OHIO GRAPE--WINE SHORT COURSE

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PREFACE

Approximately 175 persons attended the 1981 Ohio Grape-Wine Short Course, which was held at the Fawcett Center for Tomorrow, The Ohio State University, Columbus, Ohio, on February 17-18. 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.
THE WINESAP IS NOT NECESSARILY AN APPLE, PART II

Bern C. Ramey, Vice President
Paul Masson Vineyards, California

For some time now, I have been in exile in an exotic land, known to some as California. Thus, even though my home was in Ohio, on my return here tonight I like to think it is somewhat like an outsider's perspective on the Ohio wine scene and hopefully, therefore, of some significance to you.

What's going on in the large world of wine is, of course, a useful starting point. In 1980, wine sales for all wines in the U.S. increased by about 9% over 1979. "Table wines" made in the U.S. increased by 20%, imported table wines by about 12%. The wine boom of the 1970's is extending into the 1980's. The imported wine figures are sustained largely by the recent marketing successes of Italian wines which now outsell French wines by a considerable margin. And, as you all know, the biggest surprise in recent years is the tremendous interest in, and sales of, sparkling wines of all types from all countries, with sales increasing in 1980 by almost 17%.

The easiest thing to do when employing statistics is to mislead. Behind the numbers lies the truth. Wine sales are led by white wines--predominantly low-priced, sweet-finished and chillable. Italian wines are led by white wines and by light reds, often the jammy, slightly sweet lambrusco types. Consumers talk about "varietals" and drink generics (Chablis, Burgundy, Rose and Rhine). They purchase bottles from "Boutique" wineries and buy cases of generics and "proprietaries" for their everyday needs.

There is a strange mental mix controlling wine consumers today--an attitude that compels them to try the new and unknown and also to buy the proven, reliable, and economical. They are comparative, curious tasters and comparative shoppers--all in the same body. They are wine thinkers, knowledgeable about many facets of wine-making, and wine drinkers, aware of the family budget.

All of this makes the wine field very competitive and pressures large producers, like Masson, to improve quality and to provide more information about the geographical and varietal origins and vintages of what is in the bottle. For the small wineries, the pressure is on to not only endure but also prevail. The continual wave of new California wineries only increases Paul Masson's pressure to compete against several hundred different Cabernets, Chardonnays, Zinfandels, Sauvignon Blancs, Chenin Blancs, French Colombards, etc... and compete we do. Compete we must--with good products, organization, and hard work.

Medium-small wineries (100,000-250,000 gallon range) now seem to sense that they really can compete head-on with larger ones in many ways: mainly in marketing expertise, continuity of supply in well-selected major areas, and in pricing their products. At the "small" winery (say, 10,000-25,000 gallons), the formula for success is really to make high quality wines, stay small, and sell direct. I see great rewards in the high-quality small winery, the cellar-door, sell-to-your-neighbor, proud grower-producer. In this day of highly structured, dehumanization, what's the value of a comfortable life-style? Millions!! Make quality, obtain the markups, and keep them in the family. Many of the smaller California wineries have trimmed their lines down to a few specialized wines or have concentrated from the opening on a very few wines. Point: Find what you can do best and specialize in that area. Not only that, but make darn sure your wines are unique in some way,
in taste, in packaging, and in your personality.

Out our way, Joe Heitz (Heitz Cellars) has since 1966 offered "Martha's Vineyard" Cabernet, a truly unique wine, but not intended for everyone's palate or budget. Joseph Phelps offers a "Signature Cabernet", Beaulieu Vineyards the "Private Reserve", Robert Mondavi his "Reserve" style, and Jordan makes only one wine for now, quite different in appeal. The recent example of an extreme approach is the news that a new winery in Napa, Hagafen Cellars, is now marketing the first Napa Valley Johannisburg Riesling from "Winery Lake" that is a Kosher Varietal! Certified indeed, and a find dry Riesling.

Back in 1966, the dare-to-be-different theme was just beginning to manifest itself. In Monterey County, the tiny Chalone winery re-opened again, and Paul Masson, Wente Brothers and Mirassou squeezed out of their homeland and made a vineyard exodus to Monterey County—a multi-million dollar gamble even though University of California at Davis had indicated that Monterey had the ideal climate for early and mid-ripening vinifera varieties. Of course, we didn't realize that Monterey would come to be recognized as the "Promised Land" for white wines in the northern section of our 60-mile pocket. So, being different is a combination of bold moves along with some luck. It just happened to turn out that Monterey whites were intensely fruity, crisp, and different in style than other California wines.

At this junction, with a forethought, may I tell you that selling Monterey County to American wine aficionados (particularly the press), who were super-saturated with the Napa-and-Sonoma syndrome was, and still is, no easy task—even though our white wines win more authentic awards. We were, early on, stigmatized with the "bell-pepper" taste syndrome—which we are overcoming!!

Our technique? First, make quality, and, of course, keep our salesmen on the doorsteps. But probably our most important salesman is a marketing group (local and national in scope) we created 4 years ago: our Monterey Wine Growers Council, some 17 producers and their PR people. The budget is a slim $20,000 (versus all California wineries' $120 million dollar budget!!). The Council sends out news releases, courts wine writers, entertains, tastes, and tickles persons of influence—all, of course, in red-carpet good taste. Also, the wine-makers make five to six cooperative group junkets to major cities annually and conduct didactic tastings with full-court press coverage. I do, indeed, recommend this approach to Ohio producers.

It took a while for those of us in Monterey to understand our unique assets and fundamental differences. We often harvest early ripening varieties in October, when Napa is finishing up with Cabernet, and complete the harvest close to Thanksgiving. "Let 'em hand" and watch the acidity and the pH as much as the sugars. We farm differently, prune for different yields, irrigate on our own schedules, etc. We do not try to make Napa Valley wines from Monterey-grown grapes. We have today's techniques pretty much down pat...we just don't know about tomorrow's!!

Now, you know I'm leading up to a point here, after a long preamble, and it really is this: Wine is "in" and growing, and most of its appeal is flavor and a wide spectrum of flavors. Individual differences and craftsmanship are what make wine exciting. Ohio, to most outsiders, falls between New York State and California, geographically. Viticulturally, it leans toward the east. Ohio should try to make the best Ohio wines possible without fear of remaining in the shadows of the two coastal wine powers, without feeling self-conscious and catatonic about its role.
Now, as I understand the situation, Ohio has roughly 40 wineries, with over 20 appearing on the scene since 1967. That is a good sign; there is vitality. Ohio has 4,000 acres planted to grapes, mostly to Concord, but with some American hybrids, French hybrids, and a smattering of vinifera. Now here is where I would like to light some fires. Ohio consumes close to 12 million gallons of wine per year, not a big figure on a per capita basis, but substantial enough as an indicator of a growing wine market. Ohio producers make about 1 million gallons of wine per year from their own vineyards and from the out-of-towners. Even an Ohio State grad can subtract 1 from 12, and come up with 11 million gallons of out-of-state vino. There is a balance of payment problem that has nothing to do with the OPEC countries. As a devoted, vinous Buckeye (a matter of genetics), I dream of the day when you will have sufficient monies for research—first, for advancing your viticultural technology, finding the right varieties, the right micro and macro-plots, improving cultural practices—in short, more fruit, good fruit, and finer wines. Then! Monies for an on-going PR/marketing organization. California has its Davis and its WI. Why not Ohio?

It seems fair to suggest that you Ohio vintners begin to work together to enjoy a bigger share of your own wine pie. Ohio has a rich wine heritage. Build upon the history, the local romance, open your winery door to the public the way California wineries did decades ago, and do today. A small taste of wine is the best PR ever invented by wine-kind. Learn from California, and from New York, but don't set out to imitate their wines—unless that is the best way to go.

If Concord, Delaware, Niagara and Catawba are your best bets, then "Go with the flow." The labrusca flavor is probably the most common and best known flavor in the U.S. I don't have to document that with reference to jellies, jams, grape juice and bubble gum, except that I just did. It should be the easiest flavor association in this world to promote and to market. For gosh sake, don't be defensive. You have something we don't have. And it's good! Good tasting. Or, as some individuals in this area have said, "If France originally had Labrusca, they'd call it Gewurtztraminer.

French hybrids could be another best shot. The wine world now accepts French hybrid wines as potentially good, balanced, flavorful wines. As someone whose trade is that of a peddler, a vagabond, and a teller of bad jokes, I tend to pick up whatever information I can, second-hand, third-hand...it doesn't matter to a professional peddler. So I heard that Dr. Wykof took some of his wines west for an annual meeting of wine educators, and from all reports, won the hearts and palates of westerners with his Seyval Blanc and Vidal Blanc. The dog-and-pony shows in the wine world do not all emanate from California or Europe, my friends.

If your budget doesn't allow for a pony or a dog, then get the wines around somehow. My good friend Ben Sparks at "Possum Trot Farm" in Indiana managed to get me a bottle of his Marechal Foch. It was tasted not long after by Darrel Corti, a well-known California wine expert and merchant, and Norm Roby, wine editor of "Vintage Magazine"—the reaction was most positive: "Delicious, balanced, flavorful. Where can we get some?" New York State is now getting some national recognition and media play. Why? Because of the small wineries—Clinton, Glenora, Benmarl—the specialists are making very fine wines from hybrids.

So, there is nothing in the wine air to indicate a national infatuation with wines made from vinifera varieties only. Besides, most consumers do not know what Italian lambrusco is; they know it suits their taste buds. About 3 years ago, a marketing research survey was taken. It turned out that the frequent buyers of "Blue Nun" did not realize that it was a general type of wine, Liebfraumilch to
begin with, nor did they know it was a wine made in Germany!! Promotions, if you can afford them, they seem to pay off. "Some of my best wines are Italian," etc.

Promote Ohio--but start promoting!! Be somebody--"You're nobody till somebody loves you," the old song goes! We all have to start someplace. I remember not so many years ago, 1960 to be exact, when there were only 600 acres of Chardonnay in California and half of these didn't have seeds!

One of the better personal tales I can tell you today derives from my early experience in selling California wine outside of California. That takes us back to the late 1940's to early 1950's. Trying to sell a really good Cabernet Sauvignon or a Sauvignon Blanc to accounts unfamiliar with the Bordeaux connection and totally baffled by "varietal" names was about as tough as selling real estate near Three Mile Island today. We could sell most of the generic wines (Chablis, Burgundy, Claret, and Rhine) but varietals--took time, effort, and patience. And money...and smart, organized PR marketing..and belly-to-belly talking and selling.

So eventually I became involved in a national campaign that surveyed consumers' responses to French wines vs. California's varietal counterparts. The California wines were preferred (51% to 49%) and the results were publicized by the industry and by the California wine institute, and the Golden State wines were off and running. Once the image barrier was broken, we discovered a receptive audience.

For the first time in American history, wine appealed not just by its flavor and food compatibility but by being a subject that could be studied and eventually mastered. A body of knowledge, a product that began growing out of the earth and ended up as a liquid that continued to change in the bottle. What made it even better was an awareness of people behind the product. There is an intimacy between the product of wine, the eventual consumer, and the dedicated grower-producer. So when I learn about the new wineries in Ohio and about the way Bob Gottesman is refurbishing the Lonz Family Vineyards and Winery on Middle Bass Island, I am thrilled, not only for my friend, but also because I know these personal stories help sell wines, and will help re-establish Ohio as a great wine state.

Each and every winery in California, Washington, Michigan, or Ohio has a story behind it. The problem is making that story known to others, either by working the crowd (and one is a crowd enough) on the winery doorstep or taking the story elsewhere. If I owned an Ohio winery, which I don't, and if I were 30, which, I regret, I am not, and if I were just starting over again, which is unlikely, I would, as personal preference, definitely adhere to my rambling philosophy expressed so far. That is, offer a unique product, promote the history and personality behind it, and proceed on a direct, person-to-person basis, while staying as small in production as economically possible and acceptable.

Chances are good I would be cognizant of the move toward low-alcohol wines in the "table wine" segment, light and white, because they would seem a natural for the area. I would also be most interested in wines that sparkle--champagnes--because that was my first love. Slightly sweet, nouveau-style red wine may some time capture the audience now enjoyed by Italian lambrusco. Yet today, knowing that establishing vineyards and making the wines requires several years, I might dare to be a little different and look down the road some. After the table-wine revolution, now in full activity, and the sparkling wine renaissance, now underway, I would ask, "What's next?" By logical extenuation, the conclusion would be, dessert wines, fortified wines (hang the statistics). And labrusca, in my opinion, also lends itself to a unique aperitif approach.

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The growing appeal of sparkling wines, following the inroads of table wines, indicates an American move toward total wine awareness. That leaves a spot for after-dinner wines. After champagne and/or white-wines-before-dinner, red-with-dinner, there is a gap afterwards that can only be plugged by dessert wines. I offer this as an aside, here, but knowing full well that one of the strong points of Ohio in this era is and should be in ports and sherries. It sure is not bad logic to take something you are known for and turn it into a specialty area.

But my opening pitch tonight was along the lines of perspective, objective distance. The world of wine is full of surprises, with a good measure of unexpectedness of craziness added. What better example can be cited than yours truly (they call me "Mr. Man" of the wine world), encouraging you to define your capabilities and to execute them while all the time representing a major California winery, Paul Masson. "Life is something that happens to you when you are making other plans", something I have learned after close to 40 years in the wine business. Louis Pasteur, a crazy and wild guy, said it better long before me: "Chance favors the prepared mind."

One aspect you might want to keep in mind is the possible return of blended table wines, creatively assembled for taste and balance. Many may carry "proprietary" names instead of generic or varietal names. As a corollary, remember that the state of Oregon gains considerable attention because it prohibits the use of the semi-generic names (Chablis, Burgundy, etc.). The reason for the potential emergence of creative blended wines is the more stringent regulations heading for the federal books in January 1983. They are generally directed toward varietal wines from vinifera, with a minimum of 75% varietal composition for most. Those within approved viticultural regions will have to be 85% varietal and 85% from that region.

The estimated total investment cost for 1 acre in California today is nearing the $20,000 mark for the first 3 years. It is increasing. The cost of real estate on California's North Coast is such that an acre of bare vineyard land, if available, averages $8,000, with $12,000 per acre in Napa not unusual. The new regulations and the high cost of establishing the vineyards in the congested coastal counties of California are likely to motivate vintners to set their imaginative sights on blended table wines. That would encourage vintners in other states to go with the trend and market blended wines, "Ohio Red" or "white" or whatever.

My thoughts and opinions can be taken in any context. Some say free advice is worth what you pay for it. Advice is cheap, and what I offer is worth exactly what it cost you--a few minutes of your attention, for which I thank you.

Also, I want to thank especially Professors Jim Gallander and Garth Cahoon--giants of Ohio scientists--for their magnanimous invitation and courtesies. I thank you most sincerely.
Grapevines may be propagated by seeds, cuttings, layers and grafts. Usually, grapevines produced from seed are not true-to-type of the parent grapevines. Therefore, seeds are not used for commercial propagation of cultivars for vineyard purposes. However, propagation of seeds is valuable in the development of new fruit and rootstock varieties by breeding (16).

Cuttings

Hardwood. Propagation of the grapevine in general is limited to asexual reproduction by hardwood cuttings. Well-matured, one-year-old, dormant canes should be selected for normally productive, vigorous vines. Make cuttings immediately after the vines are pruned. In cool, wet weather the prunings may lie in the vineyard for no more than one week without severe injury. However, two or three days of warm, dry, windy weather may dessicate them to such an extent that cuttings made from these prunings will grow and root poorly. If for some reason, cuttings are to be made from winter-tender varieties, collect wood before severe winter weather is experienced.

Well-matured, one-year-old canes from any part of the vine are suitable for cuttings. There appears to be no reason to avoid water sprouts, suckers or other canes that produced no crop unless vines were extremely vigorous. Laterals of proper quality from primary canes also are suitable to use for cuttings. The most desirable canes to use for cuttings range from 1/4 to 1/2 inch in diameter. Internode length should range from 3 to 8 inches between the fifth and sixth nodes. Very short internodes usually indicate disease or poor growing conditions. Abnormally long internodes indicate very rapid growth. Such canes are usually soft and poorly nourished, hence low in stored reserves (starches and sugars). Canes of the American-type cultivars have an internode length ranging from four to six inches between the fifth and sixth nodes. Some of the interspecific hybrids (French-hybrids) and *Vitis vinifera* L. cultivars have shorter internodes than those of American vines. Cuttings should have a minimum of two buds, and for field nursery use range from nine to twelve inches in length. The number of buds per cutting is determined by the internode length of a given variety. Therefore, each cutting may contain two or more buds. When dormant canes of a given variety are scarce or they are to be propagated under mist in the greenhouse, make cuttings five to six inches in length and containing at least two buds. When considering the amount of dormant wood needed, make approximately twice as many cuttings as the number of plants desired (16).

The actual procedure for producing dormant cuttings is as follows: from dormant prunings, select and separate only the "live" canes, which are approximately 1/4 to 1/2 inch in diameter. Periodically spot-check the condition of several buds by cutting them open with a razor blade to make certain that they are green. Also examine the dormant wood by cutting just under the bark. Prepare the canes by cutting them at a 45° angle one to two inches above the top bud. Cut horizontally slightly below the bottom bud making the cutting nine to twelve inches in length. To recognize base of cane, look for the leaf scar below the bud. The 45° angle will help in identifying top of cutting when planting in the nursery. Usually, 100, 9-12 inch cuttings of the same variety are tied together with basal ends even in a bundle, and
securely labelled with identification tags. After cuttings have been tied together, place immediately in a recommended fungicide solution, so as to prevent fungus infection and drying out. After soaking overnight in the fungicide solution, wrap immediately in plastic and place in cold storage at 32-35°F. If cold storage is not available, bury in moist, well-drained soil 12 to 18 inches deep. Cover and mark location.

The nursery production of hardwood cuttings is as follows: in the spring select a site with well-drained soil to set cuttings for root and shoot development. Select a cool spring day after the danger of frost is past. Preferably the day should be overcast. Remove cuttings from storage and plant them in a nursery row. Plow the furrow deep enough to ensure that all buds except the top bud will be below the soil surface after cuttings are set in the nursery row. The actual depth depends largely on the length of the cuttings. Usually the depth is about 12 inches. Plow only the number of furrows able to be planted at one time to ensure that the soil will not dry out. Plant cuttings 3-r inches apart in the furrow. Cuttings which are planted upside-down will not grow into acceptable grapevines. Back fill furrow and firm soil around cuttings.

Space next furrow approximately four feet away. The actual width between furrows can vary depending on the available cultivation equipment. Mark location of varieties in nursery. Also make a varietal map of nursery for future reference. Keep nursery row weed-free at all times during the growing season to prevent moisture competition and to aid in disease and insect control. Keep constant control over all insects and diseases. Refer to Ohio Commercial Fruit Spray Guide (5) and the Ohio Cooperative Extension Service for recommended weed, insect and disease control practices. The nursery may be undercut in the autumn after rooted grapevines are dormant. Store grapevines in cold storage facilities at 32°F for the winter months. Be certain to keep grapevine roots moist by packing vines in wet sawdust or peat moss; check the vines' condition at regular intervals. It is essential to prevent dessication of the roots. The following spring, the dormant, one-year-old rooted grapevines can be removed from cold storage and planted in a vineyard.

Hardwood cuttings may also be rooted during late winter under a mist system in the greenhouse. Bulletin 506, Grape Growing, describes the exact procedures (4).

Softwood. The grapevine can be easily propagated from segments of green shoots collected at any time during active growth. The main purpose of using softwood cuttings is to rapidly propagate a large number of plants in one growing season. In recent years, there has been an increasing demand for grape varieties certified to be free of known virus diseases and also new varieties and clones. If the available wood from these vines is scarce, softwood propagation can be a useful tool (16).

Softwood propagation requires a specialized greenhouse technique, intermittent mist. These details of design and operation have been described by Fretz and Smith (6) and Hartmann and Kester (9). The procedure described by Winkler et al. (16) is as follows: one-to two-node segments of green wood can be collected from current season's growth of the 'mother' vine anytime during the growing season. The cuttings are rooted in a greenhouse. Overhead intermittent mist is used which includes a cycle of about six to ten seconds on and 90 seconds off. Any time combination which keeps the relative humidity around the cuttings at 100 percent is satisfactory. Air temperatures should be in the range of 75 to 80°F. Misting is usually discontinued at night and can be automatically controlled. The rooting medium must be very well drained to remove any excess moisture which accumulated from misting.
is suggested. However, the temperature of the medium should not be more than a few degrees higher than the air temperature around the cuttings. Greenwood grape cuttings usually root easily under mist and rooting hormones are unnecessary. When both intermittent mist and bottom heat are used, almost 100 percent rooting success is obtained within fifteen to twenty days.

