THE CULTURAL MANIPULATION OF VINE VIGOR AS IT RELATES TO THE COLD HARDINESS, WINE QUALITY, AND PRODUCTIVITY OF BACO NOIR GRAPEVINES, INITIAL EFFECTS

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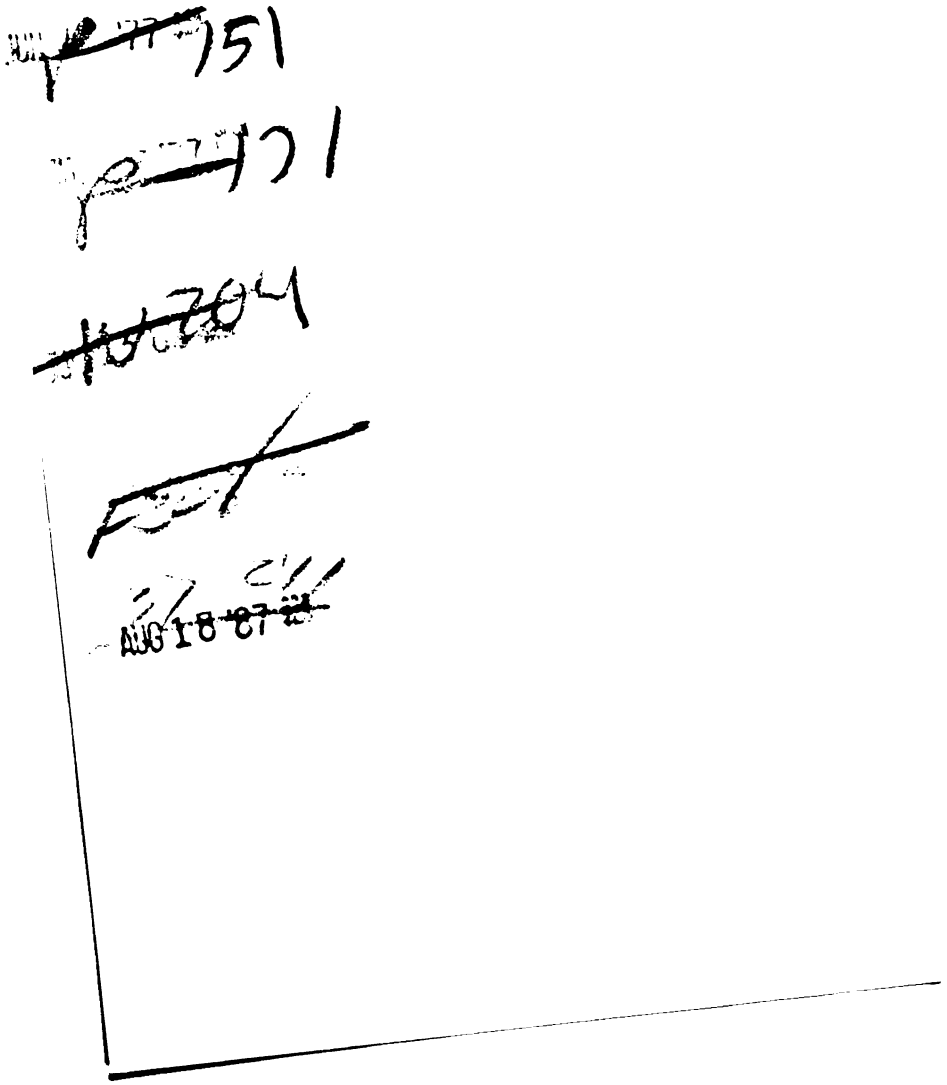

ABSTRACT

THE CULTURAL MANIPULATION OF VINE VIGOR AS IT RELATES TO THE COLD HARDINESS, WINE QUALITY, AND PRODUCTIVITY OF BACO NOIR GRAPEVINES, INITIAL EFFECTS

By

Michael Edward Byrne

The excessive vigor of Baco noir grapevines results in late season growth and winter injury. To control excess vigor, various levels of weed control, pruning severity, and suckering were applied to six year old vines and their effects on vine size, vine growth and nutrition, winter hardiness, grape and wine maturity, and productivity were measured.

For the four pruning severities used in this experiment, increased pruning severity resulted in increases in vine size, vine nitrogen levels, fruitfulness (yield/node retained), the number of clusters/node retained, fruit maturity, and wine volatile acidity, extract, pH, color, and panel preference. Increased pruning severity resulted in the decrease in the yield, number of clusters per vine and the total sugar produced per vine.

