore size of the sheet decreases. It also demonstrates how the viscosity of
the liquid affects the throughput when compared to water.

The success of filtration depends on the media chosen. The critical criteria are the nature of the solids to be removed, such as organic matter like yeast or bacteria, or inorganic matter, like a protein haze, for example. Important are the size of the particles encountered and the amount that has to be dealt with. It might be necessary to fractionate the whole process by using a coarse pad first, and then following up with a finer one. This can be achieved by either two separate filtrations or a two-step filtration in one filter by use of a change-over plate.

Very important are the hourly output and the pressures involved. It is in these areas where most of the mistakes occur. High filtration speeds and high differential pressures can result in very low throughput due to the compression of the filter media and finally its destruction.

Here are some guidelines you can keep in mind. Even though sheet filters come in all sizes, one can safely say that their filtration characteristics are more or less the same. It is the filter media that does the job! The filter itself lends support to the filter media and takes care of the proper distribution of the liquid.

As a general rule it can be said that the following velocities should not be exceeded:

- Rough and polish filtration approximately 20 gallons per square foot per hour.
- Diatomaceous earth filtration approximately 20 gallons per square foot per hour.
- Sterile filtration approximately 10 gallons per square foot per hour.

The differential pressures can be up to 30 or 40 psi when filtering rough or polish; however, this is dependent on whether the product is still clear when it leaves the filter. When filtering with DE the pressure can go all the way up to 90 psi, or even more. The DE cake is not affected that much by the pressure, nor is the supporting media. But due to the compression, a certain decrease in flow can be experienced. The highest differential pressure allowed in deep bed filters when filtering sterile is 25 psi. It can be considered safe to achieve a sterile product if the flow of 10 gallons per square foot per hour and the 25 psi differential are not exceeded.

This is where the deep bed filters differ considerably from a membrane filter. The deep bed filter can be damaged and its integrity jeopardized when filtration speed and pressure differential are not contained within the recommended limits. Furthermore, the matrix can be influenced by a CO₂ release in the liquid, when counterpressure is insufficient to keep the CO₂ in solution. This gets worse the higher the build-up of the differential pressure gets.

It must be remembered, however, that the hourly capacity is governed by the smaller filter section. The flow rates cited before should not be exceeded. For example: the pre-filter section has 30 square feet for polish filtration, the final section has 15 square feet for sterile filtration. The hourly flow rate according to the smaller section is 150 gallons for the whole unit, even though the pre-filter section could handle 300 gallons per hour.

Now, I would like to come to the final step in filtration, namely sterilization
I mentioned before that satisfactory results can be achieved with a deep bed filter, if all directions are followed carefully. This method, by the way, is still being used in over 90% of the cold sterile bottling operations in Europe.

It has become customary, however, to install a membrane filter as a final filter prior to bottling. These filters have the advantage that such things as high differentials, high flow rates and/or pressures shock usually won't damage them. In other words, they are more fool proof as far as the removal of microorganisms is concerned. Their disadvantage is the fact that they clog up very rapidly, if pre-filtration was not fine enough.

It should be stressed that the purpose of such a final filter, be it membrane or deep bed, is the removal of microorganisms potentially harmful to wine. These filters are not intended to supplant or replace a pre-filter, they are not supposed to have the job of cleaning the wine. Therefore, it is essential to pre-filter wine with a highly polishing filter media. It is common today to use even a sterilizing deep bed filter prior to going through a membrane. It is simply a matter of economics when it comes to the final filtration. Membranes are rather expensive, and the sterile bottling is jeopardized when such a filter has to be repacked because it plugged due to insufficient pre-filtration.

In summarizing, I would like to say that the filtration of wine is indeed a complex task. Even the experienced winemaker combines a mixture of knowledge gathered over the years, and trial and error.

Most filter manufacturers have a vast amount of knowledge at their disposal to help with the use of their products. When in doubt, give them a call!
The principle type of grape grown in North Carolina is a native American species *Vitis rotundifolia*, more commonly called the muscadine grape. Interestingly, the first wines made in America (circa 1562-64) were probably made from muscadine grapes (1) and legend has it that Scuppernong, the most famous muscadine cultivar, was found growing in the wild in northeastern North Carolina (4).