After rooting, the vines are removed from the mist environment and transplanted into four-inch pots and held in a greenhouse or outdoors if moderate temperature permits. After transplanting, reduce light and maintain moderate temperature and high humidity. Four to six weeks later, the grapevines will have established themselves in the pots. They are then hardened-off in partial shade outdoors for a few days before planting in the permanent vineyard site. The entire process, from cutting to field planting requires 50 to 60 days.

The post-planting care of the small grapevines in the vineyard is critical. Since they are actively growing, their roots must become established in the soil. Supplemental irrigations and intensive weed control are necessary during the first summer, along with insect and disease control.

**Grafting**

Desirable wine grape cultivars of V. vinifera have limited or no tolerance to grape phylloxera, Daktulosphaira vitifoliae (Fitch), parasitic nematodes, and/or in some cases adverse soil conditions. Therefore, depending on location, cultivars must be grafted onto resistant rootstocks (14,16).

Benchgrafting is the most common method of producing grafted grapevines and is conducted indoors during later winter and early spring (10). Newly made grafts are callused in a special environment and grown for one growing season in a nursery.

Wood for scions and rootstocks must be obtained while vines are dormant. Scion wood is usually obtained from varietal vineyards. Wood for rootstock cuttings should be obtained from vineyards planted for the sole purpose of producing grafting wood. Planting distances in rootstock vineyards are approximately the same as for growing grapevines for fruiting, with plants placed six feet apart in rows nine feet apart. Plants are supported by individual posts ten feet in length with one wire strung across the top of these posts which are set to a depth of two feet into the ground. Wire size is variable. Generally it is number 9 soft, annealed wire. Shoots are tied up along the posts at frequent intervals during the season in order to develop straight canes and keep leaves well exposed to light. After the shoots reach the wire, they can be trained laterally. It will be necessary to tie them loosely to the wire at frequent intervals (8).

The procedures for wood selection and preparation of scions and rootstocks for benchgrafting are similar to those used for producing dormant hardwood cuttings.

The flow chart in Figure 1 depicts the tongue and groove benchgrafting method used in research studies with Haeseler and Romberger (8,13,14) at The Pennsylvania State University, Erie County Field Research Laboratory, North East, PA. Other similar charts providing benchgrafting information have been published by Alley, Becker and Loenholdt (1,2,3,11,12).

In March, dormant wood is obtained and cuttings are made. The wood selection procedures for cuttings used in grafting are the same as those previously described for "hardwood cuttings". Care must be taken during grafting procedures to keep all
dormant wood labelled correctly regarding variety.

Wood is normally stored in bundles of 100 (Figure 1). Prior to storage, soak all wood in bundled cuttings for at least 12 hours in a recommended fungicide solution or at least in water. Becker (2,3) has shown that scion and rootstock material should be soaked for 15 hours in a 0.3 to 0.5% Chinosol solution. Chinosol is a quinoline compound which inhibits the development of microorganisms, such as molds, fungi and bacteria. One solution of Chinosol can be used three times to soak propagation material (11,12).

After soaking, wrap wood in plastic and store at a temperature of 32 to 35°F with as high a relative humidity as possible. Lønholm (11,12) stated that the storage of propagation material in plastic bags has proven very successful. An open storage resulted in loss of moisture. Moisture loss can be prevented if the wood is kept at a relative humidity of 96-98% until it is used for grafting.

Although the best environment for storing the wood is a cold storage unit, one may not be available. In this situation, pack wood in moist peat or sawdust and cover loosely with a piece of plastic to reduce moisture loss from storage area. Select a cool area and add water as needed.

When time is available prior to grafting (April 1-15, Figure 1), rootstocks should be disbudded to discourage sucker growth. To facilitate ease in handling, scions should be soaked in the form of 3-5 bud cuttings (8-12 in). These will eventually be cut into one-bud scions. Both the one-bud scions and rootstock cutting should be graded according to the diameter of the cuttings ends to be united in the graft. Wood of the scion and rootstock should be of the same diameter when grafted so that the cambium layers can be properly aligned. The graded scion and rootstock cuttings can then be labelled and returned to storage.

Just prior to grafting (April 15-30, Figure 1) the propagation material should be soaked for one to ten hours depending on the amount of dehydration. Material which has been presoaked in Chinosol and was stored in cold storage usually needs only a very short soaking period (11,12).

After the grafting wood has been resoaked, the actual benchgrafting process may begin. There are several types of grafting cuts which can be used (7,11,12). The hand-grafting cut which is used only by experienced grafters is the "Short Whip Graft" (11,12).

Because skilled grafters are scarce, machine grafting is the usual method used in Eastern United States (11,12). The "Saddle Graft" is made by machine. The cuts are in the shape of a "V". The graft must be tied to provide mechanical rigidity to the union. Tying materials are raffia or budding strips. When tied, the graft union should not be entirely covered. Tie only enough to provide union support (7).

The next type of machine graft is the "Tongue and Groove Graft". Before the actual grafting can occur the base of the scion and top of the rootstock must be recut (Fig. 1). These cuttings are recut in order to obtain fresh green surfaces on the ends to be united in the graft (12). The scions and rootstocks are cut separately with this electric machine and then joined together by hand. The tongue and groove cut forms a union tight enough so that tying is unnecessary (7,12).

The "Omega Graft" is machine made and creates a graft union in the shape of the greek letter, omega. This machine is semiautomatic and also forms a union tight
enough so that tying is unnecessary (7).

After the graft is made by any of the above cuts, the entire top of the graft is dipped for less than one second into special grape grafting wax to a point about one inch below the graft union on the rootstock. The grafting wax prevents the graft from drying-out and provides support to the graft union (7,11,12). "Ribinol" or "Stahler" are special grafting waxes with a combination of wax and higher hydrocarbons. The melting point is between 150 and 158°F. The wax is melted in a water bath, and the temperature must be controlled with a thermometer. Be careful not to heat the wax over 158°F. After dipping the grafts into the wax, the wax will harden immediately and the grafts are now ready for callusing (12).

Before grafts can be planted into the nursery, they must be placed into a special environment for callusing. Containers used for callusing may be wooden boxes or cardboard cartons. When a box is used, it is laid down on its side with the removable side removed. It is lined with two inches of wet medium to a height that covers the rootstock to a point just below the graft union. A suitable medium consists of 3 parts peat moss, 3 parts vermiculite, and 1 part pulverized limestone. After lining the callus box, a layer of grafts is placed on the layer of moist medium and then covered with another 2 inches of medium. This process is repeated until the box is filled. Then the side is replaced and the box is set in an upright position. Fine dry sawdust or peat moss may be sifted in the callus box to cover the graft union and scion. On top of this dry layer of sawdust, a two inch layer of wet peat moss is packed evenly over the sawdust (7,11,12).

Descriptions of European benchgrafting methods indicate that the scions and graft unions may not need covering (1,11). In recent research (13,14) covering the grafts with sawdust and wet medium was not advantageous compared to noncovering. In these research studies, heating cables were used to control temperature and the grafts were waxed. Loenholdt (12) further emphasized that a controlled environment for callusing and waxing of the grafts are essential for good callus tissue formation without covering the grafts with sawdust and wet medium.

The packed callusing boxes can then be placed into a callusing room. If it is too early for callusing, they may be stored at 32°F in a cold storage room. The ideal temperature for callusing should be 84-86°F for the first 5 days to initiate callus tissue growth and then lowered to 77-79°F for the remainder of the callusing period. In addition, a high relative humidity (96-98%) is necessary (7,11,12).

It is ideal to have callusing completed in all callus boxes at the same time. The actual length of time for callusing depends on the development of callus tissue. The callusing is finished when a complete callus ring has developed around the graft union. With a controlled environment callusing room, the time for callus development should be about 15 days. After callusing is complete, gradually lower the temperature in the room over a few days to the average outside temperature. The callusing boxes and their grafts may then be placed outdoors in a cool, protected area to harden-off. Water the boxes if necessary and be certain to protect from spring frosts (7,8,11,12,13,14).

When cartons are used, grafts are placed into individual 1 1/2 inch square cartons that range from 4 to 15 inches in height. The taller cartons are filled with moist medium to a point just below the graft union. The filled cartons are then placed in a callusing house which is similar to a hotframe in design (7,8).
roof sections. Grafts callused in cartons in a callusing house may remain in the house to harden-off by removing the roof sections (8).

Cartons for benchgrafting are also utilized in California when producing greenhouse-forced benchgrafts. The objective is to grow benchgrafts (in the greenhouse) that have shoots and a root system. These grafts can then be planted directly into the vineyard under favorable climatic conditions (15).

If the callused, hardened benchgrafts are to be planted in the nursery, specific weather conditions should prevail. After the last spring frost, monitor weather conditions so that cool, cloudy weather will prevail for a period of 3 to 4 days when the plants are set in the nursery (7).

Nursery rows should be spaced at a distance convenient for cultivation (approximately 4 feet). Grafts should be planted 4 to 6 inches apart, and to a depth of 1 to 2 inches below the graft union. It is also possible to use plastic mulch in the nursery. Irrigation should be available in case of need. If growth has started on grafted plants prior to being set in the nursery, irrigation will be necessary. After planting, hill-up-to the graft union with soil to a level just below the bud and retain the hill until late July or early August to protect against moisture loss. When the hill is removed, any scion roots which have developed should be removed. If the grafts are to remain in the nursery over-winter, the union should be recovered with soil for protection (7,11,12).

Freedom from disease, insects and weeds is necessary throughout the entire season. It may be desirable to plant a cover crop near the end of the growing season to aid in maturation and ripening of the shoots (7).

Nursery plants are dug either when dormant in the fall or prior to growth in the spring. Grafts are then bundled, labelled securely and stored prior to setting in the vineyard. Storage conditions are the same as for grafting wood (7).
**PSU BENCHGRAFTING METHOD**

MARCH 1-31

- OBTAIN DORMANT WOOD

CUT SCION AND ROOTSTOCK CUTTINGS

- 100/BUNDLE
  - 20-30cm

SOAK IN Fungicide

- CHINOSOL
  - 16 HR.

WRAP IN POLYETHYLENE

- APRIL 1-15
  - CUT-SCIONS-5cm

STORE AT 1°C

- DISRUPT ROOTSTOCKS

GRADE

APRIL 15-30

- RESOAK IN H₂O
  - 2 HR.

RECUR

- SCION-BASE
  - ROOTSTOCK-TOP

BENCHGRAFT

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Figure 1. Flow chart of grapevine benchgrafting method used at the Pennsylvania State University, Erie County Field Research Laboratory, North East, PA (8,13, 14), and utilized by the Department of Horticulture, The Ohio Agricultural Research and Development Center, Wooster, OH.
Figure 1. Flow chart of grapevine benchgrafting method used at the Pennsylvania State University, Erie County Field Research Laboratory, North East, PA (8,13, 14), and utilized by the Department of Horticulture, The Ohio Agricultural Research and Development Center, Wooster, OH.
Layering

Layering is another method of vineyard propagation. The most important use of layers in an established vineyard is to replace occasional missing vines. Competition with older vines may make it difficult to fill in vacancies with rooted cuttings (16). In addition, layering may be used to renew a trunk on an existing vine. Benefits of layering are: vines attain full production more quickly from layers; when renewing trunks by layers, crop loss may be avoided.

In vineyards a simple layer is used (9). The first step occurs during pruning. Select a long, vigorous, one-year-old, dormant cane from a vine adjacent to the missing vine or on the vine to be renewed. Tie the cane securely around the top trellis wire and mark well. When pruning the "mother vine", reduce the number of buds to compensate for the additional buds left on the layer.

In the springtime, bend the selected cane down and plant ten to twelve inches deep into the soil. the end of the cane should arise from the soil at the location desired for the new vine. Tie cane to trellis wires. Remove all growth during the growing season on the layered cane except the shoots that will form the trunk and vine structure. Be certain to remove growth on layered cane between "mother vine" and soil where layered cane arises. Tie the cane to the trellis to develop the vine into a straight trunk. Training of the new vine must begin the year the layer is made.

The new layered vine should not be allowed to bear fruit the first year, and only a limited crop the second year. Remove all flower clusters before bloom. Removal of fruit will enable the vine to produce better root and shoot growth. Generally the third year, the vine will be able to produce a normal fruit crop. It is important to maintain insect, disease and weed control on the layer.

The new layered vine should not be separated from the "mother" vine until it can support itself. This duration ranges from one to three years.

Layering of grapevines cannot be used to replace missing vines or renew vine trunks where vines must be grafted onto phylloxera- and/or nematode-tolerant rootstocks.
LITERATURE CITED


LITERATURE CITED (cont.)

It is common knowledge in Ohio, as well as the surrounding states, that diseases and insects are major problems in the production of grapes. Understanding these diseases and the chemical spray programs necessary to control them are the subject of several talks here at the 1981 Grape-Wine Short Course.

The topic I wish to address today deals with those cultural practices, which, in addition to chemical spray programs, can be employed to reduce the potential for destruction by diseases and insects in your vineyard. The goal is to help you align your entire program so as to minimize losses from these pests.

The first series of factors I wish to deal with cannot actually be called cultural practices but are items that should be considered and handled well in advance of planting. They come under the heading of site selection and include soil type, internal and external drainage, planting direction, slope of the land, etc. They are of value in the overall program and not just for pest control because they enhance frost protection, water movement out of the vineyard and general micro-climate.

A vineyard sloping to the south, either southeast or southwest, would begin its growth earlier in the year than one on a northern slope. It also follows that in a vineyard facing south and especially southeast, wet foliage would dry off earlier and faster on a given morning than one facing northwest. Conditions associated with free water allow for the rapid multiplication and spread of most of our grape diseases. Thus, in the case of rain or dew, this free water would be removed earlier in the morning on this southeastern slope and thereby, reduce the length of the potential infection periods.

Another factor involved in site is the row direction. If one is considering air movement through the vineyard, then orienting the rows into the direction of the prevailing wind would appear to be advantageous. One caution, however, on a given site running the rows across the slope must take precedence over facing the rows into the wind, but downhill, because of potential erosion. If the slope of the land is so slight that this would not matter, then both goals can be attained. All of these decisions would necessarily be made before the first vine was planted.

Before planting a vineyard, tests should also be made for nematodes or phylloxera to see if they are present in high populations. If so, the soil should be treated or fumigated (Fig. 1). As shown in Fig. 2, this will also have its impact upon weed control the first year. Injections are being made here with Vorlex. Other commercial soil fumigants can be used and include: methyl bromide with chloropicrin, nematicur, furadan, and others.

The next cultural practice I wish to discuss and one that significantly affects air movement through a vineyard is weed control. It should be obvious from Fig. 3 that movement of air through this vineyard would be very restricted due to excessive weed growth. A good chemical weed control program in the vineyard row plus frequent mowing or cultivation between rows, as shown in Fig. 4, is imperative. Both in relationship to disease and insect control, as well as in vine vigor and productivity. It has been proven, for example, that weed competition in a vineyard,
especially during the first 3-4 years can cause a very significant reduction in growth.

Some of the choices to consider by which the weeds can be controlled are: 1) the use of chemicals beneath the trellis plus a sod middle; 2) the use of chemicals beneath the trellis and a cultivated middle; 3) cultivation (by the grape hoe) under the trellis as well as in the middles; 4) chemical control throughout the entire vineyard. The prime consideration is, of course, not to let the weeds become a factor in affecting the season's growth. As shown by Fig. 4, it is rather obvious that air can move through this vineyard in a desirable manner, both down the row and underneath the trellis.

The weed control method that should be favored is the one that will develop the best actual control, cost the least and result in the best overall growing conditions. My personal preference is for the use of chemicals underneath the trellis row, combined with frequent enough mowing of a sod (bluegrass) to prevent serious dew and free moisture from remaining in the vineyard any longer than necessary. Such a program will reduce erosion as well as minimize competition for soil moisture between the vines and the sod. Sod middles with infrequent mowing results in nearly as bad a condition for air movement and soil moisture as tall weed growth. Bluegrass is my choice of ground cover, because of the minimal competition it offers during the hot summer months.

It should be rather obvious by now that another practice of importance in the vineyard which is directly related to air movement is the training system. As shown by Fig. 5, the trellis should be approximately 6 feet in height. This will allow good light exposure, as well as keep the vines off the soil surface during the major part of the growing season. The use of single curtain or double curtain training systems also has its advantages, as shown in Figs. 6 and 7, since the major portion of the foliage develops in the upper parts of the vine. Of course the average vineyard with moderate to good vigor may have shoots that grow long enough to reach the soil surface by season's end. This will vary considerably according to variety, as will be shown later.

The choice of the single or double curtain training system, not only results in the development of foliage in the upper part of the trellis, but fruit as well (Fig. 5). If both of these trellis and training systems are combined with shoot positioning, as recommended, a condition will result whereby sunlight as well as air movement will be enhanced.

The Umbrella Kniffin system, as compared to either the single or double curtain systems, allows for the development of fruit and foliage much closer to the soil surface (Fig. 8), simply because fruiting canes were placed lower on the trellis. For the more disease susceptible varieties, this is probably a disadvantage rather than an advantage.

Still another cultural factor that has relevance to the control of disease in the vineyard would be the selection of a variety. There is a wide range among varieties for resistance, or susceptibility, to disease. For example, it is well known that Chancellor is very susceptible to downy mildew. Aurora and Concord are very susceptible to black rot. Many cultivars of V. vinifera, as well as others, have susceptibility to both downey and powdery mildew. Thus, the considerations that can or should be made in lining out your vineyard would be to: 1) plant varieties with the least disease susceptibility; 2) put the most susceptible varieties in the locations with best air movement and sunlight exposure (greatest potential for foliage
drying, etc.) The growth habit of some of the French hybrids, and certainly most
cultivars of V. vinifera, are much more upright than those of Concord, Catawba,
Niagara, etc. As can be seen by Fig. 9, Concord vines can form a very heavy, dense
canopy over the trellis and severely restrict light underneath. This in turn, can
also restrict the penetration of the pesticides into the vines during application.

Varieties and vine spacing must interact in order to produce an adequate and
continuous canopy of foliage. But having either the rows or vines so close together
that light and/or air movement will be significantly restricted is a disadvantage.

Among some of the other varietal characteristics that relate to disease con­trol are cluster and berry size and compactness. As shown in the Figs. 10 and 11,
varieties such as DeChaunac, Concord, and/or Catawba have relatively loose, open
clusters, while Foch, Baco, Vidal and White Riesling are known to have very compact
clusters (Fig. 12). All of this can be accentuated within a variety by cultural
practices which promote increased productivity and fruit set, such as mechanical
cluster thinning and the use of Alar. Also, during seasons with above average mois­
ture, berry size will increase and tend to make clusters more compact. High mois­
ture conditions will also encourage excessive vegetative growth which in turn pro­
duces vines with poorly exposed leaves and clusters.

Another cultural practice that can influence disease as well as insect control,
is the use or rather the misuse of fertilizers. It is well established in the lit­
erature that nitrogen is the most needed element for good healthy, vigorous growth.
Yet this must all be balanced against the crop to be produced and the vigor desired
to fill the canopy and provide good leaf surface for the manufacture of carbohydra­
tes. The factor to be stressed here is not too little fertilizer, but generally
too much. As discussed previously, extensive vegetative growth becomes a problem
because long shoot growth, with large leaves and a canopy that restricts air move­
ment, is difficult to penetrate with most regular vineyard spraying equipment. The
use of foliar analysis in coordination with good observations on the growth, matur­
ity, etc., and common sense are the tools you should use to keep nitrogen levels in
balance.

It should be rather obvious by now from the way most of these factors inter­
relate that a balanced pruning program is also a valuable aid in 1) producing the
maximum crop from the vines, 2) maturing the fruit in good condition; and 3) main­
taining adequate but not overly vegetative shoot growth. Over-pruning labrusca
cultivars will result in lower production and excessive vegetative growth. French
hybrids, as have been discussed at several of our short courses, are much more dif­

ticult to over-prune. As a related item, removal of pruning wood during winter and
early spring is also to be encouraged. Diseases such as Eutypa dieback can be spread
by the presence of old stumps and pruning wood left in the vineyard.

In summary, it should now be obvious that there are many things that you can
and should do in your vineyard to reduce potential disease and insect problems, be­
sides applying a good chemical spray program. Careful and thorough preparation be­
fore planting will enable you to take maximum advantage of your site. Carrying out
all the cultural practices discussed here will not reduce but enhance the potential
of your vineyard to produce maximum quantities of high quality fruit. In other
words, keeping your vineyard well pruned, groomed and trellised, with good weed con­
trol under the row and mowed or cultivated between rows are things you should al­
ready be doing. Hopefully this discussion has just given you a few additional rea­
sons for getting them done properly.
Fig. 1. Soil fumigation prior to planting.