Weed control resulted in increased vine size, vine nitrogen, cane length, number of nodes per cane, number of clusters per node

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retained, fruitfulness, total sugar per vine, yield per vine and wine pH, extract, color, and panel preference. Weed control reduced vine potassium and phosphorus, and reduced wine volatile acidity.

Removing suckers increased vine nitrogen, number of clusters per vine, yield per vine, and wine extract and color while reducing vine size and delaying acclimation. It is tentatively concluded from these initial findings that Baco noir should be pruned less severely than is now commercially practiced. Light pruning will increase yields while still maintaining a constant vine size with no important decrease in fruit maturation or wine quality. This will also accelerate acclimation in the fall while only slightly reducing the maximum hardiness level. Initial data suggests that all weeds should be removed from the vineyard despite the slight delay in fall acclimation since yields are increased and fruit maturity does not suffer. Suckering was found to produce more moderate effects than other treatments, and is considered a less critical practice. Therefore, base bud stripping from the trunk is recommended, but root suckers should be left for trunk renewal.

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This thesis is dedicated to my advisor, Stan Howell, who gave me the opportunity to do this research and whose friendship and guidance were as real as they were valuable, and to my wife, Mary Lou, whose support and love brightened every day and who helped produce this manuscript.

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LITERATURE REVIEW

Introduction

The billion dollar wine industry in the United States produced over 420 million gallons of wine in 1974 (5). Recent production has been stimulated by increased consumption which has nearly quadrupled since 1947, and almost doubled in the last eight years (5). This increase has mainly been in dry table wine consumption while sweet or dessert wine consumption has decreased (5, 47). On the basis of such statistics, thousands of acres of wine grapes have recently been planted (47), creating new problems and challenges for the wine industry. The increased economic competition increases the need for better use of resources and of the grape crop through improved vineyard cultural practices and vinification techniques. However, both vinification technique and economics are beyond the scope of this study.

European viticulture and western viticulture in the United States have relied on the Vitis vinifera L. (9) grape cultivars which produce high quality wines, but lack the resistance to fungal diseases and phylloxera (Dactylosphaera vitifoliae Shimer).

Most V. vinifera L. cultivars also lack the hardiness against cold stress which is needed in temperate zone states (111). Therefore, eastern viticulture has relied on V. labruscana Bailey (9) grape cultivars which possess resistance to cold and to many diseases and insects (111). Unfortunately, most of these cultivars are not well received for use in the production of dry wines due to their strong flavor. Therefore, grape growers in temperate states have begun conversion to growing French-American hybrids.

The hybrids were bred after the spread of phylloxera in France to produce wine grapes which combined the more widely accepted fruit and wine qualities of V. vinifera L. with the resistance of several native American species to phylloxera (83, 92). Thus, the costly process of grafting V. vinifera L. scions to the American rootstocks could be avoided. The American species used in breeding attempts were V. rupestris Scheele, V. riparia Michx., V. Berlandieri Planch., V. rotundifolia Michx., V. cinerea Engelm., V. Lincecumii Buckley, V. aestivalis Michx., V. labruscana Bailey, and others which provided a large and varied gene pool with which to combine the various V. vinifera L. cultivars (9, 130).

Phylloxera was introduced into France along with powdery mildew (Oidium Tuckeri Berkeley), downy mildew (Plasmapara viticola deBary), black rot (Guignardia Bidwelli Viala & Ravaz) from the Americas in the nineteenth century (92). Since these diseases were

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present during the evolution of American grape species, selection pressure favored resistance to each, depending on the particular diseases present in the region where a particular species developed. The wide dispersal of these species resulted in the tolerance or resistance to many climatic and soil conditions in addition to phylloxera.

The resultant hybrids not only possessed various degrees of resistance to phylloxera but also to the aforementioned diseases and such adverse conditions as soil salinity, heat, humidity, drought, and cold (32, 92). The French-American hybrids have made it possible to grow high yielding, quality wine grapes in areas which have been limited to production of cultivars whose grapes produce less well received table wines.

Often in the quest for specific results using scientific experimentation, the facets which make up a total living organism are categorized and separated to facilitate the better understanding of each part. The danger with the use of that approach is that one may lose sight of the fact that all the environmental aspects and viticultural practices involved in the growth of a grape vine are interrelated. To avoid this, one must determine the impact of any vine treatment on other important aspects of its life. Prospective cultural practices must be weighed against the outcome of the vines' nutritional state, cold hardiness, productivity, and quality of the

grapes and resultant wine. All of these facets, as a result of the interaction of given environmental conditions and of the various treatments, must prove satisfactory for a new cultural practice to be acceptable.