In cooperation with USDA, North Carolina State University has an ongoing grape breeding program which dates back to 1907. Prior to prohibition, North Carolina had many large muscadine vineyards and a significant wine industry (1,4). However, the advent of prohibition ended commercial wine-growing in North Carolina. In the early 1960's interest was renewed in the commercial production of muscadine grapes for wine and many new plantings were established.

At the present time, North Carolina has over 2,200 acres of muscadine grapes in production which represents nearly 60% of the estimated total muscadine acreage in southeastern United States. Other southeastern states having sizeable plantings of muscادات are South Carolina, Georgia, Florida, Alabama and Arkansas. Most of the commercial vineyards in North Carolina are located in the southeastern section of the state although some plantings have been established as far west as the foothills of the Blue Ridge mountains. Muscadine vines are not very cold hardy and do not tolerate temperatures below 10°F very well.

Muscadine grapes grow in short clusters (usually of four to fifteen berries) rather than in bunches. Depending on the cultivar, individual berries are round or oval and range in size from three to over ten grams. The newer cultivars such as Carlos, Magnolia and Noble can yield about ten tons to the acre when recommended cultural practices are followed.

Enological research activities were initiated at North Carolina State University in 1968. Initially, the wine research program was concerned primarily with the muscadine grapes. However, in the past several years research has also begun on the wine quality of bunch grapes (hybrids and vinifera) grown in North Carolina.

The objectives of the wine research program at North Carolina State University are:

a. To evaluate the potential of selected clones of muscadine and bunch grapes for the production of wines. This research is done in cooperation with our grape breeder and viticulturist, Dr. W.B. Nesbitt of the Department of Horticultural Science.

b. To characterize the chemical composition of fruits of selected cultivars of muscadine and bunch grapes grown in North Carolina.

c. To determine the effects of selected processing factors on quality of wines made from muscadine and bunch grape cultivars.

In the remainder of this presentation, I'll give several specific examples of our research activities and some of the results obtained.
One of the first projects was to screen over a hundred muscadine clones from the breeding program for their potential wine quality. A complete workup on must and wine composition as well as sensory evaluation of wine samples was made. Results from this screening procedure provided us with much useful information. For example, it was found that less than 40% of the dark-skinned clones made red wines having acceptable color. This led to work confirming that the pigments present in muscadine grapes were nonacylated 3, 5 diglucosides of malvidin, peonidin, petunidin, cyanidin and delphinidin (2). Additional work involved development of a rapid test method for evaluation of potential color quality of dark-skinned muscadine clones for wine production (13). Larger amounts of malvidin 3, 5 diglucoside were associated with good red wine color while smaller or trace amounts were associated with poor color. A more detailed study confirmed the importance of malvidin 3, 5 diglucoside and also indicated that petunidin 3, 5 diglucoside contributed significantly to good red color in muscadine wines (3). Information of this type is very useful in selecting parents in the grape breeding program.

In evaluating a cultivar or clone from the breeding program for wine quality, wine is made under controlled conditions in the Plant Products Laboratory (Food Science Department). For example, the following regimen is followed in making a white wine: Grapes are crushed → 100 ppm SO2 added → grapes pressed → sugar added to 20°Brix → amelioration (optional) → addition of a wine yeast culture → fermentation to dryness at ca. 60°F → rack → store and age → cold stabilization → filter → bottle (cork finish) → bottle age → chemical testing and sensory evaluation. Red wines are made in a similar way except the initial fermentation takes place "on-the-skins" and the temperature of fermentation is about 72°F. Musts are checked for °Brix, pH and total titratable acidity. Finished wines are made for reducing sugar, pH, titratable acidity, % ethanol, extract value, total phenols, total volatile acidity and color specification by use of a Hunter Color Difference Meter. Sensory quality is evaluated by a panel of eight to ten members and the wines are scored on a 20 point system based on evaluation of sample attributes (9). All wine samples are identified by code only.

The cooperative research with personnel of the Department of Horticultural Science has resulted in the release of five new muscadine cultivars which are suitable for wine use. The light-skinned cultivars Carlos, Dixie and Sterling are used for white wine production and the two dark-skinned cultivars, Noble and Regale, for red wine production. Carlos, which was introduced in 1970, is the most widely planted grape cultivar in North Carolina. In addition to its use as a wine grape, Carlos is widely used as a fresh market grape. It picks with a dry stem scar, stores well for a muscadine and has good fresh fruit characteristics.