Fig. 2. Weeds will be greatly reduced the first year following fumigation.

Fig. 3. A vineyard with weed problems and poor air circulation.

Fig. 4. A vineyard with good weed control and good air circulation.

Fig. 5. A cordon training system which produces fruit relatively high on trellis.

Fig. 6. Some dormant vines trained to the Single Curtain system.
Fig. 7. Vines trained to the Geneva Double Curtain trellis system—shoot positioned.

Fig. 8. Dormant vines trained to the Umbrella Kniffin system.

Fig. 9. Concord vines with dense foliage canopy.

Fig. 10. Typical loose clusters of DeChaunac grapes.

Fig. 11. Typical clusters of Catawba grapes.

Fig. 12. Typical tight clusters of Foch grapes.
The rose chafer, *Macrodactylus subspinosus*, is at times a serious pest of vineyards in Northeastern North America. It occurs most commonly in light sandy soils where the immature stages feed on grass roots. Although the adults attack numerous fruit and ornamental plants they probably are more destructive to grapes than any other crop. Adults emerge from the soil at the same time grapes bloom in the spring. They fly directly to blossom clusters before, during, and after bloom. Damage to grapes is caused by the feeding of the adults on blossom buds and flowers. They also attack the foliage and may nearly defoliate susceptible, thin-leaved cultivars. However, damage to the foliage of 'Concord' and thick-leaved cultivars is usually minimal.

Johnson in 1940 reported trapping large numbers of rose chafer in Japanese beetle traps but did not mention the attractant used. Food-type chemical attractants for the Japanese beetle have been extensively studied for many years in the U.S. to identify chemicals for use in survey and control.

Since the rose chafer is an economic pest, a bait suitable for monitoring adult populations would be useful. In this study we evaluated a number of candidate lures to determine their potential as a rose chafer attractant.

Attractiveness of various aromatic compounds to adult rose chafer was evaluated in a two-year series of tests near a 'Concord' vineyard in North Kingsville, Ohio. The trip placement shown here was similar to that used throughout this research. Lures consisted of dental wicks, 13 mm diameter and 25 mm long saturated with the candidate compounds. Lures were placed in standard Ellisco Japanese beetle traps. Traps were suspended ca. 1 m above ground from steel rods and spaced 8 m apart. Each candidate lure was replicated 4 or 8 times in randomized complete blocks.

In 1979 two separate experiments were conducted. A preliminary experiment was undertaken to determine if the rose chafer was trappable and to assay several candidate compounds. In this experiment, we tested the following lures that are attractants for the Japanese beetle: Phenethyl propionate (PEP) + Eugenol (7:3), Eugenol, Eugenol + Geraniol (1:1), Phenethyl Butyrate (PEB), and Eugenol + Caprioc Acid (1:1). The captures were interesting, but not spectacular except the mixture of Eugenol + Caprioc Acid. PEB and Eugenol, by themselves and in combination with other compounds, showed little attractancy.

In the second experiment, following a similar experimental design, PEB, Eugenol, Caprioc Acid, Caprioc Acid + Eugenol (1:1), PEB + Eugenol (1:1), females, and a check were compared. In order to determine if females produce a sex attractant, we placed five females in traps along with the wet dental wick. Virgin females were unobtainable; however, we assumed that this would be of little consequence, since females mate several times. The control consisted of a dental wick saturated with water. Each chemical was replicated eight times in the aforementioned manner. Traps were rebaited on alternate collection periods.

During subsequent trapping periods after June 16, the addition of Eugenol to Caprioc Acid had no impact on its attractancy. Both Eugenol + Caprioc Acid and Caprioc Acid captured beetles in significantly greater numbers than any of the other
lures tested (Table 1). The number of beetles captured in traps containing females was not significantly greater than in the control. Since the females used were not virgin females, these results did not eliminate the possibility of a sex attractant for the rose chafer as pheromone production may cease after an initial mating encounter.

Results of the 1979 tests influenced the selection of candidate lures in 1980. All lures were straight chain carboxylic acids including butyric, valeric, capric, and heptanoic acids. Eight traps, each a replicate, were placed at the same site as in 1979. All lures were exposed in the same manner as in the previous year. Beetles were collected on alternating three and four day intervals and traps were rebaited weekly.

Table 2 presents the mean captures of beetles for the 1980 experiments consisting of 7 trapping periods, ranging from June 9 to July 3. Valeric acid showed a slightly greater attractancy than capric acid, although the difference was statistically significant in only one trapping period. None of the other lures attracted a significantly greater number of beetles than did the control.

The data presented in this paper indicate that use of either Capric Acid or Valeric Acid in Ellisco Japanese beetle traps could be used for detecting and monitoring rose chafer populations. Further study will be needed to test whether these lures are effective enough to be used in mass trapping or can be developed for predicting population density and subsequent crop damage.

Literature Cited

Table 1. Attractiveness of selected baits in Ellisco traps to rose chafer beetles in Ashtabula County, Ohio, May 31-July 6, 1979.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average No. Beetles per Trap&lt;sup&gt;a/b&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>May 31-June 13</td>
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<tr>
<td>Eugenol/Geraniol (1:1)</td>
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<td>PEP/Eugenol (7:3)</td>
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<tr>
<td>PEB</td>
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</tr>
<tr>
<td>Eugenol</td>
<td>5.2</td>
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<tr>
<td>Eugenol/Caprioe Acid (1:1)</td>
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<tr>
<td>Caprioe Acid</td>
<td>--</td>
</tr>
<tr>
<td>PEC/Eugenol (1:1)</td>
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</tr>
<tr>
<td>Females</td>
<td>--</td>
</tr>
<tr>
<td>Check (empty traps)</td>
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</tr>
</tbody>
</table>

<sup>a</sup> Data for first two trapping periods are averages of 4 traps per compound; for last 4 periods, data are averages of 8 traps per compound.

<sup>b</sup> Means followed by the same letter are not significantly different at 5% level by Duncan's New Multiple Range Test.
Table 2. Attractiveness of various carboxylic acids in Ellisco traps to rose chafer beetles, Ashtabula County, Ohio, June 9-July 3, 1980.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>June 9-13</th>
<th>June 13-16</th>
<th>June 16-20</th>
<th>June 20-23</th>
<th>June 23-27</th>
<th>June 27-30</th>
<th>June 30-July 3</th>
<th>Total</th>
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<tr>
<td>Valeric</td>
<td>8.0 ab</td>
<td>59.0 c</td>
<td>62.9 b</td>
<td>76.0 b</td>
<td>96.3 b</td>
<td>34.4 c</td>
<td>10.9 b</td>
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<td>Caprioc</td>
<td>10.4 b</td>
<td>49.1 bc</td>
<td>57.6 b</td>
<td>63.4 b</td>
<td>82.4 b</td>
<td>23.4 b</td>
<td>8.6 b</td>
<td>294.9</td>
</tr>
<tr>
<td>Butyric</td>
<td>4.1 a</td>
<td>27.8 ab</td>
<td>16.5 a</td>
<td>28.9 a</td>
<td>39.8 a</td>
<td>11.0 a</td>
<td>3.0 a</td>
<td>131.1</td>
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<tr>
<td>Heptanoic</td>
<td>2.9 a</td>
<td>26.8 ab</td>
<td>20.5 a</td>
<td>26.1 a</td>
<td>36.4 a</td>
<td>7.8 a</td>
<td>2.1 a</td>
<td>122.6</td>
</tr>
<tr>
<td>Check</td>
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<td>19.4 a</td>
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<td>6.3 a</td>
<td>1.3 a</td>
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</table>

a/ Data are averages of 8 traps per compound.

b/ Means followed by the same letter are not significantly different at 5% level by Duncan's New Multiple Range Test.
Eutypa dieback of grapevines, formerly called "dead arm", was for many years thought to be caused by the fungus Phomopsis viticola. Recently, however, the fungus Eutypa armeniacae (imperfect stage: Cytosporina) was shown to cause the cankers and dieback symptoms previously associated with "dead arm". Phomopsis viticola is still recognized as the cause of cane and leaf spot and occasional fruit rot. Eutypa dieback has been reported on grapes for several grape-growing regions of the world and is also an important disease of apricot.

The foliar symptoms of Eutypa dieback are characterized by stunted shoots with cupped leaves that are frequently yellowish. Leaves may cup upward or downward. The cupped leaf symptom of Eutypa dieback distinguishes this disease from symptoms of winter injury where injured buds may throw stunted shoots bearing small leaves. Marginal or interveinal chlorosis and necrosis can also be part of the symptom expression on leaves affected by this disease.

Eutypa dieback initially affects only a portion of the vine; but over a period of years the symptoms become progressively worse until the affected arm or the entire vine dies. It seems logical that severe winters might result in more dead infected vines or arms due to their weakened state caused by the disease. Foliar symptoms are most easily found early in the growing season when healthy shoots are 12 to 30 inches long. As the season progresses, healthy shoots tend to overgrow diseased shoots, hiding them. In some cultivars, as diseased shoots continue to grow, new leaves appear normal and by mid-August affected vines might appear healthy.

Foliar symptoms of Eutypa dieback are always accompanied by one or more cankers that frequently surround old pruning cuts on trunks or cordons. The cankers are not obvious although the trunk may become flattened in the canker area as the healthy portion of the trunk continues to grow. When the bark is removed, the canker becomes obvious and appears as a brown area in the wood surrounded by white healthy wood. The canker tends to extend more rapidly with the long axis of the trunk rather than laterally. In cross section the canker appears wedge-shaped. The canker may extend the entire length of the trunk and it may extend below ground. To confirm Eutypa dieback, wood chips from the canker margin must be plated on agar and the subsequent fungal growth must be properly identified.

Since the fungus cannot be isolated from shoots and leaves showing symptoms, and since a line of vascular tissue can usually be traced from the canker to the shoots showing symptoms, it is suspected that a toxin is produced in the canker and is translocated up the vascular system to developing shoots. Infection and canker development usually precede foliar symptom development by three or four years.

Winter-injured trunks might be confused with cankers caused by Eutypa, but if studied carefully one can see a distinction between the two. If winter-injured, the entire trunk is usually affected; or if only one-sided (southwest injury), the necrosis does not follow the vascular pattern and twist around the trunk. Furthermore, the dead tissue usually ends abruptly, such as at the snow line, and does not gradually decrease to a point, so typical of cankers caused by Eutypa.

The infectious spores of Eutypa are found in old, dead grapevine stumps infect-
ed previously with the fungus. After the bark weathers away from the canker area and the dead wood is exposed, the fungus produces a thin, hard, black growth on the surface of the dead wood. This black tissue is called a stroma and within it the fungus produces spherical fruiting bodies called perithecia. Perithecia are produced abundantly in this stromatic tissue and if a sharp knife is used to cut through the surface of the stroma, the numerous perithecia have a honey-comb appearance (as observed through a 10X hand lens). If the stromatic tissue is moistened, the contents of the perithecia absorb water, swell, and appear shiny black.

The infectious spores of the fungus, called ascospores, are formed in sacks within the perithecia. There are eight ascospores per sack and when the perithecia are wet, ascospores are forcibly ejected into the air where they are picked up by air currents and disseminated great distances. These spores are produced abundantly and can be found on dead grapevine stumps in many eastern vineyards.

Ascospore release by Eutypa has been studied at Geneva by placing Concord grape stumps, bearing fruiting bodies of the fungus, around a spore trap. The spore trap was in continuous operation from November 1977 to November 1980. The results of the study indicated that ascospore release is triggered by water, continues throughout rainy periods, and stops when stumps dry.

These studies also revealed that ascospore release could be triggered by water from snowmelt. This fact was discovered when the spore trap was buried in a drift during a snowstorm. Heat generated by the vacuum pump motor on the trap melted snow around its base and stumps became wet enough to stimulate spore release. Daily records from March 1978 indicated natural spore release occurred during snowmelt in the absence of rain.

Monthly totals for rainfall and spore numbers revealed a seasonal pattern for spore release. Data from 1978 and 1979 indicated that the greatest numbers of spores were released in January, February, March and April. Therefore, spore release occurs when most grapevine pruning is in progress, a significant factor since this is a wound pathogen. Furthermore, we have successfully inoculated vines pruned the beginning of December through the end of April.

At present, the recommendations for controlling Eutypa dieback involve cultural practices. As mentioned previously, fruiting bodies of Eutypa can be found on dead weathered grapevine stumps. When these stumps are left in the vineyard, chances of spreading the disease increase. Therefore, dead stumps and excised trunks should be removed from the vineyard and destroyed by burying or burning. A pile of dead vines left at the end of the row or in the woods will provide inoculum for many years and perpetuate the infection of healthy vines.

The double trunk system of training, in which each trunk is pruned to carry half the number of buds, has been a useful system for minimizing crop loss from infected trunks. When one trunk must be removed because of disease, the remaining trunk can be pruned leaving the full number of buds until a second trunk can be re-established. Since it takes three to four years after infection before infected vines show foliar symptoms, it is wise to vary the ages of the two trunks.

Infected trunks or cordons should be removed early in the growing season when shoot symptoms of Eutypa dieback are most obvious (May and June). Trunk removal at this time is recommended because wounds are less susceptible to infection during the growing season and the availability of ascospores for reinfection is at a minimum. When the trunk or cordon is removed, the cut should be made well below the
canker area in healthy wood. The cut surface should be protected from reinfection by painting with a wound dressing. If the canker has extended below the level from which shoots will develop or trunk renewal or if the canker is well below ground, the grower should consider replacing the vine since renewal trunks are likely to become infected. Trunks and cordons cut from vines should be removed from the vineyard and destroyed.

The practice of renewing old trunks during the normal pruning season, when large pruning cuts are exposed to high levels of inoculum, may be one explanation for canker development at the base of vines in some vineyards. The following approach to trunk renewal might be worthwhile in vineyards with a history of Eutypa dieback. Cut off the trunk to be removed several inches above ground during the normal winter pruning period. Since infection of the remaining stub by Eutypa is a possibility, remove the remaining stub during the growing season when inoculum potential is low. This procedure 1) eliminates infection at the pruning wound made during winter, 2) removes the trunk stub as a site for future inoculum production, 3) provides a fresh wound that is less susceptible to infection while the vine is growing, and 4) is done when spore production is low.

Recent research at Geneva indicated that Benlate 50W painted on pruning wounds the day of pruning would prevent infection by Eutypa. Pruning cuts in two-year-old wood were treated with a 2.4% suspension of Benlate 50W (1/5-1b Benlate per gallon of water) the day of pruning and inoculated with Eutypa ascospores the following day. One year later, Eutypa was recovered from 92%, 100% and 75% of the inoculated pruning wounds in Concord, Catawba and Aurore, respectively; but it was recovered from only 15%, 7% and 0% of the Benlate treated, inoculated pruning wounds in the same cultivars. Benlate treatment provided 84%, 93% and 100% control of Eutypa infection in Concord, Catawba, and Aurore, respectively. Benlate is not presently registered for this use, but we hope to have it labeled for use next year. Although one- and two-year-old wood is susceptible to infection, yearly pruning probably removes infected wood before symptoms develop so painting all pruning wounds would not be necessary. The use of Benlate would be recommended only where large pruning wounds are made on the main trunk or on cordons of the vine, such as in trunk renewal, grafting, or retraining. For best results, the fungicide must be applied to the cut surface as soon as possible, and certainly before a rain.

At present, experiments are in progress to determine 1) the time of year when vines are most susceptible to infection, 2) the length of time pruning wounds are susceptible to infection, 3) the relative susceptibility of various cultivars, 4) the effectiveness of various wound dressings and fungicides, and 5) the best cultural practices to use in renewing trunks and preventing their infection.
DISEASE--A MAJOR FACTOR LIMITING GRAPE PRODUCTION IN OHIO

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In 1859, Ohio led the nation in grape production. Major vineyards were located in Southern Ohio near Cincinnati and eastward along the Ohio River. In 1870, these vineyards were abandoned due, primarily, to the inability to control diseases such as black rot and downy mildew.

Today, Ohio's grape and wine industry has regained importance in the state's economy and is continuing to grow. Much of the growth in the grape industry is due to the development of effective fungicides and disease control recommendations. At present, all grape cultivars commercially grown in Ohio are susceptible to black rot and downy mildew. Furthermore, commercial plantings of French hybrids and vinifera cultivars are increasing substantially, and these are generally more susceptible than American hybrids. Even with the development of more effective fungicides, diseases still remain a major factor limiting grape production in Ohio. This is especially true in Southern Ohio where environmental conditions are highly conducive to disease development.

Black rot, downy mildew and powdery mildew are still the most destructive grape diseases in Ohio. Once introduced into the vineyard, they can result in 100 percent loss of fruit under the proper environmental conditions. By developing a better understanding of these diseases, a grower should be more effective in controlling them. The purpose of this paper is to review the symptoms, disease cycles and control recommendations for each of these diseases.

BLACK ROT

Black rot is probably the most common and serious disease of cultivated and wild grapes in Ohio. The disease affects all green parts of the vine (leaves, shoots, leaf and fruit stems, tendrils, and fruits). The most damaging effect is to the fruit.

Early infections can destroy blossom clusters or cause developing berries to fall off the cluster.

Later infection periods can destroy a high percentage of the berries, turning them into hard, black, shriveled "mummies". When warm muggy weather in the spring and summer is prolonged, unsprayed grapes may become almost completely rotted by harvest.

Symptoms

On leaves, reddish-brown, circular-to-angular spots appear in the late spring. When several spots merge they form irregular, reddish-brown blotches. The number of spots or lesions per leaf may vary from 1 to more than 100, depending on the severity of the infection. The center of the leaf spot turns tannish-brown and is surrounded by a black margin (Fig. 1). Fungus fruiting bodies (pycnidia) that are speck-sized and black appear as if arranged in a definite ring just inside the margin of the spot. Only young, rapidly growing leaves are susceptible to infection.

Fruit infections can take place shortly after the calyptra falls, but most in-
Infections occur when the fruit is half to nearly full size. A small, circular, whitish spot, which is soon surrounded by a brown ring, first appears on the berry—usually while it is still green. The spots enlarge rapidly, darken, and may cover half of the berry within 48 hours. The center of the spot rapidly becomes sunken, wrinkled, and dark. Within a few days, the entire berry becomes coal black, hard, and "mummified" (Fig. 2). Most diseased fruit "shell" or shatter and drop early. The surface of withered fruit is soon covered with minute, black, pimple-like pycnidia.

Lesions may also develop on young shoots, cluster stems, and tendrils. The lesions on these parts are dark purple to black, oval to elongated, and somewhat sunken. The speck-sized black pycnidia are found scattered over the surface of the lesions. If the berry stem is infected early, the flow of sap is shut off and the berry fails to develop.

**Disease cycle**

Black rot is caused by the fungus, Guignardia bidwellii. The black rot fungus overwinters in canes, tendrils, and leaves on the vine or on the ground. Mummified berries which are on the ground or still clinging to the vines become the major source of infection in the spring. During rains, microscopic spores (ascospores) are shot out of numerous, black fruiting bodies called perithecia, and are carried by air currents to the young expanding leaves. In the presence of moisture the ascospores germinate slowly, often taking 36 to 48 hours, and then penetrate the young leaves and fruit pedicels. The infections become visible in 8 to 25 days. The spots usually appear on the lower leaves first. When the weather is moist, ascospores are released throughout the entire spring and summer, providing for continuous primary infection.

Every leaf spot contains a number of pycnidia, each of which produces hundreds of summer spores (conidia) that ooze out in winding tendrils during wet weather. The splash of raindrops spreads these spores to other leaves and to the young fruit. If water is present, the conidia germinate and penetrate young tissue. Black rot infections continue as long as the rains of late spring and summer continue. The conidia are capable of germinating and causing infection several months after being formed.

After early August, the pycnidia are transformed into an overwintering stage (pycnosclerotia) which, in turn, gives rise to perithecia within which the spring spores (ascospores) are produced. This completes the disease cycle.

**Downy Mildew**

Downy mildew is one of the most serious grape diseases in Ohio and throughout the Midwest. The disease develops whenever weather during the growing season is humid, rainy and temperatures are cool to moderate. The optimum temperature for disease development is 64 to 70°F (18 to 24°C), a minimum of 54 to 58°F (12 to 13°C), and a maximum of about 86°F (30°C). The downy mildew fungus attacks leaves, fruit, shoots and tendrils. The disease may cause premature defoliation in middle to late summer that results in a weakening of the vine and reduced sugar content of the fruit. Fruit infection may result in berries unfit for eating or marketing. Under favorable conditions for disease development, 50 to 75% of the fruit crops may be destroyed if the disease is not controlled. All common species of wild and cultivated grapes (Vitis species) are susceptible. The European grape (V. vinifera) is generally more susceptible than cultivated American grapes. French hybrids are
somewhat intermediate.