General Theory and Concepts of Woody Plant Hardiness

Parker has stated that cold stress is the most limiting factor in the distribution of plants (89). Minimum winter temperature tolerance of a cultivar and susceptibility to spring and fall frosts can exclude the use of a cultivar in a particular region. In the fall, plants must acclimate before the first hard frost, and in the spring, buds should not develop too rapidly until after the last hard frost. Plants growing in cold climates must therefore be able to correctly perceive the signals of seasonal change and respond by developing sufficient resistance to cold injury.

Change in daylength is the most consistent calendar available to plants, and many plants utilize decreasing daylength as their first signal to begin the cold hardening process (29, 45, 48, 49, 80, 132). McKenzie found that the daylength effect is red-far red light reversible and concludes that this first stage of acclimation is phytochrome mediated (80). As the red light susceptible form of phytochrome accumulates in the leaves under short days, the leaves produce a hardiness

promoter which is translocated to the living bark where it initiates the hardening process (29, 45, 49, 80, 122). Only one pair of leaves is needed for acclimation to take place, thus indicating that the hardiness promoting substance is needed only in small amounts, and is therefore likely to be a hormone (46).

Since stage I of the hardening process is mediated by phytochrome, it seems plausible that there is an inhibitor-promoter complex as in the phytochrome mediated flowering process (29, 44, 49). It has been found that leaves exposed to long days do produce an inhibitor (29, 48) which is translocated (45) and may control a mRNA operon as a repressor (136). A critical threshold of promoter-inhibitor ratio would be responsible for derepression of this operon to begin the cold hardening process. The differences in the development of cold hardiness between varieties and species could therefore be due to either the level of this threshold or to the day length at which the promoter begins to be produced. The latter case seems to be better supported since grafting experiments have shown that hardier varieties with their leaves retained caused acclimation in defoliated less hardy varieties to which they were grafted (29).

When talking of a hardiness promoter or inhibitor, this is not the normal terminology used to speak of plant hormones. In fact, hardiness promoters and inhibitors may be exact opposites of growth promoters and inhibitors. Also it is the relative proportions of

promoter to inhibitor levels and the sensitivity to those ratios which determines a tissue's response to the many plant hormones (1, 82). Thus, there is a minimum time required for vegetative growth in the summer for the increased growth inhibitor-promoter ratio in the fall to cause leaf abcission (82) and for the plant to enter dormancy (50, 129). In hardiness terminology, the increase in promoter to inhibitor ratio causes the onset of hardening.

Accompanying the daylight change is a change in light quality. In temperate zones where solar elevation significantly decreases in the fall, the ratio of far red light at twilight increases as well as the length of twilight (94). Such light quality changes preceding the dark period can alter the critical dark period for the phytochrome mediated floral initiation (17), and can hasten and increase acclimation (80). This could account for the initiation of acclimation found under "long days" and high temperature conditions in a greenhouse in the fall (45). Once stage I is initiated, however, light has little or no effect on further cold hardening (80).

The second stage of acclimation appears to be induced by temperatures below five degrees centigrade, especially being triggered by a hard frost (45, 48, 79, 120, 132). This phase of cold hardiness promotes tolerance to much lower temperatures than does stage I, but to a slightly lesser degree (45, 48, 79, 120). As in

the vernalization requirement for the phytochrome mediated floral initiation, the temperature induced phenomenon of cold resistance is not translocatable (44). Whereas the temperature exposed time required to begin acclimation to a particular variety's maximum potential differs before completion (79, 85, 132). It is at this stage where macromolecules probably undergo transformations into their more cold stable forms which can withstand the severe dehydration of freezing stress (136). Levitt points out that drought and heat tolerance parallel cold tolerance, and postulates that the same mechanism may be involved in all three processes because in essence, each is the tolerance to dessication (66).

Many changes are taking place in cells of supposedly dormant woody plants during acclimation. A quantitative increase in total protein content due to synthesis and catalytic depolymerization is associated with qualitative protein changes (24, 65, 66, 113). These new proteins may play a role as membrane cryoprotective agents (33, 39, 40). Along with protein changes, sugar contents also increase which may protect against freezing injury in proteins by replacing structural water (37, 39, 40, 99, 120). Increases also occur in cellular contents of DNA and RNA (11, 70, 99, 113), to the SH to SS bond ratio in proteins (69), amino acids, especially of prolines which can act as growth retardants (65, 99), vitamins such as C (76), bark

anthocyanins (43, 132), organic phosphorus, and unsaturated lipids (28), all of which have been linked to hardiness.