Dr. Nesbitt has also developed several bunch grape-muscadine hybrids which look promising. We hope to have enough fruit to make wine from them this fall. They are averaging sugar concentrations in the 22% range.

We are interested in the chemical composition of our North Carolina grown grapes. In one study, the concentrations of individual sugars and organic acids in the "hard pressed" juice of twelve commercially important cultivars of muscadine grapes were determined in each of three years (8). Considerable variation in the chemical composition of individual cultivars as well as significant seasonal differences were observed. We have followed changes in the contents of the principle organic acids and sugars of the muscadine cultivar Scuppernong throughout the ripening season (12). Although some differences were noted, the basic chemical changes and relationships observed were similar to those reported for Vitis vinifera and labrusca cultivars.
We are presently finishing a study on following changes in free amino acid contents and other chemical constituents of two muscadine cultivars as a function of ripening of the grapes.

Muscadine cultivars grown in North Carolina typically yield musts containing 11 to 18% sugar (av. = 15%), total titratable acidity of 0.5 to 1% (av. = 0.8%) and pH values in the range of 3.1 to 3.5.

We also have been involved in cooperative research on methods of sorting muscadine grapes into different classes of ripeness. One method makes use of low-frequency vibrational energy of 200 to 100 Hertz (11). Percent soluble solids, % total acidity, soluble solids to acid ratio and pH value of the juice were used as chemical parameters of ripening and correlated highly with the frequency of removal of the grapes from the vibrator. Recent work using a "Berrymatic" fiber optic sorter has shown that muscadine grapes can be accurately sorted nondestructively into ripeness classes. Using this unit (7), we sorted "Carlos" muscadine grapes into four ripeness classes and wine trials were made on the sorted grapes. Grapes of optimum (mid-range) ripeness produced wines superior to those from unsorted grapes (control group), unripe grapes, or slightly overripe grapes. These results emphasize the relationship of degree of grape ripeness to wine quality.

We are interested in the production of sparkling wines from muscadine. In a recent study (6), sparkling wines were prepared from Carlos, Magnolia, Scuppernong, and Noble by the "bottle-fermented" method. Several blends from these cultivars were also made. The finished sparkling wines were evaluated by physical, chemical, and sensory procedures. The fruity aroma and flavor characteristics of the muscadines come through well in a sparkling wine and we think the product has commercial potential. Further studies with muscadine sparkling wines are in progress.

We are very much interested in the wine-growing of bunch grapes in North Carolina and Dr. Nesbitt has developed a number of hybrids (bunch type) which we are looking forward to evaluating in wine trials. Preliminary work (10) indicates that good quality table wines can be produced from certain French-American and other hybrid cultivars when grown at selected sites in western North Carolina. This observation is further supported by chemical, physical and sensory evaluations of wines produced from hybrids grown in the test vineyard of a cooperating company (5). Selected vinifera cultivars have recently been included in the wine growing trials but this aspect of the project is not advanced enough to report any results.

LITERATURE CITED


Our objective is to discuss those diseases of the vine that normally are controlled by the application of fungicides. These diseases may include, more or less in the order of their initial appearance during the growing season, Phomopsis cane and leaf spot, black rot, downy mildew, Botrytis rot, and powdery mildew. For many growers, the disease control program is centered around the control of black rot. This emphasis is sound, as black rot can be the limiting factor in crop production in many seasons.

Until forecast and prediction systems for one or more of these diseases become operational, my concept of grape disease control is based on maintaining as low disease potential in the vineyard as is consistent with economical crop production. Further, I believe this can best be done by keeping the initial infections to a low number. Such a goal is especially important in those diseases with repeating cycles. These include all I have listed with the possible exception of Phomopsis cane and leaf spot.

Each of these major diseases may not occur in every vineyard, nor on all cultivars in a vineyard. Thus, a first step in a vineyard disease control program is the knowledge of the presence of specific diseases on the various cultivars in the planting. The second step is to know when the initial infections of each disease are likely to occur. The third step is the wise choice of a fungicide or fungicide combination that will protect the vine from the expected infections, whether or not disease symptoms are present. The fourth step is an evaluation of the in-season control program to determine adjustments that can be made in the timing of applications, changing the rates, or even changing the fungicides being used. Finally, vineyard practices that may reduce infections or reduce overwintering inoculum need to be carried at appropriate times. As a part of the proceedings of this short course, I will include three tables. One will show the major vineyard fungus diseases and the portions of the growing season when fungicides often are needed to control them should the pathogens be present. The second table will be my ranking of the various fungicides labeled for vineyard use in their control of the major diseases. The third table will list the relative susceptibility of a number of grape cultivars to some of the major diseases. These relative susceptibilities may not agree with your own observations because several of the pathogens can occur in different strains, and because environmental conditions in the vineyard site can influence disease severity.