Symptoms

On leaves, young infections are very small, greenish-yellow, translucent spots that are difficult to see. With time the lesions enlarge, appearing on the upper leaf surface as irregular pale-yellow to greenish-yellow spots up to 1/4 inch or more in diameter (Figure 3). On the underside of the leaf, the fungus mycelium (the "downy mildew") can be seen as a delicate, dense, white to grayish cotton-like growth. Infected tissue gradually becomes dark brown, irregular, and brittle. Premature defoliation exposes the berries to sunscald, and if the vine loses its leaves before the fruit ripens, the berries do not mature normally. Usually the older leaves in the center of the vine are the first to show symptoms.

On fruit, most infection occurs during two distinct periods in the growing season. The first is when berries are about the size of small peas. When infected at this stage, young berries turn light brown and soft, shatter easily, and under humid conditions are often covered with a downy-like growth of the fungus (Fig. 4). Generally, during hot summer months little fruit infection occurs. As nights become cooler in late summer or early autumn, the second infection period may develop. Berries infected at this time generally do not turn soft or become covered with the downy growth. Instead, they turn dull green, then dark brown to brownish-purple. They may wrinkle and shatter easily and, in severe cases, the entire fruit cluster may rot.

On shoots and tendrils, early symptoms appear as water-soaked, shiny depressions on which the dense downy mildew growth appears. Young shoots are usually stunted, become thickened and distorted. Severely infected shoots and tendrils usually die.

Disease Cycle

The fungus, Plasmopara viticola, overwinters in infected leaves on the ground, and possibly in diseased fruit or shoots. The overwintering spore (oospore) germinates in the spring and produces a different type of spore (sporangium or conidia). These sporangia are spread by wind, splashing rain, and by handling wet plants. When plant parts are covered with a film of moisture, the sporangia germinate and penetrate the lower surface of young leaves, shoots, tendrils and blossom clusters, resulting in primary infection. Once inside the plant the fungus grows and spreads through tissues. In time, the fungus grows out of infected tissue and produces microscopic, branched, tree-like structures (sporangioptores) on the surface of the leaf. On the tips of these tree-like structures more spores (sporangia) are produced. The small sporangiophores plus sporangia make up the cottony, downy mildew growth. These sporangia are spread and cause secondary infections.

At the end of the growing season, oospores are formed in old diseased tissue and the fungus overwinters as oospores until the next spring.

POWDERY MILDEW

Powdery mildew is a disease that occurs in many vineyards, but is generally considered to have a little economic importance in Ohio on most bunch grape varieties, such as Concord. However, on some varieties such as Seneca, Interlaken, and many French hybrids, powdery mildew can cause severe losses. The disease can affect any new growth on susceptible varieties but is most conspicuous on leaves and fruit.
Berry infection may result in fruit unfit to eat.

**Symptoms**

On leaves, small, white patches of fungal growth appear. Usually, these patches enlarge until the entire upper leaf surface has a powdery, white to gray coating (Fig. 5). In some cases the patches remain limited throughout the greater part of the season. Severely affected leaves may curl upward during hot, dry weather.

On young vines the patches are more likely to be limited but have the same general appearance as on the leaves. Later in the season, these areas become discolored, at first brown and later almost black. If blossom clusters are affected, the flowers may wither and drop without setting fruit. Affected berries may have spots on the surface similar to those on the leaves, or the entire berry may be covered with the white, powdery growth (Fig. 6). Infected berries are often misshapen or have rusty spots on the surface. Severely affected fruit have a tendency to split open. As the fruit approaches maturity it becomes immune to the disease. Late in the season, many black specks may develop on the surface of infected areas. These are the sexual fruiting bodies (cleistothecia) of the fungus.

**Disease Cycle**

Powdery mildew of grape is caused by the fungus, *Uncinula necator*. The fungus overwinters as cleistothecia or as spores or mycelium in sheltered areas on shoots or fallen leaves. In the spring, spores (ascospores) are released from cleistothecia that survived the winter. Ascospores are carried by wind to any green surface on the developing vine, where they germinate and penetrate into the plant. The fungus grows and another type of spore (conidia) are soon formed over the infected area. The conidia and fungus mycelia upon which they are formed give the powdery or dusty appearance to infected plant parts. Conidia are spread by wind and cause additional infections.

Unlike most other grape diseases, powdery mildew is considered a "dry weather" disease. It is generally a greater problem in dry areas or dry seasons when most other grape diseases are usually not present. The fungus grows rapidly at temperatures between 70 and 90°F, but is slowed down at higher or lower temperatures.

**CONTROL**

The use of fungicides for disease control is an important part of the overall grape production program. However, we must remember that various cultural practices can be equally important in obtaining effective disease control. Through the integrated use of specific cultural practices and properly timed applications of the proper fungicides, we should be able to effectively control these destructive grape diseases.

**Cultural Practices**

1) **CHOOSE A PLANTING SITE WITH GOOD SOIL DRAINAGE AND AIR CIRCULATION.**

Water is essential for the development of most plant diseases caused by fungi. The quicker vines, foliage and fruit dry off following dew, rain, or overhead irrigation, the less chance for black rot and downy mildew to develop. Select open sunny areas and avoid shady areas. If possible, plant rows with the prevailing wind in order to promote better
air circulation and faster drying.

2) MAINTAIN GOOD WEED CONTROL IN THE VINEYARD. Weeds not only compete with the vines for water and nutrients, they also make excellent windbreaks that can greatly reduce air circulation within the vineyard. Heavy weed populations below the vines tend to hold water longer, and therefore, increase drying time. Increased drying time can lead to increased incidence of black rot and downy mildew.

3) PRUNE AND TRAIN VINES PROPERLY IN SUCH A WAY AS TO REDUCE SHADING AND INCREASE AIR CIRCULATION. Excessive foliage within the row can increase the chances of disease development. Increased shading and reduced air circulation result in slower drying time and increased disease incidence. In addition, excessive foliage will reduce the penetration of pesticides (fungicide) into the row. This results in poor coverage and increased disease incidence. If vines are allowed to fall on the ground, the surfaces of leaves that are in contact with the ground dry very slowly. Leaves that are in contact with the ground or are buried in dense weeds are generally "hot spots" for black rot and downy mildew.

4) SANITATION. All three of these diseases overwinter within the vineyard either in old berries (mummies), dead leaves on the ground, or infected shoots and tendrils. Any practice that will destroy or remove mummies and old dead leaves on the ground will decrease disease inoculum levels for the following season and aid in decreasing disease incidence. When pruning, remove diseased tendrils from the wires and select healthy looking fruiting canes that are free of lesions and discoloration.

5) GRAPE VARIETIES DIFFER IN SUSCEPTIBILITY TO THESE DISEASES. None of the commercial grape varieties produced in Ohio are resistant to these diseases, but some are much more susceptible or sensitive to them than others. In general, European grapes (Vitis vinifera) are much more susceptible than cultivated American grapes. French hybrids are somewhat intermediate.

Fungicide Sprays

In order to produce grapes in Ohio (especially southern Ohio), a good fungicide spray program is essential. An effective fungicide spray program must consider: 1) correct disease identification, 2) selection of the proper fungicide, 3) proper timing of application, and 4) thorough coverage of all susceptible plant parts.

A discussion of these points is available in the Proceedings of the 1980 Ohio GrapeWine Short Course. For the most current fungicide recommendations and spray schedules in Ohio, commercial growers are referred to Bulletin 506, "Ohio Commercial Fruit Spray Guide" of the Ohio Cooperative Extension Service, The Ohio State University, Columbus, OH 43210.
Figure 1. Typical dark bordered leaf spots of black rot.

Figure 2. Different stages of black rot development on fruit. Note the black, shriveled mummies.
Figure 3. Leaf spots on upper leaf surface caused by downy mildew.

Figure 4. Berries infected by downy mildew. Note the white fungal growth on fruit surface.
Figure 5. Grape leaf infected with powdery mildew. Note the white, powdery layer of fungal growth on the upper leaf surface.

Figure 6. Fruit infected by powdery mildew.
POWDERY MILDEW AND BUNCH ROT OF GRAPES -
AN UPDATE OF RESEARCH IN NEW YORK

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New York State Agricultural Experiment Station

Powdery Mildew

Powdery mildew, caused by Uncinula necator and referred to as Oidium in Europe, is a disease familiar to grape growers around the world. It attacks all green tissue, but it is most obvious on leaves. We generally think of powdery mildew as a white powdery covering on vine parts, but on canes it appears dark brown-to-black. It is easily seen on green immature canes, but it also can be found on mature canes during the pruning season. Powdery mildew on the fruit is the most destructive phase of this disease. If infection of fruit of susceptible cultivars, such as Aurore, occurs shortly after fruit set, the berry stops growing and it may abort. If infection occurs when the berry is pea size or larger, the epidermis or skin stops growing, but the contents continue to expand, and the berry splits. Early season berry infection can result in total crop loss. Once the berry reaches veraison and accumulates sugar, it is no longer susceptible to infection by the powdery mildew fungus.

During the past two years, we have been investigating the short-term and long-term effects of powdery mildew on yield, fruit quality, and vine vigor with the ultimate goal of establishing economic threshold levels for this disease. This investigation has been a cooperative project between the Departments of Plant Pathology, Pomology and Viticulture, and Agricultural Economics and has been supported by the USDA's Northeast Pesticide Impact Assessment Program. In field trials, we have used Benlate on different schedules as a tool to encourage the development of mildew at different times during the season. Early-season sprays were applied during June, mid-season sprays were applied in July, and late season sprays were applied in August. These treatments were compared to full-season sprays or no sprays. Not until the second year of these treatments did significant crop reduction occur in the nonsprayed plots compared to the rest of the treatments, although vines on the full-spray program had the highest yields in both years. Vines on the late-season spray program had the lowest yield compared to vines sprayed earlier in the season.

Vine vigor, as measured by pruning weight, was affected by the treatments in the first year and was even more pronounced in the second year. Vine size in the nonsprayed plots was significantly lower than that in the sprayed plots. Among the sprayed plots, the full-season program promoted the best growth and there was no significant difference among the early, mid- or late-season spray programs.

Soluble solids (°Brix) was determined as a measure of fruit quality. The nonsprayed vines had the lowest Brix readings in the first season, but in the second season they had the highest readings. Apparently a reduced crop and greater light exposure accounted for the high Brix readings in the fruit that developed on nonsprayed vines. A similar trend was observed in the late-season sprayed vines. The highest Brix readings and largest yields were observed in the plots receiving midseason or full-season sprays. If a grower chooses to omit sprays, omission of late-season sprays would be least detrimental. Mid-season sprays appear to be most important, but early sprays are beneficial.
In recent years, benomyl has become increasingly popular as a fungicide for control of powdery mildew. Growers have been pleased with the effectiveness of benomyl and the absence of injury, which can occur with use of alternative mildewicides; furthermore, growers have recognized the added benefit of oxidant stipple control and compatibility with commonly used insecticides.

The history of benomyl usage has been longest in Experiment Station vineyards where control of powdery mildew was exceptional for many years. However, in 1977 and 1978 at Fredonia, control started declining and in 1979 it was greatly reduced. The field experience of 1977 and 1978 suggested that the possibility of resistant strains should be investigated.

To test for benomyl-resistant strains of the powdery mildew fungus, the foliage of potted Riesling cuttings at the 7-8 leaf stage was dipped in a suspension of benomyl at 600 ppm (equivalent to one pound Benlate 50W in 100 gallons of water) and air-dried. Benomyl-treated and nontreated vines were then inoculated with a spore suspension of the test fungus and incubated. Sensitive strains of the fungus grew only on the nontreated vines, whereas resistant strains grew equally well on both the Benlate-treated and the nontreated vines.

Benlate at 1 lb/acre was compared to Karathane (dinocap) at 1 1/4 lb/acre in a field trial on Delaware grapes at Fredonia during 1979. On the basis of canopy surface area infected with powdery mildew and percent clusters infected with powdery mildew, there was no difference between the Benlate treatment and the nontreated check, whereas the low rate of Karathane provided considerable control (Trial A, Table 1).

The unanswered question among researchers and extension people is how to prevent the buildup of fungicide-resistant strains. Two approaches to preventing resistance have been suggested. Some suggest the combination approach where benomyl is combined with another material, either at full rates or at reduced rates. The full-rate approach is expensive, but more likely to be effective. If the reduced-rate-combination approach is followed, one must be careful in choosing the proper fungicide because the effectiveness of the combination is dependent on the relative effectiveness of each component (Table 1, benomyl-sensitive strains). For example, we found that reduced rates of Benlate and Folpet in combination were inadequate for controlling benomyl-resistant strains of the powdery mildew fungus, but the reduced-rate-combination of Benlate and Karathane was more effective, although not fully satisfactory (Trials B and C, Table 1).

The other approach is to alternate fungicides throughout the season. The grower would apply the full rate of one mildewicide in one application and the full rate of another unrelated mildewicide in the next application. Unfortunately, we do not have experimental data indicating either approach will guarantee freedom from resistance. We feel the important points are: 1) that Benlate not be used as the only mildewicide in a season-long program; 2) that an effective mildewicide unrelated to Benlate be used during the season; and 3) that all sprays be applied at the recommended rate per acre.

Two new fungicides that have shown promise for use on grapes to control powdery mildew and black rot are Bayleton from Mobay Corp. and CGA-64251 from Ciba Geigy Corp. In field trials at Fredonia, where Benomy1-resistant strains of the powdery mildew fungus were prevalent, both Bayleton and CGA-64251 controlled the disease. In a trial on Aurore, Bayleton and CGA-64251 on a full-season program of six sprays, starting one week before bloom, provided better control than the standard ferbam +
TABLE 1. Control of benomyl-sensitive and benomyl-resistant strains of grape powdery mildew in the field.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dosage (formulated) (lb/acre)</th>
<th>% Canopy surface area infected</th>
<th>% Clusters infected</th>
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<tr>
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<td>100a</td>
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<td>4c</td>
<td>1d</td>
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<td>2d</td>
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<td>Folpet 50W</td>
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<td>34b</td>
<td>76b</td>
</tr>
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<td>8c</td>
<td>4d</td>
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Benomyl-resistant strains:

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<td>100a</td>
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<tr>
<td>Karathane 19.5W</td>
<td>1.25</td>
<td>15b</td>
<td>76b</td>
</tr>
<tr>
<td>Benlate 50W + Karathane 19.5W</td>
<td>0.5 + 0.75</td>
<td>21b</td>
<td>75b</td>
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</table>

Values followed by the same letter do not differ significantly, (P \(\leq 0.05\)).

\(y\) Trial on Delaware grape at Geneva, N.Y. Treatments applied on June 27, July 11, 24 and August 17, 1979.

\(z\) Trial A on Delaware grape at Fredonia, N.Y., treatments applied on June 29, July 12, 23 and August 21, 1979; Trial B on Concord grape at Fredonia, N.Y., treatments applied on June 29, July 12 and August 17, 1979; and Trial C on Concord grape at Westfield, N.Y., treatments applied on July 2, 26 and August 12, 1979.
sulfur spray. Because of the development of benomyl resistance in some vineyards and the effectiveness of Bayleton on benomyl-resistant strains in 1979, we obtained a Section 18 in 1980 to permit the commercial use of Bayleton on a limited basis where benomyl resistance was suspected.

Recently there has been a lot of interest in flowable sulfurs and flowable copper sprays. In a trial on Delaware, flowable sulfur at 2 qt per acre (equivalent to 3 lb sulfur per acre) was significantly better than wettable sulfur at 4 lb per acre and at 1 qt per acre (equivalent to 1 1/2 lb sulfur per acre) provided control equivalent to the 4 lb per acre rate of wettable sulfur. A trial was also established to determine whether flowable sulfurs were less phytotoxic to Concord foliage than wettable sulfurs. Unfortunately, the results indicated that the flowable formulation was even more phytotoxic at equivalent rates. Top Cop, the flowable copper-sulfur combination, failed to control powdery mildew at the rates tested, whereas 2 lb of copper plus 8 lb lime per acre provided good control. Furthermore, the Top Cop formulation caused severe leaf bronzing on Concord.

Generally, in New York the preferred fungicide for control of powdery mildew is sulfur on those cultivars that can tolerate it. Other fungicides used to control powdery mildew are copper plus lime, benomyl, Karathane and folpet. The choice is dependent on the cultivar, time of the season, disease severity, and cost of material.

**Botrytis Bunch Rot**

Bunch rot of grapes is a problem in most grape-growing regions of the world. The list of microorganisms associated with rotting berries is extensive, but not all rot organisms occur in each geographical region of the world. In New York State, most bunch rot has been attributed to Botrytis, but fungi such as Alternaria, Aspergillus, Cladosporium, Penicillium, Phomopsis, and Rhizopus as well as bacteria and yeasts, have been observed in cracked fruits and bunch rots. Crop loss from bunch rot in processing grapes is usually limited to weight loss. However, rotting grapes may affect the quality of wine or grape juice if mixed in substantial quantities with sound grapes.

Our studies in New York have concentrated on various aspects of controlling Botrytis bunch rot. We have been concerned with proper timing of fungicide applications, benomyl resistance, screening new fungicides, and gibberellic acid treatments.

In order to properly time a fungicide application to control any disease, one must have an idea when infection is most likely to occur and what tissue is most likely to become infected. Studies in California suggested that infection by Botrytis takes place through the stigmatic surface of the style when it becomes necrotic shortly after bloom. The necrotic stigma as well as pollen serve as a food base for which the fungus may invade the healthy fruitlet. European researchers believe Botrytis enters sound fruitlets shortly after bloom by first colonizing debris in the cluster, such as dehisced calyptras (caps) and stamens (male parts of the flower), from which it moves into healthy berry tissue. In each case, following infection at bloom, the fungus remains inactive until the sugar content of the berry increases and the acid content decreases to a level that supports fungal growth, at which time the fungus resumes growth and rots the berry. This sequence of events is undoubtedly important in a dry climate like California where summer rains occur infrequently. However, under New York and Ohio conditions where summer rains readily occur, we believe infection by Botrytis commonly occurs after veraison when the
sugar content of the berry starts to increase. Our attempts to isolate Botrytis from necrotic stigmas shortly after bloom commonly yielded Alternaria and Cladosporium, whereas Botrytis was found only infrequently. Similar studies in California frequently yielded Botrytis, as well as Alternaria and Cladosporium.

Timing trials with effective fungicides have provided circumstantial evidence for the time of infection, but more importantly they have identified the proper time to apply fungicides to control the disease under New York conditions. A trial on Ravat 51 using Ronilan during 1979 demonstrated the importance of sprays after sugar build-up in the berries and also demonstrated the lack of importance of sprays at 5% and 90% bloom. Sprays at berry touch were of questionable importance. A similar trial on the same cultivar in 1980 indicated that sprays at 90% bloom and berry touch were not helpful, but that sprays applied beginning at 4 °Brix were crucial. Two properly timed sprays after the beginning of sugar build-up in the berries were just as beneficial as four or five sprays applied throughout the season starting at 90% bloom. Although sprays applied at bloom prevent rot at harvest in California, a trial there in 1978 indicated bloom sprays would be insufficient if summer rains were common. They applied two sprays of benomyl plus captan at bloom and where no rain occurred afterward, control was adequate, but when one inch of rain fell one week before harvest, no benefit from fungicides applied at bloom was observed. These results tend to substantiate our findings.

The discovery of Benomyl-resistant isolates of Botrytis in New York State complicates control practices considerably. Laboratory tests in 1978 revealed that sensitive isolates would not grow on agar plates amended with 1 ppm benomyl, but resistant isolates would grow readily on agar amended with 100 ppm benomyl. Since this initial discovery, we have found benomyl resistance in all grape-growing areas of the state. We have also recovered resistant isolates from apple, bean, strawberry, and raspberry in addition to grape. Furthermore, isolates from one host grow happily on the other hosts, so benomyl-resistant isolates from one host could easily spread to other hosts where benomyl has never been used and account for benomyl failures the first year of use.