Phomopsis cane and leaf spot often is the first of the common fungus diseases to appear in the vineyard. It is one of two distinct diseases that were once believed to be the single disease termed dead-arm. The causal fungus can infect leaves, new shoot growth, and leaf and cluster stems of all grape cultivars. Most infections will occur in the first 8 internodes of new shoot growth. Under unusually wet conditions, berries may be infected between mid-season and harvest. Fruit infections, though, are not common.

The fungus overwinters under the bark or epidermis of infected canes. In the first and second springs following new shoot infections, the fungus spores ooze from their overwintering sites and are rain-splashed to the new growth. To prevent in-
Infections, two fungicide applications may be necessary when shoots are about one and six inches long. The amount of shoot infection the previous two years in the vineyard, combined with the presence or absence of prolonged rainy periods during early shoot growth, are the indications of the need for none, one or two fungicide applications. Captan and folpet are the most effective fungicides.

Black rot often is the second disease to appear in the vineyard, though early leaf infections are missed easily. It is the fungus spores from these early leaf and shoot infections that are the initial source of spores for the repeating cycles. Spores from both overwintering sites and from new infections can cause severe fruit loss. Thus, preventing the first infections in the vineyard is a most important part of the black rot disease control program.

The fungus can infect all green portions of the vine. It overwinters on any infected plant parts that remain on the vine or on infected mummied berries lying on the ground. Spores from these overwintering sites escape in rains during early growth stages and are rain-splashed to the new green tissues. The overwintering sites need to be water-soaked in order for the spores to escape, and the spores germinate slowly. For these reasons, new infections take place during wet periods, either continuous or with short interruptions, of 48 hours or longer. There can be numerous repeating cycles of this disease during the growing season in wet periods.

The overwintered inoculum can be reduced somewhat by covering infected prunings and mummied berries with soil, or by removing the prunings from the vineyard before new growth begins. In vineyards where black rot was present the previous year, fungicide sprays should begin at the time of the first 48-hour wet period, or when new shoot growth begins. Many growers from central Pennsylvania and south into North Carolina apply their black rot sprays at the end of the 48-hour wet period, spraying in the rain if it is necessary. Infections from the overwintering sites will end about the time the berries are pea-sized. If infections have been prevented up to then, there need be little concern over the dreaded fruit rot phase of the black rot disease. The most effective fungicides are ferbam, mancozeb (Dithane M-45, Manzate 200), and Dithane M-22 Special. Ferbam may cause a dark, russet-like condition on the berries of some cultivars when it is used in a season-long spray program. We have seen this injury on Chelois, Villard Blanc, and Baco Noir. Predictive systems for timing black rot fungicide sprays are under development here in Ohio and in Michigan.

Downy mildew may be the next disease to appear in the vineyard, often showing the first symptoms on leaves about the time the flower clusters can first be seen. Except for a few cultivars, such as Chancellor, this disease usually does not need to be of great concern. Vineyard sites with good air drainage, sites with good weed control, tight, high trellis wires, and one of the cordon training systems often are the only control needed. Fortunately, these same factors contribute many other pluses in vineyard management.

The fungus overwinters in infected leaves lying on the ground. In the spring, after the leaves have soaked in puddles of water, the spores are rain-splashed to the new shoot and leaf growth. Thus, the earliest infections often occur on mud-splattered growth near the ground. Infections only occur when there is a film of water on the vine surfaces, but there can be repeating cycles of the disease during the growing season. Infections in the shoots can become systemic, and all succeeding growth then will be infected. Berries can be infected directly when pea-sized or smaller. Larger berries become diseased by means of infection through the berry stems.
I have already mentioned some of the control practices. Cultivating the vineyard before the new shoots are 5 inches long will bury many of the overwintering spores. When fungicides are needed, a 4- or 5-spray schedule beginning just before bloom, or in severe situations beginning 2 weeks before bloom, should provide the needed control. The most effective fungicides are the copper-lime combination and mancozeb (Dithane M-45, Manzate 200). Copper should not be used on the French hybrids unless their tolerance to copper injury is known. The copper-lime combination has several incompatibility problems with other pesticides. Captan and folpet can be quite effective when the disease does not get out of hand before they are used.

Botrytis is commonly associated with the decay of mature or nearly mature berries. It is this phase of the disease that causes by far the greatest economic losses. Three other phases are important in disease development in the vineyard. These are infection of the blossoms, green berries and cluster stems.

Botrytis often invades the dying or dead blossom parts, and healthy blossom parts during periods of wet weather and high humidities. Sometimes portions of the flower cluster will become infected and killed as will cluster stems. These dead blossoms often become buried within the developing bunch, producing spores that can infect the nearly mature fruit.

Green berry infection occurs when the fungus spreads from diseased stigmas or from diseased stamens that adhere to the fruit. No symptoms of infection show until about one month before maturity when the berries decay and become covered with the spores of the fungus. Berries nearing maturity can be infected directly through the skin, but much infection also occurs through skin cracks, and bird and insect injuries.

The major sources of spores for Botrytis rot of the maturing berries are infected blossoms, blossom parts adhering to berries, cluster stems, the early Botrytis fruit rot which also originated about blossom time, and from any decaying plant material in the vine or in the vineyard. Two fungicide sprays are suggested during the bloom period on very susceptible cultivars such as Aurore, Seyval Blanc, and Riesling. The first should be applied when the first few caps have shed, and the second when most have shed. These two sprays will reduce the number of infected flower parts, cluster stems and young berries. Two additional applications are suggested as the berries near maturity. Benlate is the only effective fungicide in the control of Botrytis, but it should be combined with captan or folpet to delay the appearance of Botrytis tolerance to Benlate.

Powdery Mildew is the last disease we will consider. The possible economic losses from this disease include reduced photosynthesis of infected leaves, which is important in fruit quality and proper maturation of wood, the shedding of berries prior to and during harvest as a result of infected shriveled berry and cluster stems, and sometimes a direct fruit loss due to berry splitting and shriveling.

The fungus can attack all current season's growth and often is first noted on the upper surface of the leaves. There are numerous repeating cycles during the growing season. High relative humidities, but not high rainfall, favors the pathogen. It's spores are wind-blown.

The fungus can overwinter on infected parts of the vine, but recent studies show that buds infected during the mid- to late-summer are most important in initiating the disease the following season. The fungicide control season generally begins with the post-bloom spray. A second application should be made 7 to 12 days later.
For varieties only moderately susceptible to powdery mildew, and not close to ones undergoing a rapid disease increase, these two applications may be sufficient. On very susceptible varieties, or those near a disease outbreak, several later applications may be necessary. By monitoring the vineyard, growers should be able to judge the need for additional applications. Pay particular attention to the period from mid-August to the end of September. Where there are concentrations of very susceptible varieties, it may be necessary to begin the control season with one or more pre-bloom fungicide applications. Some have suggested that a postharvest powdery mildew spray is advantageous on early and mid-season varieties. The aim is to keep the leaves functional as long as possible to increase winter hardiness of the plants.

Four fungicides are very effective in the control of powdery mildew. These are Benlate, copper-lime, Karathane and sulfur. The sulfur and copper-lime can injure some grape cultivars, and the copper-lime is not compatible with all pesticides used on grapes.

In summary, a sound vineyard disease control program is based on several factors. These include:

1. The knowledge of the specific diseases on each cultivar in the vineyard.
2. The knowledge of when initial infections are likely to occur during the growing season.
3. Choosing effective fungicides for the complex of diseases can be controlled.
4. Protecting the vines from initial infections to limit repeating disease cycles to reduce fungicide use, and to reduce overwintering inoculum.
5. Carrying out those vineyard practices, compatible with production practices, that may reduce infections and reduce overwintered inoculum.