Fungicide screening trials for alternatives to benomyl have revealed several promising new fungicides. Ronilan and BAS 436 from BASF Corp., Serinal from Montedison, and Rovral from Rhone-Poulenc each provided excellent control of Botrytis bunch rot on a four-spray schedule (90% bloom, berry touch, 6 °Brix and 10 days after harvest) as opposed to captan, botran or benomyl, which failed to control Botrytis. When applied only on the last two dates, Ronilan and BAS 436 still provided excellent control and control by Serinal and Rovral was much better than the standards. Ronilan is close to registration and might be available for commercial use by 1983.

The severity of bunch rot is much worse in clusters that are compact and tight, and cultivars that have this characteristic tend to have more bunch rot problems. Timely applications of gibberellic acid (GA) can cause elongated, less compact clusters where individual berries are not likely to squeeze one another. Clusters of this type are less susceptible to severe bunch rot because spread of Botrytis from one infected berry to adjacent berries is minimized. Trials with GA on Aurore over the past three years have demonstrated reductions in severity or nesting of bunch rot, but not in the incidence or number of infected clusters. The GA treatment should be applied at 4-6 inches of growth on Aurore because later applications increase the chance of crop reduction the following year. We are impressed with the results of GA treatments on Aurore and plan to look at its use in combination with fungicides applied later in the season.

-41-
USE OF SPRINKLERS FOR FROST PROTECTION AND IRRIGATION

Jim Pour and Allen Jones
Stillwater Vineyards, Ludlow Falls, Ohio

One of Mother Nature's hazards we have encountered almost every spring is the late frost or freeze. In six of the eight years we have been involved in the grape business, we have been subjected to killing frosts or freezes. According to the U.S. Weather Bureau in Vandalia, Ohio, the area in which we are located is subjected to possibly the most volatile and unpredictable weather in the entire United States. Just a few miles north and south of our location, the weather is not as volatile. After seeing our vines frozen in 1976 and 1977, we came to the conclusion that if we were to continue in the grape business we had to have some type of protection from Mother Nature.

We found the most common methods in use to combat frost were smudge pots, wind machines, helicopters and sprinkling systems. Each method has some undesirable and some desirable characteristics and the system we chose, the sprinkling system, had the fewest of the undesirables in our situation.

The things we considered, although not in priority order were:

1. Initial cost
2. Positive control
3. Negative effect on the vines
4. Operating cost
5. Degree of control

The initial cost for the system is very high. Our system was purchased in late 1977 and the purchase price was approximately $33,000 installed. Prices in 1981 would be almost double that figure. Our system covers a ten acre area and has a pump capacity to double that area. This system requires excellent drainage which if not naturally present must be installed. We did not have that expense since we have excellent drainage built into our vineyard by nature. Our soil strata is a layer of sandy clay topsoil underlain by what can best be described as a gravel pit.

The system will give complete protection and control down to 18°F. This is achieved simply by increasing the water flow as the temperature drops. We have complete confidence in the systems' ability to prevent damage in the sprinkled area. Operation costs are also extremely low. The pump engine uses 3 gallons of diesel fuel per hour.

The system has no direct adverse effect on the vines. However, if drainage from the vineyard is not sufficient the possibility of all the problems associated with wet soil exists. Even with the excellent drainage condition present in our vineyard, we sometimes have a problem getting equipment through the vineyard. An additional problem encountered is leaching of nutrients needed for proper grape production and vine health.

There is one other item necessary for a sprinkler system which is not needed for any other method we have mentioned. That item is a high volume water supply. To provide protection at 24°F, the system applies a quantity of water equal to .1 inch of rainfall per hour over the entire protected area. That totals approximately 360,000 gallons over a 12 hour period which is typical for each night the system is operated. However, if the temperature should drop below 24°F., the rate
must be increased. We can see from Fig. 1 that at 18°F, we must pump twice as much water as was needed at 24°F. That volume must be available each day on a continuous basis. The possible sources of water in the necessary quantities are a pond or lake, large wells, or a stream. In our case we use the Stillwater River.

The basic principle of a sprinkler system is fairly simple. When water passes from liquid at 32°F. to ice at 32°F., it gives off 144 BTUs per pound. If a sufficient supply of water is applied continuously, the heat released in freezing will ensure the temperature of the ice will not drop below 32°F. Since damage to the green tissue of the vine occurs at 28° to 29°F., the 32°F. ice will not damage the tissue. The critical point is the continuous supply of water. In addition to the protection supplied by the ice, when the system has been in operation for a short time, the water vapor rising above the vines and around the perimeter of the vineyard in effect forms a blanket over the vineyard and inhibits the radiation of heat into the atmosphere. According to technical data supplied to us, the longest period of time the sprinkling can be interrupted without damage to the vine is 3 minutes. We have never experienced an interruption and hopefully never will. By calculation the tremendous quantities of heat potentially available in the water are as follows:

POTENTIAL HEAT GENERATION

\[
\begin{align*}
500 \text{ gal/min} & \times 8.33 \text{ lbs/gal} = 4165 \text{ lbs/min} \\
40°F \text{ water} & = 8 \text{ BTU/}1\text{b} \ [40°-32°] + 144 \text{ BTU/}1\text{b} \ [\text{heat of fusion}] = 152 \text{ BTU/}1\text{b} \\
4165 \text{ lb/min} & \times 60 \text{ min} = 249,900 \text{ lbs/hr} \\
249,900 \text{ lbs/hr} & \times 152 \text{ BTU/}1\text{b} = 37,984,800 \text{ BTU/hr} \\
37,984,800 \text{ BTU/hr} & \times 10 \text{ hrs} = 379,848,000 \text{ BTU/10 hrs} \\
379,848,000 \text{ BTU} & = 2713 \text{ gal #2 fuel oil} = 30 \text{ gal Diesel oil to operate the pump}
\end{align*}
\]

When a frost or freeze is forecast, we monitor the vineyard temperature on an hourly basis. When the temperature drops to approximately 34°F. the system is started and operated continuously until the temperature rises above the freezing point and all ice is melted from the vines.

The end point usually occurs between 7:30 and 9:30 A.M. depending on when the temperature rises above freezing. Immediately after the system is started, a visual check is made of all the nozzles to ensure that none are clogged. The nozzles have to be checked at regular intervals throughout the night because on occasion they do get clogged. Needless to say, it is a nasty, cold experience unclogging nozzles. Our system consists of a Hale pump rated at 1000 gallons per minute at 90 psi head pressure. The pump is powered by a 90 hp Deutz air-cooled diesel engine. A DeLaval silt separator is installed in the line to remove sand and silt that could erode and damage the nozzles. Also, you will note that the entire pump and filter system is mounted on a trailer. During the remainder of the year the pump is unhooked and stored out of the weather. That feature reduces maintenance and eliminates the possibility of vandalism. All lines are aluminum.

The main delivery line is 8 inches in diameter. The field header lines are 6
and 4 inches in diameter and the laterals are 3 inches in diameter. The sprinkler nozzles are Rainbird brand oscillating type and will make a complete circle in one minute or less.

The nozzles are mounted on 6 1/2 foot risers to place them above the vines. They are alternately spaced on 60 ft centers and cover an 80 foot diameter circle which produces an overlap of 20 ft and ensures complete coverage.

In conclusion, I must say we have been well satisfied with the results produced by the system. However, not every vineyard can successfully employ this type of frost prevention system for several obvious reasons. Those are: drainage problems, water supply and probably the most prominent--cost. With the price of grapes and costs to produce them at present levels, it is not economically feasible to use this type system even though we believe it is overall the best available method.
Fig. 1. Relationship between water flow rate through the irrigation system and the temperature (°F) to which the plants can be protected.
Grape production in Ohio and other eastern states has changed in recent years. Concord acreage continues to decline in Ohio while plantings of French hybrids have increased. Prices received for Concord grapes actually declined in 1980 leaving grapes unharvested in the field because of a large carryover of processed product from 1979.

Although grapes are harvested by hand, mechanical harvest is most favorable in the northern part of Ohio because it has large plantings that are close to each other which allows efficient use of expensive equipment. Other areas of the state do not use mechanical harvesters because plantings are small, non-bearing or scattered.

The eastern grape industry is coming under increased competition from Washington state. Washington is the leading Concord grape producing state and will produce 127,000 tons in 1980, which is up 25% from 1979. Production per acre is higher than in the east.

French hybrid production in the east is mainly for wine while Concord is marketed for both wine and juice. The large wine grape acreage in California (237,000, 1979), has increased by 196,000 acres since 1970. However, between 1969 and 1978 the sale of wines in the U.S. increased by 83%. The eastern U.S. wine business suffered a 7% loss in their share of the market in 1978.

Although prices for Conords has been low, prices for certain French hybrids have been higher than Conords. It is anticipated that such prices will cause an increase in grape wine acreage in the east, particularly for high quality white wine cultivars. As growers anticipate changing from Concord to white wine cultivars, an economic analysis is essential for management decisions. Annual summations of costs and returns do not reflect the early years of a large investment and the delayed return several years later. The time of the investment and lag of return must be considered. An internal rate of return analysis which uses cost and return estimates of the expected life of a crop indicates highest possible interest rate a grower can afford to borrow and/ or indicates potential profit of alternative crops.

Analysis. All costs were developed from early 1980 prices. All labor (hired and supervisory) included social security and workmens compensation was calculated at $5.50/hr. Equipment size is based on a 120 acre farm having 30 acres of small fruit crops and 20 acres of other fruit (Table 5). A $3,000 per acre land charge was applied to costs at planting and land salvage value was applied at the end of the respective analysis. Time inputs are based on Ohio conditions. Yields were estimated for each year and a five year moving average was calculated (Table 4).

Results. The internal rates of return for hand vs. mechanically harvested grapes are shown in Table 1. The annual summation of cost and returns that are the basis for the internal rates of return are shown in Tables 2, 3 and 4.

Machine harvested grapes had a higher rate of return than hand harvest over 12 or 18 years of investment, while hand harvest had a positive return at 26¢/lb.
Conclusions. If a grower has similar data as in this study and must borrow the entire investment at a rate higher than indicated in Table 1, then he should not consider planting grapes. It would be unwise to produce grapes at less than 4 tons/acre and receive less than 20¢/lb ($400/ton).

Mechanically harvested grapes had higher rates of return than hand harvested grapes. However, the machine cost in this study was based on 150 hours per season as indicated in Tables 5 and 6. But this is based on both types operating at the same speed (1 acre/hr). If one machine is slower (1 hr. 10 min/acre), their cost would nearly be the same if both used 150 hours per season (Table 6). However at 50 hours per season, the cost per ton is much lower with the pull type machine. Thus, if time per acre is nearly the same, then a pull type machine is more economical for small acreage.

Table 1. Internal rates of return for hand harvested and machine harvested grapes for 12 or 18 years, Ohio, 1980.

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<th>Production years</th>
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<tr>
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<tr>
<td>12 yr. hand</td>
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</tr>
<tr>
<td>12 yr. machine</td>
<td>&lt; 0%</td>
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</tr>
<tr>
<td>18 yr. machine</td>
<td>&lt; 0%</td>
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Table 2. Cost of mechanically harvested (self-propelled) grapes.¹ Ohio. 1980.

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<th>Yr.</th>
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<th>Material</th>
<th>Machine³ Overhead</th>
<th>Total cost</th>
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¹. Machine harvest at 1 acre/hr and operates 100 hrs/season or 12.5 working days.
². Mechanical harvest begins in year 4 when machine cost is less than hand labor cost.
³. Mechanical harvest includes bulk bin containers and hauling in the field. Does not include machine transfer cost or cleanup of machine.
⁴. All labor calculated at $5.50 per hour.
Table 3. Hand harvested wine grapes\(^1\), Ohio, 1980.

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<th>Yr.</th>
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<td>166.50</td>
<td>697.07</td>
<td>213.17</td>
<td>224.17</td>
<td>85.20</td>
<td>1,219.61</td>
</tr>
<tr>
<td>14</td>
<td>260.85</td>
<td>284.24</td>
<td>166.50</td>
<td>711.59</td>
<td>218.17</td>
<td>229.17</td>
<td>85.20</td>
<td>1,244.13</td>
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<td>15</td>
<td>260.85</td>
<td>290.40</td>
<td>166.50</td>
<td>717.75</td>
<td>237.67</td>
<td>236.67</td>
<td>85.20</td>
<td>1,277.29</td>
</tr>
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<td>16</td>
<td>260.85</td>
<td>266.64</td>
<td>166.50</td>
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<td>212.17</td>
<td>223.17</td>
<td>85.20</td>
<td>1,214.53</td>
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<tr>
<td>17</td>
<td>260.85</td>
<td>275.44</td>
<td>166.50</td>
<td>702.79</td>
<td>215.17</td>
<td>226.17</td>
<td>85.20</td>
<td>1,229.33</td>
</tr>
<tr>
<td>18</td>
<td>269.85</td>
<td>281.60</td>
<td>166.50</td>
<td>708.95</td>
<td>217.17</td>
<td>228.17</td>
<td>85.20</td>
<td>1,239.49</td>
</tr>
</tbody>
</table>

1. Harvest based on calculated yield and assumes 1,500 lbs/8 hr day per person harvested.
2. Includes container cost.
3. Based on 50 acres of fruit production and 50 acres of other crops.
Table 4. Estimated grape yield - Ohio, 1980

<table>
<thead>
<tr>
<th>Yr.</th>
<th>Yield expected 1 (lbs/A)</th>
<th>Yield 2 (lbs/A)</th>
<th>Return/1b/2A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10¢</td>
</tr>
<tr>
<td>1</td>
<td>000</td>
<td>000</td>
<td>$0</td>
</tr>
<tr>
<td>2</td>
<td>000</td>
<td>000</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3,000</td>
<td>3,200</td>
<td>320</td>
</tr>
<tr>
<td>4</td>
<td>6,000</td>
<td>5,000</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>7,000</td>
<td>6,600</td>
<td>660</td>
</tr>
<tr>
<td>6</td>
<td>9,000</td>
<td>8,400</td>
<td>840</td>
</tr>
<tr>
<td>7</td>
<td>8,000</td>
<td>8,400</td>
<td>840</td>
</tr>
<tr>
<td>8</td>
<td>12,000</td>
<td>9,000</td>
<td>900</td>
</tr>
<tr>
<td>9</td>
<td>6,000</td>
<td>10,000</td>
<td>1,000</td>
</tr>
<tr>
<td>10</td>
<td>10,000</td>
<td>9,400</td>
<td>940</td>
</tr>
<tr>
<td>11</td>
<td>8,000</td>
<td>9,300</td>
<td>930</td>
</tr>
<tr>
<td>12</td>
<td>11,000</td>
<td>9,600</td>
<td>960</td>
</tr>
<tr>
<td>13</td>
<td>11,500</td>
<td>9,200</td>
<td>920</td>
</tr>
<tr>
<td>14</td>
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<td>15</td>
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<td>9,900</td>
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<td>16</td>
<td>10,000</td>
<td>9,100</td>
<td>910</td>
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<td>17</td>
<td>12,000</td>
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<td>940</td>
</tr>
<tr>
<td>18</td>
<td>7,500</td>
<td>9,600</td>
<td>960</td>
</tr>
</tbody>
</table>

1. Note: 10 yr avg. = 3.3 tons/A
       16 yr avg. = 4.2 tons/A

2. Returns/A calculated by using 5 yr. average.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>New Cost</th>
<th>Salvage value</th>
<th>Years life</th>
<th>Ownership cost/year</th>
<th>Hours, year</th>
<th>Ownership</th>
<th>Repair</th>
<th>Per hour fuel and lube</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>520</td>
<td>$13,000</td>
<td>$3,900.00</td>
<td>10</td>
<td>$2,177.50</td>
<td>400</td>
<td>$5.44</td>
<td>$1.10</td>
<td>$3.12</td>
<td>$ 9.66</td>
</tr>
<tr>
<td>380</td>
<td>9,330</td>
<td>3,172.20</td>
<td>10</td>
<td>1,553.45</td>
<td>300</td>
<td>5.18</td>
<td>.93</td>
<td>2.28</td>
<td>8.39</td>
</tr>
<tr>
<td>Sprayer (air blast)</td>
<td>4,200</td>
<td>672.00</td>
<td>12</td>
<td>659.40</td>
<td>100</td>
<td>6.60</td>
<td>1.58</td>
<td>.20</td>
<td>8.38</td>
</tr>
<tr>
<td>Sprayer (boom)-weeds</td>
<td>1,746</td>
<td>280.00</td>
<td>12</td>
<td>274.12</td>
<td>50</td>
<td>5.49</td>
<td>1.31</td>
<td>.20</td>
<td>7.00</td>
</tr>
<tr>
<td>Truck (1/2 ton)</td>
<td>5,300</td>
<td>1,346.20</td>
<td>8</td>
<td>992.68</td>
<td>200</td>
<td>4.96</td>
<td>1.03</td>
<td>3.64</td>
<td>9.63</td>
</tr>
<tr>
<td>Plow (3-16&quot;)</td>
<td>1,800</td>
<td>360.00</td>
<td>12</td>
<td>306.00</td>
<td>75</td>
<td>3.60</td>
<td>4.08</td>
<td>.20</td>
<td>7.88</td>
</tr>
<tr>
<td>Disc - 9 ft.</td>
<td>2,700</td>
<td>540.00</td>
<td>12</td>
<td>423.00</td>
<td>50</td>
<td>8.46</td>
<td>3.69</td>
<td>.20</td>
<td>12.35</td>
</tr>
<tr>
<td>Fert, spreader</td>
<td>900</td>
<td>144.00</td>
<td>12</td>
<td>141.30</td>
<td>50</td>
<td>2.83</td>
<td>.60</td>
<td>.20</td>
<td>3.63</td>
</tr>
<tr>
<td>Rotary Mower 7'</td>
<td>1,900</td>
<td>380.00</td>
<td>8</td>
<td>361.00</td>
<td>100</td>
<td>3.61</td>
<td>1.54</td>
<td>.20</td>
<td>5.35</td>
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<tr>
<td>Wagon</td>
<td>1,050</td>
<td>168.00</td>
<td>12</td>
<td>164.85</td>
<td>50</td>
<td>3.30</td>
<td>1.08</td>
<td>.20</td>
<td>4.58</td>
</tr>
<tr>
<td>Post hole auger</td>
<td>620</td>
<td>100.00</td>
<td>12</td>
<td>97.33</td>
<td>20</td>
<td>4.87</td>
<td>1.47</td>
<td>.20</td>
<td>6.54</td>
</tr>
<tr>
<td>Transplanter-3 pt.</td>
<td>650</td>
<td>104.00</td>
<td>12</td>
<td>102.05</td>
<td>20</td>
<td>5.10</td>
<td>1.63</td>
<td>.20</td>
<td>6.93</td>
</tr>
<tr>
<td>Mulcher</td>
<td>4,200</td>
<td>672.00</td>
<td>12</td>
<td>659.40</td>
<td>120</td>
<td>5.49</td>
<td>1.66</td>
<td>.20</td>
<td>8.79</td>
</tr>
<tr>
<td>Rototiller</td>
<td>3,300</td>
<td>660.00</td>
<td>10</td>
<td>561.00</td>
<td>80</td>
<td>7.01</td>
<td>3.42</td>
<td>.20</td>
<td>10.63</td>
</tr>
<tr>
<td>Well, pump, tanks</td>
<td>4,000</td>
<td>------</td>
<td>20</td>
<td>660.00</td>
<td>40</td>
<td>8.25</td>
<td>----</td>
<td>----</td>
<td>8.50</td>
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<tr>
<td>Self-propelled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>harvester</td>
<td>65,000</td>
<td>16,187.50</td>
<td>8</td>
<td>12,137.50</td>
<td>150</td>
<td>81.25</td>
<td>18.42</td>
<td>6.38</td>
<td>106.05</td>
</tr>
<tr>
<td>PTO harvester</td>
<td>45,000</td>
<td>11,250.00</td>
<td>8</td>
<td>8,438.00</td>
<td>150</td>
<td>56.25</td>
<td>12.75</td>
<td>.50</td>
<td>69.50</td>
</tr>
</tbody>
</table>
Table 6. Comparison in cost per ton for self propelled (SP) or pull type (PT) mechanical grape harvester, Ohio, 1980.

<table>
<thead>
<tr>
<th>Tons/acre</th>
<th>Hours/Season</th>
<th>SP</th>
<th>PT</th>
<th>SP</th>
<th>PT</th>
<th>SP</th>
<th>PT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>100</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>$326</td>
<td>$240</td>
<td>$176</td>
<td>$146</td>
<td>$127</td>
<td>$100</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>163</td>
<td>120</td>
<td>88</td>
<td>73</td>
<td>63</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>109</td>
<td>88</td>
<td>59</td>
<td>49</td>
<td>42</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>81</td>
<td>60</td>
<td>44</td>
<td>36</td>
<td>32</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

Includes straight line depreciation (8 yrs), interest (13%), repair, fuel ($1.10/gal), shelter and insurance. Self-propelled (2 wheel drive) initially $65,000 and pull type initially $45,000.

1. Cost includes harvester plus tractor (38 hp) wagon and forklift. Does not include labor, container cost, nor equipment transfer and cleanup cost. Assumes both machines travel at the same speed at 1 hr/acre.

2. Pull type (PT) includes tractor (62 hp) cost that operates at 400 hrs/year. Pull type would be equal in cost if it harvested an acre in 1.25 hrs. and self propelled (SP) harvested at 1 hr/acre.
Ohio Grape Production
Cost/Acre - Years 1-10 - 1980
Hand Harvest

1st Year

Plants - 8 x 10 - 550 x $1.25 $687.50
Land Preparation - Equipment 57.48
    Labor - 6 hours @$5.50 33.00
Fertilizer - 30 lbs./actual/A each - N,P,K 21.30
Lime - 1.5 tons @$13.50/T 20.25
Equipment - Well, fertilizer, spray, mow, pesticide 159.26
Plant Labor - 31.3 hours 172.35
Pesticide 115.96
Overhead - Electricity, buildings, pickup, etc. 85.20
Total $1,352.30

2nd Year

Trellis - End post - 16 @$4.00 $64.00
    Line post - 209 @$2.75 574.75
    Anchors - 16 @$6.85 109.60
    Wire vise - 32 @$0.85 27.20
    Wire - 4,000 ft. @$0.035 280.00
Plants - 30 @$1.25 36.00
Labor -
    Trellis - 47 hours @$5.50 462.00
    Tying - 24 hours @$5.50 139.20
    Pesticide - 8.5 hours @$5.50 46.75
    Other - 4.1 hours @$5.50 22.55
Pesticide 106.17
Fertilizer 10.00
Equipment 186.75
Overhead 85.20
Total $2,151.67

3rd Year

Labor
    Pruning, etc. - 34 hours @$5.50 $187.00
    Harvest - 19 hours @$5.50 104.50
    Pesticide - 4.5 hours @$5.50 24.75
    Supervisory - 20 hours @$5.50 110.00
Machine 153.77
Fertilizer 15.00
Pesticides 105.72
Containers 32.00
*Hauling 15.00
Overhead 85.20
Total $832.94

* Hauling included in machine charge year 6 to 10.
4th Year

Labor - 84 hours @$5.50
Pruning, etc. 35 hours
Pesticide - 4.5 hours
Harvest - 26 hours
Supervisory - 19 hours
Machine
Fertilizer
Pesticides
Containers
Hauling
Overhead
Total

5th Year

Labor - 105 hours @$5.50/hour
Pruning, etc. - 35 hours
Harvest - 35 hours
Supervisory - 30 hours
Pesticide - 4.5 hours
Machine
Hauling
Fertilizer (lime)
Pesticide
Containers
Overhead
Total

6th Year

Labor - 122.5 hours @$5.50/hour
Pruning, etc. - 43 hours
Pesticide - 4.5 hours
Harvest - 45 hours
Supervisory - 30 hours
Machine
Fertilizer
Pesticide
Containers
Overhead
Total

7th Year

Labor - 122.5 hours @$5.50/hour
Pruning, etc. - 43 hours
Pesticide - 4.5 hours
Harvest - 45 hours
Supervisory - 30 hours
Machine
Fertilizer
Pesticide
Containers
Overhead
Total
8th Year

Labor - 125.7 hours @ $5.50/hour $ 691.35
    Pruning, etc. - 43 hours
    Pesticide - 4.5 hours
    Harvest - 48 hours
    Supervisory - 30 hours

Machine 209.77
Fertilizer 15.00
Pesticide 106.17
Containers 112.00
Overhead 85.20
Total $1,219.49

9th Year

Labor - 131 hours @ $5.50/hour $ 720.39
    Pruning, etc. - 43 hours
    Harvesting - 53.5 hours
    Pesticide - 4.5 hours
    Supervisory - 30 hours

Machine 205.77
Fertilizer 15.00
Pesticide 106.17
Containers 103.00
Overhead 85.20
Total $1,235.53

10th Year

Labor - 128 hours @ $5.50/hour $ 720.39
    Pruning, etc. - 43 hours
    Harvesting - 50.5 hours
    Pesticide - 4.5 hours
    Supervisory - 30 hours

Machine 207.77
Pesticide 106.17
Fertilizer 22.50
Containers 118.00
Overhead 85.20
Total $1,242.43
PRESERVATION OF FRESH GRAPE JUICE

Don F. Splittstoesser
Cornell University
New York State Agricultural Experiment Station

Extending the shelf life of grape juice is a topic of interest to growers who wish to sell juice to the amateur winemaker. It also may be of interest to the larger wineries who would like to be able to conduct fermentations over a longer time period.

General Principles

In a typical microbial growth curve, there first is a period where little cell multiplication occurs (the lag phase). This is followed by a period of rapid growth (the logarithmic phase). Then there is a maximum stationary phase where multiplication ceases but fermentation continues. Finally, in the death phase, the cells slowly die off.

Temperature has a marked effect on this growth curve, particularly on the lag phase (Table 1). It can be seen that a Concord grape must could be held 42 hours at 54°F before rapid growth was initiated compared to only 8 hours at 86°F. The growth rate, expressed as population doubling time, also was affected but to a lesser extent than the lag phase. Most rapid multiplication occurred at 68°F where the population doubled every four hours.

Another important variable that affects the growth curve is the initial yeast population. As illustrated in Table 2, a must having an initial population of 14 million yeasts per gram produced 0.1% alcohol in only 2.5 hours at 66°F compared to 40 hours in some of the samples containing only 340,000 yeasts per gram. The initial yeast population affects the length of the lag phase rather than the multiplication rate.

Table 3 shows the yeast population that can be found on sound grapes. It can be seen that 13% of the samples yielded counts of ten million or higher per gram. This fruit was hand harvested and crushed under laboratory conditions. Commercial processed grapes might possess even higher populations due to contamination during harvesting and pressing.

Low Temperatures

Freezing is used for the preservation of grape juice concentrate and certain grape pulp products. Undoubtedly the process is too expensive for the preservation of large volumes of single strength juice.

Refrigeration, alone, will not preserve juice that is heavily contaminated with microorganisms because many yeasts are psychrotrophs that have the ability to grow at low temperatures (see Table 6). While pasteurized Concord juice is stored commercially for a number of months at 28°F, in time even it will ferment due to the introduction of chance contaminants. Some of the yeasts that have been isolated from Concord juice stored at 28°F, e.g. Leucosporidium species, are true psychrophiles in that they actually prefer a lower temperature for growth.
TABLE 1. Influence of temperature on the growth of yeasts present as natural contaminants in a Concord must.

<table>
<thead>
<tr>
<th>Holding temperature (°F)</th>
<th>Lag phase (before growth initiated)</th>
<th>Growth rate (doubling time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td>68</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>86</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Initial yeast population = 600,000 per gram of must

TABLE 2. Influence of the initial yeast population on the fermentation of Concord must.

<table>
<thead>
<tr>
<th>Yeasts per gram</th>
<th>Hours required to produce 0.1% ethanol at 66°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,000,000</td>
<td>2.5</td>
</tr>
<tr>
<td>1,100,000</td>
<td>10</td>
</tr>
<tr>
<td>340,000</td>
<td>20 to 40</td>
</tr>
</tbody>
</table>

TABLE 3. Number of viable yeasts on 135 grape samples.

<table>
<thead>
<tr>
<th>Yeasts per gram</th>
<th>% of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000-99,000</td>
<td>23</td>
</tr>
<tr>
<td>100,000-990,000</td>
<td>34</td>
</tr>
<tr>
<td>1,000,000-9,900,000</td>
<td>30</td>
</tr>
<tr>
<td>10,000,000 and over</td>
<td>13</td>
</tr>
</tbody>
</table>

TABLE 4. Heat resistance of microbial types capable of spoiling grape juice.

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>D-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAST: Saccharomyces bisporus v. bisporus Y-2</td>
<td>16 min 124°F</td>
</tr>
<tr>
<td>BACTERIUM: Lactobacillus fructivorans</td>
<td>10 min 140°F</td>
</tr>
<tr>
<td>MOLD: Byssochlamys fulva</td>
<td>120 min 185°F</td>
</tr>
</tbody>
</table>

*aTime and temperature needed to kill 90% of the cells*
Pasteurization

Most of the organisms capable of spoiling grape juice possess little heat resistance. A temperature of 140°F is lethal for many; as the temperature is raised above this, the time needed to kill a given population decreases. Heating juice briefly to temperatures of 180 to 190°F will kill all yeasts and aciduric bacteria and almost all molds (Table 4). A few molds, however, such as species of Byssochlamys and Aspergillus fischeri produce spores that will survive the heat treatments commonly given to commercially processed fruit products.

Although heat resistant mold spores can be recovered from grapes and other samples taken from the vineyard, the numbers usually are quite low (Table 5). This may explain why spoilage of thermally processed grape juice is not a significant problem in the Northeast. In addition, most grape juice is filtered to achieve a product of high clarity; it is believed that this treatment removes many mold spores.

Sorbic acid

Sorbic acid is an effective inhibitor of yeasts and molds, especially when populations of these organisms are not excessively high. On the other hand, it has little activity against acetic acid bacteria and lactic acid bacteria, microorganisms that also are potential spoilers of grape juice. Since sorbic acid is a yeast inhibitor, it is not used for the preservation of juice that later will be used in winemaking.

Sulfur Dioxide

Many yeasts possess considerable resistance to sulfur dioxide and the concentrations normally used in winemaking will not prevent fermentation. Recently a process has been developed in which high concentrations of sulfur dioxide, 1200 to 2000 ppm, are added to juice which then can be stored at ambient temperature. When the juice is to be used in winemaking, most of the sulfur dioxide is removed by first flash heating to about 212°F in the absence of air, and then stripping with nitrogen or steam. Although sulfur dioxide may be difficult to remove from some juices, the process is being used commercially, especially for the preservation of white juice. Specialized equipment is required.

Sulfur Dioxide and Refrigeration

Several years ago we investigated the use of low temperature coupled with sulfur dioxide as a means of extending the shelf life of juice that later was to be fermented. A temperature of 41°F was chosen since it is attainable in a bulk milk cooler, equipment that might be available to the grower. The levels of sulfur dioxide did not exceed those permitted in winemaking.

In the absence of sulfur dioxide, the shelf life of refrigerated juice was brief, especially when the initial yeast populations were high (Table 6). The addition of 100 ppm sulfur dioxide helped considerably in that now only 13% of the 135 samples fermented during the 30 week storage period (Table 7). When the concentration of sulfur dioxide was increased to 200 and 300 ppm, only three and two samples respectively fermented and no mold growth was obtained. The three juices that fermented in the presence of the higher concentrations had high initial yeast populations, ranging from 10 million to 36 million per gram.

It was concluded that a temperature of about 40°F combined with 200 ppm sul-
TABLE 5. Incidence of heat resistant molds in grape environments

<table>
<thead>
<tr>
<th>Sample</th>
<th>No. tested</th>
<th>% contaminated</th>
<th>Av. spores/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapes, sound</td>
<td>25</td>
<td>76</td>
<td>3.2</td>
</tr>
<tr>
<td>Grapes, decayed</td>
<td>20</td>
<td>90</td>
<td>72</td>
</tr>
<tr>
<td>Grape pomace</td>
<td>4</td>
<td>100</td>
<td>over 100</td>
</tr>
<tr>
<td>Grape leaves</td>
<td>10</td>
<td>50</td>
<td>13</td>
</tr>
<tr>
<td>Vegetation, vineyard floor</td>
<td>8</td>
<td>62</td>
<td>150</td>
</tr>
</tbody>
</table>

TABLE 6. Shelf life of 135 grape juices stored at 41°F

<table>
<thead>
<tr>
<th>Initial yeast population per gram</th>
<th>Average days before fermentation initiated</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000-99,000</td>
<td>52</td>
</tr>
<tr>
<td>100,000-990,000</td>
<td>44</td>
</tr>
<tr>
<td>1,000,000-9,900,000</td>
<td>13</td>
</tr>
<tr>
<td>10,000,000 and over</td>
<td>4</td>
</tr>
</tbody>
</table>

TABLE 7. Influence of sulfur dioxide on the shelf life of grape juice stored at 41°F.

<table>
<thead>
<tr>
<th>ppm SO₂</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Over 85% of the samples&lt;sup&gt;a&lt;/sup&gt; fermented, most within three weeks. Almost all became moldy.</td>
</tr>
<tr>
<td>100</td>
<td>Only 13% fermented during 30 weeks of storage. Eight juices exhibited mold.</td>
</tr>
<tr>
<td>200</td>
<td>Three samples fermented. No mold observed.</td>
</tr>
<tr>
<td>300</td>
<td>Two juices fermented. No mold observed.</td>
</tr>
</tbody>
</table>

<sup>a</sup>A total of 135 juices tested.
fur dioxide might be a feasible method for holding grape juice providing that the initial yeast populations were not too high. This would require the harvesting of sound fruit and the maintenance of sanitary conditions during the harvest, pressing and storage.

Literature Cited


WINE YEAST

J. Kevin Kraus
Universal Foods Corporation, Milwaukee, Wisconsin

INTRODUCTION

In the baking and brewing industries only a few fairly well characterized strains of Saccharomyces cerevisiae or S. uvarum are used. In contrast, fermenting must contains strains belonging to several genera of yeasts and a large number of different species. Terms such as "natural yeasts", "wild yeasts", "culture yeasts", or "wine yeasts" are not very useful unless they are well defined. In the following, the term "natural yeasts" will be used for strains which occur on grapes or on winery equipment and which constitute the "natural" inoculum of musts. Such natural yeasts may, of course, include species of S. cerevisiae or S. uvarum which are considered highly desirable, and which may also be added to musts as so-called "culture yeasts".

Wine makers and wine chemists do not always follow the strict terminology of taxonomists. This is small wonder since taxonomical classification of yeasts undergoes constant change. For instance, the bottom fermenting beer yeast, S. carlsbergensis, is presently included in the species S. uvarum.

SPECIES SYNONYMS

<table>
<thead>
<tr>
<th>Name of Species in Wine Literature</th>
<th>Name of Species in Lodder (1970)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candida pulcherrima</td>
<td>Metschnikowia pulcherrima</td>
</tr>
<tr>
<td>Hanseniaspora guillermondi</td>
<td>Hanseniaspora valbyensis</td>
</tr>
<tr>
<td>Saccharomyces carlsbergensis</td>
<td>Saccharomyces uvarum</td>
</tr>
<tr>
<td>Saccharomyces ellipsoideus</td>
<td>Saccharomyces cerevisiae</td>
</tr>
<tr>
<td>Saccharomyces oviformis</td>
<td>Saccharomyces bayanus</td>
</tr>
<tr>
<td>Torulopsis bacillaris</td>
<td>Torulopsis stellata</td>
</tr>
</tbody>
</table>

(In the following, the classification of Lodder (1970) will be used except in instances where it is impossible to determine the current classification for yeast names appearing in the older literature.)

NATURAL FERMENTATIONS

Yeasts responsible for natural (or spontaneous) fermentation of musts enter with the grapes or can be found abundantly on the crushers, conveyors, and fermenting tanks of the winery. In 1940 Mrak and McClung found yeast species belonging to 14 different genera on fresh grapes. However, the total cell count was rather low. The number of yeasts increases rapidly when the grapes are handled by pickers, during transport to the winery, and particularly after crushing and pumping of the must. There is a tremendous range of yeast cell counts on fresh grapes. Saller (1957) who found from 2.7 to 124 x 10^6 cells per gram of grapes observed that the cell count increased during transport of the grapes to the winery and during crushing, but that the total count decreased again during pressing with a Willmes press. Winkler (1962) reported cell counts from 0.1 to 1 x 10^6 per ml. of freshly pressed grape juice.

During the early stages of must fermentations, asporogenous yeasts predominate to be replaced during the latter stages of the fermentation entirely by sporogenous
yeasts. Fermentation is usually initiated by yeasts with a low tolerance for ethanol such as Hanseniaspora guillermondii, Kloekera apiculata, Torulopsis and Candida species. These are superseded by the more alcohol tolerant Saccharomyces yeasts. This particular phenomenon has been described abundantly by French, Italian and Czech authors over the last 20 years. (Castelli, 1954; Brechet et al., 1962; Minarik et al., 1960, 1969; Domercq, 1957.) The following table shows results obtained by Minarik (1960).

NUMBER OF YEASTS ISOLATED AS PERCENTAGE OF ALL YEASTS

<table>
<thead>
<tr>
<th>Yeast</th>
<th>Prior to Fermentation</th>
<th>During Fermentation</th>
<th>Just before end of Fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. cerevisiae</td>
<td>32.9</td>
<td>65.1</td>
<td>80.1</td>
</tr>
<tr>
<td>S. oviformis</td>
<td>2.5</td>
<td>3.3</td>
<td>5.5</td>
</tr>
<tr>
<td>S. uvarum</td>
<td>3.9</td>
<td>5.4</td>
<td>3.1</td>
</tr>
<tr>
<td>S. rosei</td>
<td>5.6</td>
<td>0.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Candida pulcherrima</td>
<td>12.0</td>
<td>7.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Kloekera apiculata</td>
<td>32.7</td>
<td>13.3</td>
<td>1.5</td>
</tr>
</tbody>
</table>

(Numbers do not total 100% because less frequent species have been omitted.) From: Minarik et al., 1960.

The dramatic disappearance of the asporogenous yeasts and the eventual dominance of the Saccharomyces genus are clearly evident. As expected there were considerable differences between wine regions, although the overall picture as described above is generally true. Castelli (1954) reported that the frequency of Kl. apiculata in Italian musts increases from Southern to Northern Italy, while the reverse was true of S. cerevisiae. Differences in the yeast flora between white and red wine regions of the Gironde have been reported. Torulopsis bacillaris was found to be more frequent in the white wine regions. There is no need to consider the details of the breakdown of yeast species found in fresh musts since no definite conclusions can be drawn with regard to the flavor and aroma of the wine, except that the presence of spoilage yeasts such as Brettanomyces is always undesirable.

It has already been mentioned that the ability to form ethanol and to tolerate ethanol varies greatly with the species, and even to some extent within a species. The following shows the maximum percentage of ethanol produced by several species in musts and synthetic sugar solutions:
Only the most general conclusions can be drawn from this table. Considerable variability is introduced into experimental results not only from the use of different strains but also by variations in temperature, length of fermentation, or osmotic pressure of sugar solids. For instance, Brettanomyces is a slow fermenting yeast attaining about 9% of ethanol (by vol.) in 63 days, while *S. cerevisiae* yeasts attained the same alcohol level in 11 days under identical experimental conditions.

It has often been asserted that wines made by fermentation with natural yeasts have an aroma and flavor superior to wines made by inoculation with pure culture yeasts. Many wines of high quality are also produced (and more consistently so) in countries where the most modern and scientific technology is used, including routine inoculations with selected strains of wine yeasts.

**PURE CULTURE FERMENTATIONS**

When selected wine yeasts are used for the inoculation of musts, the resulting fermentations are neither "natural" fermentations or "pure culture" fermentations but mixed fermentations in which the culture yeasts predominate. The musts containing their natural microorganisms are treated with SO2 to retard growth of these yeasts and bacteria. They are then inoculated with a wine yeast starter prepared from isolates of a particular species. *S. cerevisiae* var. ellipsoideus is the most frequently used species. It can be acclimatized to high levels of SO2, and in practice it will rapidly outgrow the natural yeasts. This dominance of the "culture" yeast stems from the high number of viable cells of the starter and from the relative resistance of this yeast to SO2.

For instance, if white or red musts were inoculated with 2% (by vol.) of a starter culture of *S. cerevisiae* containing 100 million cells per ml., the number of culture yeasts was 20 to 100 times that of the number of natural yeasts. After seven to eight days of vigorous fermentation, almost all of the colonies obtained from isolates of the wine yeasts could be recognized as those of the pure starter culture. In these experiments, visible fermentation occurred after two days when the cell count in the musts had reached 10 million cells per ml. In the musts to which no starter culture had been added, fermentation started four days later. (Rankine and Lloyd, 1963.)

There are, of course, considerable differences in the performance of different species and even between different strains of a single species. For instance, Ferreira (1959) found that at 30°C the Burgundy strain of *S. cerevisiae* produced
30% more volatile acids (expressed as acetic acid) than the Montrachet strain. Rankine (1955, 1968) found substantial differences in the production of glycerol, volatile acids, acetaldehyde, hydrogen sulfide, and higher alcohols in various strains of S. cerevisiae.