The following tables may assist growers in making management decisions that will aid in sound vineyard disease control programs.
Disease susceptibility and sulfur sensitivity of certain grape varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Black rot</th>
<th>Downy mildew</th>
<th>Powdery mildew</th>
<th>Botrytis</th>
<th>Sulfur sensitive</th>
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<tbody>
<tr>
<td>Aurore</td>
<td>+++</td>
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<td>++</td>
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</tr>
<tr>
<td>Baco Noir</td>
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</tr>
<tr>
<td>Cascade</td>
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<td>+</td>
<td>++</td>
<td>-</td>
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<tr>
<td>Catawba</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
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<tr>
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<td>+++</td>
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<td>-</td>
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</tr>
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<td>Missouri Riesling</td>
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<tr>
<td>Moore's Diamond</td>
<td>+++</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Niagara</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Rosette</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Rougeon</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>Yes</td>
</tr>
<tr>
<td>Seyval Blanc</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>No</td>
</tr>
<tr>
<td>Van Buren</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>White Riesling</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>No</td>
</tr>
</tbody>
</table>

+ = somewhat tolerant; ++ = moderately susceptible; +++ = very susceptible; - = no information.
Pre-harvest intervals and effectiveness of fungicides for the control of grape diseases.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Phomopsis</th>
<th>Black rot</th>
<th>Downy mildew</th>
<th>Powdery mildew</th>
<th>Botrytis rot</th>
<th>Pre-harvest interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benomyl</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>7</td>
</tr>
<tr>
<td>Captan</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Karathane</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>21</td>
</tr>
<tr>
<td>Ferbam</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Fixed copper &amp; lime</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Folpet</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Sulfur</td>
<td>-</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Zinc Ion-Maneb</td>
<td>+</td>
<td>+++</td>
<td>-</td>
<td>0</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>(Dithane M-45, Manzate 200)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+++ = highly effective; ++ = moderately effective; + = slightly effective; 0 = not effective; - = not labelled for use. When benomyl is used, combine it with another fungicide to delay the appearance of pathogen strains tolerant to benomyl.

Times when fungicides may be needed for control of major vineyard diseases.

<table>
<thead>
<tr>
<th>Time of applications</th>
<th>Phomopsis cane and leaf spot</th>
<th>Black rot</th>
<th>Downy mildew</th>
<th>Botrytis</th>
<th>Powdery mildew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early shoot growth</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pre-bloom</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Bloom</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Post-bloom</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>First cover</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Second cover</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Third cover</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Fourth cover (pre-harvest)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+ fungicide may be required
- fungicide not usually required

-56-
Aging has been described as "one of the most interesting and important, yet one of the most complex processes in wine making" (1). Certainly, from the consumer's standpoint, it is one of the most overemphasized aspects of wine quality. Even knowledgeable enophiles sometimes equate quality with age. As is shown in Figure 1, the drinkability of wine increases with age to an optimum, which varies from wine to wine, and remains at this optimum for a longer or shorter length of time until finally it goes "over the hill" and once again becomes undrinkable.

It was the Greeks who discovered, through their invention of the airtight amphora, that wine could be stored longer than one year and that many wines would benefit from this prolonged storage. Certainly, many antique wines were capable of incredible longevity and reference has been made to a certain Falernian wine that was still drinkable after 160 years. However, there is still a prevalent misconception that all wine is capable of aging and will continue to improve almost indefinitely with age.

During the aging of wine, changes occur in the color, taste, bouquet and flavor and the body or mouthfeel. The color shifts towards brown and amber hues and, in red wines, there is a diminution of the overall red color. The taste becomes less harsh and acidic and there is an overall 'smoothness' that occurs. The flavor and bouquet become less fruity and more complex with time. The mouthfeel or body of the wine becomes smoother. All these chemical changes can be associated with definite chemical changes which, although complex and poorly understood, are, nevertheless, moderately well defined.

Chemical Changes Affecting Color

The chemical changes which affect color and perhaps the best understood and the best defined of all the changes which are responsible for maturation and aging. Basically there are two phenomena--oxidation and pigment precipitation.

Aging may be considered as basically a very slow process of oxidation. This is clearly seen in the color changes where, in a white wine, the color changes from a pale yellow or gold to a deeper yellow and, finally to a brown. This is basically the effect of oxidation and the tannins which results in a browning reaction. The process is analogous to the browning of the cut surface of an apple or potato. The colorless tannins or polyphenols react with oxygen to form quinones which then undergo polymerization to form complex brown pigments.

In red wines, besides the browning process, there is another process of pigment precipitation. The anthocyanin pigments, which are chemically related to the tannins, undergo similar reactions and react with the tannin to form a precipitate.