S. cerevisiae var. ellipsoideus is the principal species used for seeding wine fermentations, but other species are used as well. S. bayanus (which currently includes the yeasts formerly classified as S. oviformis) is used for secondary champagne fermentations. Film forming yeasts are used for sherry fermentations. S. uvarum, a species which includes the bottom fermenting beer yeasts (formerly called S. carlsbergensis) has been used for low temperature fermentations (Gandini, 1968). Schizosaccharomyces pombe has been used at some time for secondary fermentations of sparkling wines since it reduces the malic acid content of the wine. It is interesting to note that S. exigus, a wine yeast mentioned in the older literature, has been isolated from San Francisco Sour Dough (Sugihara et al., 1971). It is not really surprising to find that doughs with a pH below 4.0 to 4.2 require a wine yeast for vigorous fermentation.

Pure cultures of wine yeasts may be obtained in test tube slants from universities and agricultural experiment stations in most wine producing countries. In the United States, the collection of the University of California at Davis and the American Type Culture Collection in Washington, D.C., are the best known sources for pure cultures. Special wine yeast cultures may also be obtained from commercial consulting laboratories. In some instances, wineries have cultured and preserved their own cultures. These cultures are also preserved by transfers in the laboratory using pure culture techniques. However, the cultures may not have been derived from a single cell isolate; and, in that case, there is no guarantee that one is not dealing with a mixed culture.

For the production of starter cultures the wine yeast is grown in successively larger vessels in sterilized (boiled) or pasteurized (at 60°C) grape juice. Grape juice concentrate diluted to a Balling of 22 is suitable for this purpose. A common sequence of vessels is from the test tube to a 1-liter fermenter, to a 5-gallon fermenter, and then to a 50 to 100-gallon tank. Transfers from one container to the next larger one should be made when the juice is fermenting vigorously. Provision for the escape of CO₂ through cotton bungs or preferably through liquid traps should be made. It is also desirable to stir the fermentation with filtered air (see Amerine et al., 1967, p. 263).

About two or three gallons of the yeast starter culture are used to inoculate each 100 gallons of must for the commercial, large scale production of wine. It is desirable to regulate the amount of inoculum in such a way that 5 to 10 million yeast cells (per ml) are present at the start of the fermentation. It is also desirable to add 100 to 150 ppm of SO₂ to the fermenter liquid in all of the stages of starter culture preparation so that the yeast will become acclimatized to levels of SO₂ used in commercial fermentations.

In some cases, one fermentation can be inoculated with the vigorously fermenting must of a preceding fermentation. However, continued use of pure yeast starters provides insurance against dominance by undesirable microorganisms.

ACTIVE DRY WINE YEAST

The idea of producing wine yeast by the same aerobic propagation methods used for bakers yeast was first proposed by Castor (1953). Compressed wine yeast was
first produced commercially by Universal Foods (then Red Star Yeast Company) in 1960. The Montrachet strain from the University of California at Davis was used and the results were described by Thoukis et al. (1963).

Compressed yeast has a relatively short shelf-life even under refrigeration and its distribution in frozen form to wineries is not practical. This prompted the development of bulk wine yeast in active dry form in 1965.

Active dry wine yeast is grown under highly aerobic carbohydrate limiting conditions, normally using purified, pasteurized molasses as the substrate. The yeast is acclimatized to sulfur dioxide through addition of bisulfite during propagation and is then separated from the fermentation liquid by centrifugation. The yeast in "cream" form is then washed to remove all traces of molasses before pressing to produce a 30% solids compressed yeast "cake". The compressed yeast is extruded into a size and shape suitable for drying with warm air. Freeze-drying (lyophilization) is not normally used for the preparation of bulk wine yeast.

Small tan pellets (about 1.0 mm in diameter) of pure yeasts are produced by roto-louvre drying using no additives. Other shapes may also be found depending on the drying method. The pellet yeasts are characterized chemically by a nitrogen content of 7%, a P2O5 content of about 2% (both based on solids) and a moisture content of about 8%. These yeasts typically contain between 20 and 30 x 10⁹ cells/g.

Several strains of wine yeasts are now available in active dry form but Montrachet and Pasteur Champagne continue to be the most used.

Montrachet is the University of California, Davis #522 strain of Saccharomyces cerevisiae. It is a fast-starting vigorous fermenting strain with an especially high resistance to sulfur dioxide. It is generally considered to have good flavor characteristics that are well suited to a wide variety of red and white table wine types.

Pasteur Champagne is the Pasteur Institute strain of Saccharomyces bayanus (University of California, Davis #595). It has a moderate fermentation rate and strong finishing characteristics that may be beneficial in the presence of high CO2 and alcohol levels or extremes of temperature. The strain is considered to have good flavor characteristics that some may describe as "flinty". It is frequently used for the secondary fermentation of sparkling wines along with certain table wine, concentrate and stuck fermentations.

Other strains available in active dry form are used for more specialized applications. California Champagne is the University of California, Davis #505 strain of Saccharomyces bayanus used for sparkling wine fermentations because of its rapid and compact flocculation. Flor Sherry is the University of California, Davis #519 strain of Saccharomyces fermentati used for submerged culture sherry fermentation because of its high aldehyde production.

Active dry wine yeast may be added directly into the fermenter at cellar temperature or first rehydrated in warm water or must. All dry wine yeasts appear to benefit from the warm temperature rehydration and typically have two to three times the activity when rehydrated than when added directly. Rehydration may consist of adding 1 kg yeast to 5-10 liters of water, must or diluted wine at 38-41°C (100-105°F), waiting 10-20 minutes, then mixing well and using.

Assuming 20 x 10⁹ cells/g in dry wine yeast, calculations can be made to
achieve a desired initial yeast concentration in the fermenter. A normal addition rate might be 25 g/100 liters (2 lb/1000 gal) to give $5 \times 10^6$ yeast/ml. This could be increased for stuck fermentations, fruit concentrate or other difficult applications or decreased for very fast fermenting table wines.

For sparkling wines, flor sherry, or stuck fermentations, dry wine yeast requires acclimatization to alcohol. This can be done by first growing it in juice or sweetened diluted wine until one-half the sugar has fermented, then adding it to the remainder of the wine.

LITERATURE CITED

LITERATURE CITED (cont.)


One of the major problems in producing a high quality wine is determining the proper maturity to harvest the fruit. In relatively cool regions, such as Ohio and northeastern United States, the sugar content is often the criterion for harvest. Under these conditions, grapes usually have excess acidity and low sugar content. Therefore, growers and wineries generally agree that the best varietal wines are produced from fruit having the highest sugar content. This follows the concept that the development of those chemical constituents necessary for flavor and aroma parallel more or less the sugar content. However, experience in our laboratory indicate that this may not be true for many varieties. Depending upon such factors as season, variety, and location, fruit with the highest sugar content (°Brix) sometimes yield a low quality wine.

For this reason, a preliminary study was conducted to determine the effect of grape maturity on wine quality and composition. In addition, three time periods of skin contact were included in the study. The purpose was an attempt to increase the varietal character of the wines.

PROCEDURE

Fruit from the variety Vidal blanc were harvested at three maturity levels (°Brix) in 1979 from a commercial vineyard in northern Ohio. After the grapes were harvested at early, mid, and late stages of maturity, they were transported to the Research Center in Wooster, Ohio. Following storage at 2°C for approximately 12 hours, the fruit were destemmed, crushed and divided into three lots and duplicated. Then, the musts were treated with 100 ppm of sulfur dioxide in the form of potassium metabisulfite. One lot was immediately pressed while the other two lots were pressed at 5 and 10 hours, respectively. From the soluble solids readings, the juices from the treatments early, and mid stages of maturity were ameliorated with sucrose to bring the soluble solids content to 21%. No amelioration was performed on the juice from the late harvested grapes (21.8° Brix). After amelioration, the juices were transferred to glass carboys (15 l each). Twelve hours after the sulfur dioxide treatment, each lot was inoculated with 2% v/v active yeast culture of Saccharomyces cerevisiae, Montrachet #522. 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.

RESULTS AND DISCUSSION

The results of the chemical analyses for the various musts are shown in Table 1. The soluble solids increased and total acidities decreased during grape maturation. With this decrease in total acidity, there was also a corresponding increase in pH. The period of skin contact had little effect upon the soluble solids and total acidity. However, the pH of the musts was increased when pressing was delayed for 5 and 10 hours. This rise in pH was probably due to the extraction of basic compounds from the skins and pulp.
Changes in total acidity, tartrates, and malates of the wines showed a general decline with grape maturation (Table 2). As expected, the pH of the wines increased with the maturity series. The results of the volatile acidity and alcohol content showed no distinctive patterns in relation to maturity. The tannin and color content of the wines tended to increase with maturity.

Little or no effect of skin contact on total acidity, volatile acidity, malates and alcohol contents was obtained in the wines. As in the case of the fresh musts, the pH values increased with an increase in skin contact. Also, longer skin contacts increased the tannin and color content of the wines at each stage of maturity. The extended times (5 and 10 hours) allowed more extraction of phenolic compounds into the juice.

TABLE 1. Chemical analysis of musts from Vidal blanc at 3 stages of maturity and 3 time periods of skin contact.

<table>
<thead>
<tr>
<th>Harvest date</th>
<th>Stage of maturity</th>
<th>Skin contact (hrs)</th>
<th>Soluble solids (%)</th>
<th>pH</th>
<th>Total acidity (g/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 2, 1979</td>
<td>Early</td>
<td>0</td>
<td>17.9</td>
<td>3.02</td>
<td>1.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>17.6</td>
<td>3.15</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>17.6</td>
<td>3.16</td>
<td>1.35</td>
</tr>
<tr>
<td>Oct. 15, 1979</td>
<td>Mid</td>
<td>0</td>
<td>18.9</td>
<td>3.01</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>18.6</td>
<td>3.25</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>18.6</td>
<td>3.21</td>
<td>1.21</td>
</tr>
<tr>
<td>Oct. 31, 1979</td>
<td>Late</td>
<td>0</td>
<td>21.7</td>
<td>3.18</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>21.8</td>
<td>3.20</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>21.7</td>
<td>3.29</td>
<td>1.14</td>
</tr>
</tbody>
</table>

a Total acidity as g tartaric acid per 100 ml.

The wines were ranked for aroma and overall taste by a panel of 11 judges. The results are shown in Table 3. The judges tended to prefer those wines made from grapes harvested at mid-maturity. Apparently the results indicated that the wine quality was not increased by delaying fruit harvest to late-maturity. For the influence of skin contact on wine quality, the results indicated that only minor differences existed among the treatments. However, a short skin contact time, 5 hours, seemed to improve the quality of the wines. Discussions after the tastings revealed that wines made from late-maturity grapes and long-time skin contacts were more mature and complex, and with more body. In contrast, the wines from mid-maturity grapes and 5-hour skin contact were described as being more fruity and clean tasting.

Since these experimental results were preliminary and limited to one season, no clear indication was established as to the effect of grape maturity and skin contact on the quality of Vidal blanc wines. However, the results do warrant its continuation and the experiment was repeated in 1980. The data from both seasons will be compiled and the results reported at a future Ohio Grape-Wine Short Course.
TABLE 2. Composition of wine made from Vidal blanc grapes at 3 stages of maturity and 3 time periods of skin contact.

<table>
<thead>
<tr>
<th>Stage of Maturity</th>
<th>Skin contact (hrs)</th>
<th>Total $^a$ acidity (g/100 ml)</th>
<th>Volatile $^b$ acidity (g/100 ml)</th>
<th>Total tartrates (g/100 ml)</th>
<th>Total malates (g/100 ml)</th>
<th>Alcohol % by vol.</th>
<th>Tannin mg/100 ml</th>
<th>Color 420 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>0</td>
<td>2.83</td>
<td>0.87</td>
<td>0.030</td>
<td>0.39</td>
<td>0.42</td>
<td>11.7</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2.91</td>
<td>0.88</td>
<td>0.027</td>
<td>0.31</td>
<td>0.43</td>
<td>11.7</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.95</td>
<td>0.89</td>
<td>0.030</td>
<td>0.31</td>
<td>0.45</td>
<td>11.7</td>
<td>42</td>
</tr>
<tr>
<td>Mid</td>
<td>0</td>
<td>2.87</td>
<td>0.78</td>
<td>0.030</td>
<td>0.35</td>
<td>0.36</td>
<td>11.3</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2.92</td>
<td>0.75</td>
<td>0.030</td>
<td>0.25</td>
<td>0.42</td>
<td>11.6</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.98</td>
<td>0.74</td>
<td>0.027</td>
<td>0.25</td>
<td>0.38</td>
<td>11.7</td>
<td>44</td>
</tr>
<tr>
<td>Late</td>
<td>0</td>
<td>2.93</td>
<td>0.77</td>
<td>0.033</td>
<td>0.25</td>
<td>0.27</td>
<td>11.9</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3.03</td>
<td>0.76</td>
<td>0.024</td>
<td>0.20</td>
<td>0.24</td>
<td>11.7</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>3.04</td>
<td>0.75</td>
<td>0.030</td>
<td>0.21</td>
<td>0.23</td>
<td>11.7</td>
<td>53</td>
</tr>
</tbody>
</table>

$^a$ Total acidity as g tartaric acid per 100 ml.

$^b$ Volatile acidity as g acetic acid per 100 ml.
TABLE 3. Aroma and taste of Vidal blanc wines made from grapes at 3 stages of maturity and 3 time periods of skin contact.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sensory Evaluation&lt;sup&gt;a&lt;/sup&gt;</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aroma</td>
<td>Taste</td>
<td></td>
</tr>
<tr>
<td>Early Maturity</td>
<td>5.1</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>0 hr</td>
<td>5.0</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>5 hr</td>
<td>4.9</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Mid-Maturity</td>
<td>5.0</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>0 hr</td>
<td>5.3</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>5 hr</td>
<td>5.1</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Late Maturity</td>
<td>4.8</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>0 hr</td>
<td>5.1</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>10 hr</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> 7-point hedonic scale, 7 being the most acceptable. Each value is an average from 11 judges and duplicated.
The two major acids in grapes are malic acid and tartaric acid. Although they both provide acidity and tartness to grapes and wines, they are different in their chemical and bacteriological stability. Tartaric acid is usually present as potassium bitartrate in grapes and is gradually lost as it precipitates during the process of alcoholic fermentation and cold stabilization. Since malic acid and its salts (except calcium malate-tartrate) are more soluble in wine, they do not precipitate during cold stabilization. Also, malic acid is stronger acid than tartaric acid, and its accumulation under a cool climate is the main cause for high acidity in grapes and wines. Bacteriologically, tartaric acid is quite inert while malic acid is susceptible to attack by yeasts and bacteria. Therefore, the presence of L-malic acid (the natural form of malic acid) in wines is usually an indication of bacteriological instability. Many species of the three genera: Leuconostoc, Lactobacillus, and Pediococcus are able to grow in wines thus causing malo-lactic fermentation. Malo-lactic fermentation is the process of degrading L-malic acid to L-lactic acid and carbon dioxide by the enzymatic action of these bacteria.

The first immediate effect of malo-lactic fermentation on wine is deacidification. Since lactic acid is a chemically weaker acid and less tart than malic acid, malo-lactic fermentation reduces wine acidity by decreasing titratable acidity and increasing pH. The second effect of malo-lactic fermentation is bacteriological stability. A complete malo-lactic fermentation will deplete L-malic acid in a wine. Thus, these bacteria are not able to grow and cause spoilage. The third effect is flavor complexity. Malo-lactic bacteria produce some flavor compounds such as diacetyl and acetoin. At their threshold levels, these two compounds may add subtle complexity to wine flavor.

There is a controversy as to whether or not malo-lactic fermentation actually improves the sensory quality of wine, other than the change in acidity. Nevertheless, natural (spontaneous) malo-lactic fermentation occurs in all the important viticultural areas of the world. It occurs in premium quality wines as well as in wines of lower quality. Malo-lactic fermentation is considered undesirable in the delicate and light white wines of Germany, because a high level of lactic acid is detrimental to the fruity character of their wines. Because of this, other decacidification methods are used to reduce acidity in many German wines. Bordeaux and Burgundy winemakers believe malo-lactic fermentation is desirable in making high-quality red wines. Malo-lactic fermentation is usually undesirable in the low-acid wines of California, however, it is encouraged in order to obtain bacteriological stability.

Since Ohio wines are generally made from grapes high in malic acid, malo-lactic fermentation is desirable from the standpoint of reducing acidity and providing bacteriological stability. Although malo-lactic fermentation may benefit Ohio wines, the incidence of malo-lactic fermentation in Ohio wines was only 10% in 1973 according to a survey of 30 wines from 15 wineries.

Many factors have been found to influence malo-lactic fermentation: pH, sulfur dioxide, alcohol, temperature, nutrients, yeast strains, bacterial strains, and insoluble solids. Among these factors, pH has a major influence. According to Kunkee (12), the critical pH for malo-lactic fermentation is 3.3. Above pH 3.3,
malo-lactic fermentation is more likely to occur. Below pH 3.3, a special effort is needed to initiate this secondary fermentation. Castino and his colleague (6) analyzed 72 Italian wines for the effects of pH, SO₂, and alcohol content on malo-lactic fermentation. They concluded that low pH alone was a powerful inhibitor and malo-lactic fermentation was impossible below pH 3.2. The same conclusion also was made by Fornachon of Australia (7). However, this was not true in New York. Rice and Mattick (16) reported that malo-lactic fermentation occurs quite regularly in New York wines as low as pH 3.0 and occasionally in wines below pH 3.0.

Despite the difference in the lowest pH limit for malo-lactic fermentation, there is an agreement that low pH is inhibitory to the development of malo-lactic bacteria, and the rate of malolactic fermentation is related to the initial pH of the wine. This is basically what we found in a preliminary study with wines made from Chancellor grapes. In this experiment, the must pH was adjusted with concentrated NaOH to obtain three pH values: 3.3, 3.5, and 3.7. After the additions of 50 ppm SO₂ and Montrachet yeast, fermentation was carried out on the skin for 5 days. Leuconostoc oenos PSU-1 was inoculated at 5°Brix. Results indicated that the malolactic fermentation rate is influenced by the initial pH of the must. At pH 3.7, malolactic fermentation was completed in 4 weeks for the inoculated wine while at pH 3.3 it took more than 8 weeks.

The pH not only affects the development of malo-lactic bacteria, but also influences the antiseptic action of sulfur dioxide. When sulfur dioxide is dissolved in water several ionic species are formed: sulfurous acid, bisulfite and sulfite. The percentage of each of these species is dependent on the pH of the solution. If the pH is 4.0, about 100% of the added sulfur dioxide will be in the bisulfite form. Both the bisulfite and sulfite species are much less effective as an antiseptic agent than sulfurous acid. As the pH decreases below 4.0, the concentration of sulfurous acid increases; therefore, more antiseptic activity.

In the range of wine pH, only sulfurous acid and bisulfite are present. The portion of these ionic species, mainly sulfurous acid, that are not bound to other compounds in musts and wines is known as free sulfur dioxide. The other form, fixed or bound, usually refers to the amount of the bisulfite which combines with carbonyl compounds. These compounds are present in musts and wines, and contain a functional group of -C=O in their structures. The free sulfur dioxide is the form that contributes most in preventing spoilage and discoloration in wines.

Although bound sulfur dioxide is less effective than free sulfur dioxide, researchers have reported that bound sulfur dioxide was inhibitory to some malo-lactic bacteria (8,13). Therefore, both forms, free and bound sulfur dioxide, have a strong influence on the susceptibility of a wine to malolactic fermentation. In order to encourage malolactic fermentation, the level of sulfur dioxide should be kept to a minimum, usually less than 50 ppm at the time of crushing. Beelman (1) has recommended the use of different sulfur dioxide levels for red musts at various pH values.

High alcohol contents in dessert wines usually inhibit malo-lactic fermentation. The alcohol content of the table wines only delays malo-lactic fermentation, but does not necessarily prevent it. For winemakers using pure cultures of malo-lactic bacteria, there has been a recommendation that bacterial inoculation be carried out in the middle of alcoholic fermentation, before the alcohol content is too high (12). However, Gallander (10) reported that bacterial inoculation during or after alcoholic fermentation was equally favorable in stimulating malolactic fermentation.
The optimum temperature for the growth of malo-lactic bacteria is between 25 to 30°C. These temperatures are higher than those recommended for making red and white wines. Low temperature and pH, and high sulfur dioxide are the main reasons for low incidence of malo-lactic fermentation in white wines. Rice (15) reported that in the range of 60 to 72°F, malo-lactic fermentation is proportional to the temperature. Low temperature favors the growth of Leuconostoc, not Lactobacillus or Pediococcus.