Chemical Changes Affecting Flavor

Flavor, in the sense used here, refers to taste which is perceived by the tongue rather than the palate. This corresponds to the sweet, acid and bitter tastes found in wine. While oxidation can play a role here, it is only very late in the maturation process that this becomes significant and then only contributes to the deteriorative aspects of the wine. An exception to this is with sherry-type wines.
where the oxidized taste is highly desirable.

Of more importance is the changes in acid levels. Two processes operate here—the precipitation of tartaric acid as its potassium salt and the conversion of malic acid to lactic acid through the malo-lactic fermentation. Both these processes, by lowering the acid level, contribute to an improvement in the taste of the wine in terms of reducing its harshness.

These processes, while essentially completed in the winery before the wine is marketed, may also continue in the bottle. The appearance of tartrate crystals may be somewhat alarming to the consumer who often mistakes these for slivers of broken glass (and wine store clerks will sometimes refer to them as sugar crystals!). While these may be regarded as a sign of a healthy maturing wine, it is necessary to eliminate them as far as possible in the winery and there are several methods of accomplishing this, notably ion exchange and cold stabilization. The malo-lactic fermentation, as has been shown elsewhere in these proceedings, is more difficult to initiate let alone control but, nevertheless, seems essential to the overall quality of a good wine.

The polymerization and precipitation of the tannins affects the bitter taste of the wine. This diminishes with time unless oxidation becomes excessive when it will return.

Chemical Changes Affecting Bouquet and Flavor

These are the most obvious of the changes affecting wine. These are, as has been mentioned above, a gradual disappearance of the 'fruity' or 'grapey' flavor of the young wine and its replacement with the more complex aroma of the matured wine. In other words, the wine tastes less and less like grape juice and more and more like wine.

Oxidation, of course, plays a part here, too. The complex by-products of fermentation are themselves oxidized. This is especially true of the aldehydes which are oxidized into the corresponding acids:

\[ R.CH_2 + O_2 \rightarrow R.COOH \]

Some of the trace alcohols may also be oxidized.

The volatile acids so produced may then react with some of the alcohols produced during fermentation to produce esters:

\[ R.COOH + R'O.H \rightarrow R.COO.R' + H_2O \]

Since most of the aromatic components of the grapes are volatile alcohols and acids, their slow interaction during the maturation process leads to different flavor types. The ethyl alcohol formed during fermentation is the principal reactant of this.

Ultimately, of course, the oxidation goes too far and the wine become oxidized or maderized. Because of the antioxidant properties of tannins, this process takes place more slowly in red wines than in whites but the ultimate fate of a wine is maderization.

Wood aging will also affect the flavor of the wine due to tannin extraction
which leads to greater complexity. Of course, aging in wood cooperage accelerates the aging process due to the greater access of oxygen to the wine through the porous wood. This theory may not be quite as simple as was once assumed due to work by Peterson (3) in which he has shown that quite high vacua are produced in sealed oak barrels.

Chemical Changes Affecting Body

The body of the wine is the mouthfeel or the mouth-filling attribute of the wine. This is affected predominantly by the tannins as well as, to a somewhat lesser extent, by the acids. It has been shown earlier how aging affects the acid content which leads to the production of a smoother wine. Similar mechanisms explain the changes in body which may be observed.

However, the chief factors affecting body are due to changes in the tannin content. Extended fermentation on the skins as well as prolonged wood aging will increase the tannin content of the wine and hence the body. It follows that extended aging, by allowing the oxidation, polymerization and subsequent precipitation of the tannins will lead to diminution of the body.

This is, in fact, what happens. The gradual precipitation of tannins which occurs, especially in red wines, leads to a lessening of the astringency which is characteristic of a young wine and to the production of a wine with a smoother mouthfeel.

In sum, therefore, the changes that wine undergoes during aging and maturation, although complex and still poorly understood, can be broken down into a few basic chemical processes. These are:

- Precipitation of acids
- Oxidation, polymerization and precipitation of tannins
- Precipitation of pigments
- Oxidation of flavor compounds
- Production of new flavor compounds through esterification

These processes are all interrelated. The most important is probably oxidation and it is this which governs the entire aging process. It is the chemical process through which wine improves during maturation and is the one which, ultimately, renders the wine undrinkable.

LITERATURE CITED


Fig. 1. Effect of Age on Drinkability of Wine—(A = point of minimum drinkability; B = point of optimum drinkability).

Adapted from Peterson (2)
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Western Branch, South Charleston, Clark County: 428 acres