Among several malo-lactic bacteria isolated from California wine, ML-34 was selected to induce malo-lactic fermentation because of its tolerance to alcohol and SO₂, and low pH, temperature, and nutrients (12). But as far as inducing malo-lactic fermentation in Pennsylvania wine, PSU-1, isolated from Pennsylvania table wines, induced a faster and more consistent malo-lactic fermentation than ML-34 (3,4). Therefore, bacterial strains also affect the rate of malo-lactic fermentation.

Since some yeast strains produce sulfur dioxide, the selection of yeast strain may be critical in stimulating malo-lactic fermentation. On the other hand, some yeast strains are able to decompose malic acid (14), and this may be helpful to encourage malo-lactic fermentation. A high level of malic acid (exceeding 0.54%) delays the initiation of malo-lactic fermentation (5).

Nutritional studies of the growth of malo-lactic bacteria in synthetic media have shown that they are fastidious. Winery practices such as fermenting-on-the-skins (2) and delayed racking (9) are believed to provide the necessary nutrients for the growth of malolactic bacteria.

Insoluble solids is another factor that influences the rate of malo-lactic fermentation. Insoluble solids are the residual from grape pulp which settles to the bottom of the juice upon standing. Our study with two varieties, Vidal 256 and Catawba, showed that a high level of insoluble solids decreased the time required to complete malo-lactic fermentation. Sulfur dioxide levels in those samples containing higher amounts of insoluble solids were found to be lower than those with a lower amount of insoluble solids. The practical significance of this experiment was that clarifying the juice before alcoholic fermentation will delay malo-lactic fermentation.

LITERATURE CITED


LITERATURE CITED (cont.)

tion initiale de l'acid malique des mouts sur le declenchement et l'évolu-

affect the spontaneous initiation of malo-lactic fermentation in wines. 
IN Lactic Acid Bacteria in Beverages and Foods. J.G. Carr, C.V. Cutting 

7. Fornachon, J.C.M. 1957. The occurrence of malo-lactic fermentation in 

8. Fornachon, J.C.M. 1963. Inhibition of certain lactic acid bacteria by 

9. Fornachon, J.C.M. 1968. Influence of different yeasts on the growth of 

10. Gallander, J.F. 1978. Effect of time of bacterial inoculation on the sti-


Ser. 137:151-170.

13. Lafon-Lafourcade, S. 1975. Factors of the malo-lactic fermentation of 
wines. IN Lactic Acid Bacteria in Beverages and Foods. J.G. Carr, C.V. 

Sci. Fd. Agric. 17:312-316.


-75-
FREEZE-DRIED CULTURES FOR INDUCING MALO-LACTIC FERMENTATION

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Department of Horticulture
Ohio Agricultural Research and Development Center

Malo-lactic fermentation is the bacterial decarboxylation of L-malic acid to L-lactic acid and carbon dioxide. Through this conversion, wine acidity will be reduced to about one-half as contributed by malic acid. This secondary fermentation occurs after alcoholic fermentation and offers a desirable means of reducing wine acidity, particularly for red wines. Generally, winemakers agree that red table wines are better suited for malo-lactic fermentation than white table wines.

Several microorganisms are capable of converting malic acid to lactic acid and carbon dioxide, but the main bacteria responsible for malo-lactic fermentation is Leuconostoc oenos. This fermentation occurs during the middle of the logarithmic growth phase when the bacteria population reaches approximately $1 \times 10^7$ cfu/ml. Beelman et al. (1977) demonstrated the importance of selecting a bacteria strain adapted to local conditions for inoculation and inducing malo-lactic fermentation. Their research was with L. oenos PSU-1.

Malo-lactic fermentation has three major effects on wine, but its primary influence, particularly in Ohio, is that it brings about a natural reduction in wine acidity. Other contributions of malo-lactic fermentation include its positive effects on the sensory quality of red wines and the stabilizing effect which prevents further spoilage (Kunkee, 1974).

Although malo-lactic fermentation is advantageous, the initiation of bacterial deacidification is often difficult. Many factors influence the fermentation in wines, such as temperature, aeration, alcohol, time of racking, pH, and sulfur dioxide. To help overcome some of these factors and to provide a more rapid and predictable malo-lactic fermentation, a recent trend has been directed towards pure culture inoculation.

With this in mind, a study was initiated to determine the effectiveness of inoculating wines with freeze-dried cultures of Leuconostoc oenos in stimulating malo-lactic fermentation. This technique was compared with a natural malo-lactic fermentation which is not always successful and rapid.

PROCEDURE

In 1979 and 1980, grapes from the varieties Foch, Baco noir, and DeChaunac were harvested from two commercial vineyards and the OARDC Southern Branch in Ohio. After the grapes were destemmed and crushed, the musts were ameliorated with sugar to bring the soluble solids content to 20%. Then, the musts were treated with 50 ppm of sulfur dioxide in the form of potassium metabisulfite. Approximately 12 hours after the sulfur dioxide treatment, the musts of each variety were inoculated with a 1% (v/v) active yeast culture (Montrachet #522). The fermenting musts were stirred twice daily.

When the Brix reading dropped to approximately $10^0$, the must of each variety was pressed and divided into 2 lots, and duplicated. One lot with no bacterial in-
oculation was used as a control. The other lot was inoculated with a freeze-dried culture of *Leuconostoc oenos* PSU-1, which is commercially available¹. All wines were fermented in glass carboys equipped with water seals and placed in 18°C storage. The wines were fermented to dryness, racked, and stored full in glass containers. After malo-lactic fermentation, the wines were racked, bottled and chemically analyzed. The progress of malolactic fermentation was monitored by using paper chromatography.

**DISCUSSION AND RESULTS**

Must analyses indicated that the varieties were high in total acidity and low in pH (Table 1). For the two seasons, Baco noir was highest in total acidity with 1.78% (1979) and 1.47% (1980). The pH of the must samples varied between 2.99 and 3.45, Foch 1979 and 1980, respectively.

The results in Table 1 illustrate the reduction in total acidity due to malolactic fermentation. This bacterial fermentation was induced in all wines inoculated with bacteria, except Foch in 1980. Its low pH, 2.99, was the main cause for inhibiting malo-lactic fermentation. The loss in total acidity from the must samples to those wines before malolactic fermentation was due to tartrate precipitation. Further reduction in acidity was the result of malo-lactic fermentation. It also brought a further increase in pH through the loss of acidity, conversion of malic to lactic acid and carbon dioxide.

Stimulation of malo-lactic fermentation was obtained by inoculating with *Leuconostoc oenos* (Table 2). This was true for every variety and season except Foch in 1980. Both the control and the inoculated wines of Foch had not undergone malo-lactic fermentation in 84 days. For all other wines, the rate of malo-lactic fermentation was increased by using the freeze-dried culture of *L. oenos*. For example, the natural malo-lactic fermentation, control, for DeChaunac in 1980 was completed in 43 days, whereas the inoculated wines occurred in 17 days.

**SUMMARY**

These results illustrate the importance of inoculating wines with *Leuconostoc oenos* for the purpose of stimulating malo-lactic fermentation. If winemakers want to initiate a malo-lactic fermentation, direct inoculation is believed to be the best practice. This bacterial inoculation provides a more rapid, predictable, and beneficial fermentation than relying on the natural malo-lactic bacteria.

**LITERATURE CITED**


1. Tri-Bio Laboratories, Inc., 1400 Fox Hill Rd., State College, PA 16801 -77-
TABLE 1. Total acidity changes in three varietal wines inoculated with *Leuconostoc oenos* for seasons 1979 and 1980.

<table>
<thead>
<tr>
<th>Variety</th>
<th>pH</th>
<th>%</th>
<th>pH</th>
<th>%</th>
<th>pH</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before M-L Fermentation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foch</td>
<td>3.45</td>
<td>1.18</td>
<td>3.54</td>
<td>0.74</td>
<td>3.67</td>
<td>0.54</td>
</tr>
<tr>
<td>Baco noir</td>
<td>3.16</td>
<td>1.78</td>
<td>3.37</td>
<td>1.14</td>
<td>3.51</td>
<td>0.85</td>
</tr>
<tr>
<td>DeChaunac</td>
<td>3.32</td>
<td>1.27</td>
<td>3.50</td>
<td>0.78</td>
<td>3.67</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>After M-L Fermentation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foch*</td>
<td>2.99</td>
<td>1.33</td>
<td>----</td>
<td>0.82</td>
<td>3.28</td>
<td>0.75</td>
</tr>
<tr>
<td>Baco noir</td>
<td>3.22</td>
<td>1.47</td>
<td>----</td>
<td>0.92</td>
<td>3.66</td>
<td>0.65</td>
</tr>
<tr>
<td>DeChaunac</td>
<td>3.17</td>
<td>0.97</td>
<td>----</td>
<td>0.69</td>
<td>3.73</td>
<td>0.54</td>
</tr>
</tbody>
</table>

* Wines had not undergone malo-lactic fermentation.

TABLE 2. Effect of bacterial inoculation on the rate of malo-lactic fermentation in three varietal wines, 1979 and 1980 seasons.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Control</th>
<th>Inoculation</th>
<th>Bacteria</th>
<th>Days to Complete M-L Fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1979</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foch</td>
<td>32</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baco noir</td>
<td>85</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DeChaunac</td>
<td>29</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1980</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foch</td>
<td>84*</td>
<td>84*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baco noir</td>
<td>84*</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DeChaunac</td>
<td>43</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Wines had not undergone malo-lactic fermentation in 84 days.
On the thousands of different microorganisms in this world, most, including the pathogens, are of little concern to the winemaker. Many microorganisms cannot grow in wine because of its high acidity (low pH) and because of the level of alcohol that is present. Chance contaminants that may be introduced into a wine usually die off quite rapidly.

The organisms that may be a problem are some molds, yeasts and several groups of bacteria. In this report we will review some of their more important properties and methods used for their control.

**Molds**

Molds are filamentous fungi whose spores are widely distributed in nature. Their growth can present a problem both in the vineyard and in the winery. One species of mold, *Botrytis cinerea*, has been called "noble rot" because under certain conditions its growth on grapes enhances the quality of wines such as Sauternes. Most molds are not noble, however. Their growth in wine or on wine-contact surfaces may result in the production of off flavors. Even worse, we now are aware that some molds produce toxic substances. Of the 100 or so mycotoxins presently recognized, aflatoxin is perhaps of greatest concern since it is a very potent carcinogen.

Molds require little water for growth and thus may develop on walls, cooperage and other surfaces where the relative humidity is 75-80% or above—a condition not uncommon in many winery rooms. The use of fungicidal paints for nonwine-contact surfaces is a means for reducing mold growth. The addition of sulfur dioxide to acidified soak water will prevent buildup in wooden tanks. Ultra-violet lights are sometimes used to destroy spores that are present in the factory atmosphere.

In general, molds are quite sensitive to sulfur dioxide and this is one means for preventing their growth in wines. Adding SO₂ to the headspace and maintaining higher levels of SO₂ in the upper layers of wine can be effective. Although molds require oxygen for growth, it generally is difficult to maintain conditions sufficiently anaerobic in tanks to completely prevent their development.

**Film yeasts**

Some film yeasts have the ability to oxidize ethanol to acetic acid and acetaldehyde. Fortunately, most species are not very alcohol tolerant and thus can be controlled by ethanol plus the presence of low levels of sulfur dioxide.

**Bacteria**

The important groups are the lactic acid and acetic acid bacteria. Another bacterium, *Zymomonas*, spoils cider but appears not to be a problem in wines, perhaps because it grows poorly at pH 3.7 or lower.

Some of the distinguishing characters of the acetic and lactic acid bacteria are presented in Table 1. Two important tests in the laboratory for recognizing the organisms are the gram stain and the catalase reaction. The latter is a simple
test in which colonies are flooded with a 3% hydrogen peroxide solution. Catalase positive organisms decompose hydrogen peroxide to water and oxygen, the latter in the form of bubbles which can be observed.

**Acetic acid bacteria.** There are two genera of acetic acid bacteria, *Acetobacter* and *Gluconobacter*. The acetobacters have the ability to oxidize ethanol all the way to carbon dioxide and water while the gluconobacters oxidize it only as far as acetic acid. *Acetobacter* has been reported to be the more important genus with respect to wine spoilage.

Growth of acetic acid bacteria in a wine results in an increase in the volatile acid content. Under certain conditions the concentration of fixed acids may also increase due to the oxidation of sugars to the corresponding sugar acids. The organisms may also produce off flavors that have been characterized as "mousey".

We have found acetic acid bacteria only in low numbers on Eastern grapes. Large populations of the organisms have been reported to build up in pomace piles and in spilled juice and wine. Since they can be transferred to wine by drosophila flies, winery sanitation is an important means of control. The pomace cap formed when red wines are fermented on their skins is another area where the organisms may grow. Frequent punching down of the cap or regular pumping over of the wine will usually minimize the problem.

The acetic acid bacteria are aerobes and thus in theory their growth can be prevented by the elimination of oxygen. It usually is difficult, however, to achieve an oxygen tension sufficiently low in bulk-stored wines to completely inhibit growth.

Most strains are inhibited by 75 to 100 ppm SO₂. Most also fail to grow when the ethanol concentration exceeds 13%. The latter probably explains why Spanish flor sherries do not undergo acetification.

**Lactic acid bacteria.** Three genera of lactic acid bacteria are important as wine spoilage microorganisms (Table 2). With the exception of the pediococci, the types most likely to grow in a wine are the heterofermenters.

The lactic acid bacteria are widely distributed in the botanical world: they can be isolated from a variety of plants including grapes. They also make up a part of the winery microflora. Proof of this is that wines made from hot pressed grapes usually undergo a malo-lactic fermentation even though the bacteria would not have survived thermovinification.

Since the lactic acid bacteria are anaerobes, they can grow in wines both before and after bottling. Their main products of sugar metabolism are lactic acid, acetic acid, ethanol and carbon dioxide. Many have the ability to degrade malic, tartaric and citric acids. When the malo-lactic fermentation occurs prior to bottling, it often is considered to be a desirable secondary fermentation rather than wine spoilage. Tartaric acid degradation is rare under wine conditions. Some lactics break down sorbic acid to a compound that has a geranium-like odor. Other changes due to growth of lactics are haze, sediment, and various off-flavors.

Most wine lactics are very fastidious in their nutrient requirements. The media required for their isolation often are supplemented with fructose, tomato juice, and higher concentrations of manganese ion. A week or longer may be required before growth is detected.
Lactics are tolerant of high alcohol concentrations and a low pH. They have spoiled dessert wines containing 21% by volume alcohol and malo-lactic fermentations have been observed in wines having a pH as low as 2.9. Most strains have little sulfur dioxide tolerance; many are inhibited by concentrations as low as 20 ppm.

Preservation of bottled wines

A wine containing very low levels of sugar, under 0.2%, is usually biologically stable. Wines containing higher concentrations of sugar, however, are susceptible to refermentation by yeasts and to growth of lactic acid bacteria. The following are important control methods.

Filters. Membrane filters are widely used to remove yeasts and some of the bacteria from wines. The procedure is attractive because biological stability is achieved with minimal effects on wine quality. The main disadvantage to the process is that unless a completely aseptic system is used, there is opportunity for recontamination from the lines, filler and bottles.

Pasteurization. A very old process that is still used by many wineries. Most lactic acid bacteria and yeasts have little resistance when heated in a wine (Table 3) and they become more sensitive to heat as the concentration of alcohol is increased (Table 4). The disadvantage to pasteurization is that the quality of some wines may be affected adversely. On the other, heat seems to hasten bottle aging of certain wines.

Sulfur dioxide and sorbic acid. These are the two preservatives permitted in the United States. Sulfur dioxide is very effective against bacteria but the amount permitted in wine, 350 ppm, will not inhibit all yeasts. Undissociated sulfur dioxide is the active form. Very little of this species is present in wines having a pH of 3.5 and above.

Sorbic acid complements sulfur dioxide in that it is very effective against yeasts but has little activity toward the lactic acid bacteria (Table 5). There is an interaction between sorbic acid and ethanol in that higher concentrations are needed to arrest yeast growth when the percentage of alcohol is reduced (Table 6).

Literature Cited

TABLE 1. Differentiating characteristics. Lactic and acetic acid bacteria

<table>
<thead>
<tr>
<th>Property</th>
<th>Lactic acid bacteria</th>
<th>Acetic acid bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphology</td>
<td>rods and cocci</td>
<td>rods</td>
</tr>
<tr>
<td>Gram stain</td>
<td>positive</td>
<td>negative</td>
</tr>
<tr>
<td>Oxygen</td>
<td>not required</td>
<td>required</td>
</tr>
<tr>
<td>Catalase</td>
<td>negative</td>
<td>positive (most)</td>
</tr>
</tbody>
</table>

TABLE 2. The lactic acid bacteria important in wines

<table>
<thead>
<tr>
<th>Genus</th>
<th>Morphology</th>
<th>Sugar fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediococcus</td>
<td>cocci, often tetrads</td>
<td>homofermentative</td>
</tr>
<tr>
<td>Leuconostoc</td>
<td>cocci, often pairs</td>
<td>heterofermentative</td>
</tr>
<tr>
<td>Lactobacillus</td>
<td>rods</td>
<td>heter- and homofermentative</td>
</tr>
</tbody>
</table>

TABLE 3. Heat resistance of potential spoilage organisms in a Niagara wine (12.1% alcohol)

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>D-value a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leuconostoc oenos</td>
<td>0.33 min 109°F</td>
</tr>
<tr>
<td>Pediococcus cerevisiae</td>
<td>0.26 min 113°F</td>
</tr>
<tr>
<td>Lactobacillus fructivorans</td>
<td>1.7 min 140°F</td>
</tr>
<tr>
<td>Saccharomyces cerevisiae</td>
<td>0.4 min 120°F</td>
</tr>
</tbody>
</table>

a Time-temperature to kill 90% of the cells

TABLE 4. Heat resistance of Saccharomyces bisporus var. bisporus in the presence of different concentrations of alcohol.

<table>
<thead>
<tr>
<th>Ethanol concentration (vol %)</th>
<th>D-value a</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>9.5</td>
</tr>
<tr>
<td>6</td>
<td>4.6</td>
</tr>
<tr>
<td>8</td>
<td>2.0</td>
</tr>
<tr>
<td>10</td>
<td>0.82</td>
</tr>
<tr>
<td>12</td>
<td>0.30</td>
</tr>
</tbody>
</table>

a Minutes at 124°F required to kill 90% of the cells
TABLE 5. Growth inhibition of lactic acid bacteria by 1000 ppm potassium sorbate in a pH 3.5 broth.

<table>
<thead>
<tr>
<th>Species</th>
<th>% inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactobacillus fructivorans WBM</td>
<td>46</td>
</tr>
<tr>
<td>Leuconostoc oenos ML-34</td>
<td>9</td>
</tr>
<tr>
<td>Leuconostoc oenos PSU-1</td>
<td>33</td>
</tr>
</tbody>
</table>

TABLE 6. Influence of the ethanol concentration on the inhibition of yeast growth by sorbic acid.

<table>
<thead>
<tr>
<th>Yeast</th>
<th>% Ethanol</th>
<th>Growth in sorbate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100 ppm</td>
</tr>
<tr>
<td>Sacch. cerevisiae</td>
<td>10</td>
<td>+</td>
</tr>
<tr>
<td>Montrachet 522</td>
<td>11</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Sacch. bisporus var.</td>
<td>10</td>
<td>+</td>
</tr>
<tr>
<td><em>bisporus</em> Y-2</td>
<td>11</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>+</td>
</tr>
</tbody>
</table>
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All publications of the Ohio Agricultural Research and Development Center are available to all on a nondiscriminatory basis without regard to race, color, national origin, sex, or religious affiliation.
Ohio's major soil types and climatic conditions are represented at the Research Center's 12 locations.
Research is conducted by 15 departments on more than 7000 acres at Center headquarters in Wooster, eight branches, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University.
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Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres
Jackson Branch, Jackson, Jackson County: 502 acres
Mahoning County Farm, Canfield: 275 acres
Muck Crops Branch, Willard, Huron County: 15 acres
North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Science and Education Administration/Agricultural Research, U.S. Dept. of Agriculture)
Northwestern Branch, Hoytville, Wood County: 247 acres
Pomerene Forest Laboratory, Coshocton County: 227 acres
Southern Branch, Ripley, Brown County: 275 acres
Vegetable Crops Branch, Fremont, Sandusky County: 105 acres
Western Branch, South Charleston, Clark County: 428 acres