Some of these changes may be coincidental or the product of low temperature inhibition of enzyme reactions. Whether causal or not, some of the changes occurring during acclimation and hardiness maintenance are active and require the expenditure of energy. It is photosynthesis that provides the energy needed at the onset of hardening (69, 80, 85) for the conversion of organic chemical structures involved in the metabolic changes from the growth stages to the cold resistant stage (85, 136). Supporting light exposure for photosynthesis is the fact that after the light initiation of stage I, the greater the light exposure, the greater is the degree of acclimation attained (80).

Although photosynthates accumulate at the onset of acclimation (8, 28, 30, 65, 69, 99, 112, 113), the natural increase of sugars per se is not correlated to cold hardiness (30, 95, 113), but rather the decrease of starches is part of the general depolymerization taking place which is correlated to greater cold hardiness (28, 65, 112, 113). Accumulation of soluble sugars is a result of the hydrolysis of these starches, a reduction of their utilization (69), and is related to reduced growth, leaf senescence, and other changes occurring at this time (30). It is possible that the light reaction of photosynthesis, which is less hindered by low temperatures than

is the dark reaction, plays a role in the increase of the reduction potential in cells (18, 69). There is also an increase in chlorophyll in the woody tissue of hardening plants (18) while photosynthesis decreases to zero by January (69). This indicates that the light induced reactions in chloroplasts may then be supplying the chemical energy to synthesize hardiness factors through the accumulation of $NADPH+H^+$ (68, 69), or by ATP generation through the electron transport system of the chloroplast (6). Levitt proposes that the increased reduction potential is used to convert dehydration sensitive SS bonds to SH bonds in proteins to protect against intermolecular SS bond formation (68, 69).

Mechanisms of protection against cold differ between plant tissues. Measuring exotherms of freezing tissue determined that buds were killed at the onset of any ice formation (at the first exotherm) while stem tissue survives until intracellular freezing takes place, or the dessication stress becomes lethal (second or third exotherm) (16). The buds' survival is based on the exclusion of intracellular freezing by the lowering of the freezing point, while the stem tissue survival is based on the exclusion of intracellular freezing by the promotion of extracellular freezing (128, 136). This could be why stem tissue is generally more cold resistant than are the buds during dehardening (22).

Many mechanisms of cold hardiness promotion have evolved to deter injury and death due to low temperature stress (75, 89, 136). The polygenetic basis for the phenomena (75, 89, 136) which assures many facets of protection is probably the reason why there exists so much conflicting data on the subject. However, since all plants are mostly composed of water, suppression or regulation of the formulation of ice is universal in the resistance to cold injury. Control of plant water includes the decrease in shoot water content (70, 95, 112), pith cell senescence and rapid dehydration (80), root water content decline (125), and root suberization and increased resistance to water absorption by over threefold (80). The cell membrane increases in permiability so that water can be lost to ice nucleation centers outside of the cells if the freezing rate is slow enough (7, 80, 98, 128).

Of the possible mechanisms that actually cause freezing injury, the classical one of mechanical damage by ice crystals has only been found to be responsible for localized tissue damage (81). The formation of extracellular ice is actually beneficial to hardened cells due to dehydration of the cell and reducing the likelihood of intracellular ice formation (54, 95, 128, 136). Another theory that increased intracellular salt accumulation denatures proteins has not been proven since comparable osmotic stresses in vitro were not able

to denature proteins (36, 81). The most plausible theories on cold injury mechanisms are the existence of a minimum tolerable cell volume past which the membrane is destroyed (81); the loss of water necessary for the retention of protein structure due to dehydration (97) which causes an unfolding of helices (36); and the formation of intermolecular disulfide bonds while cells are dehydrated, and molecules are close together, and unfolding of helices upon rehydration (68). The effect of freezing and thawing rates upon injury can be explained in terms of decreased spacial compression (68), reduced water loss, the site of crystal formation (7, 54, 96, 128, 136), and its effects on crystal structure (74, 86). Injury by cold temperatures definitely involves the denaturation of proteins (40, 113), but the exact timing and mechanisms are still in dispute.

In stage II, macromolecules are converted to more stable forms in chemical structure by depolymerization and in water binding potential (36, 66, 69) as a protection against the dehydration stress of freezing temperatures (61). The influence of these new structures upon cellular water may account for the third stage of acclimation. The hydrogen bonding of hydrophyllic molecules' hydration spheres and the polyhedral clathrate enclosures of hydrophobic molecules enable the cells to control the water critical to protein structures (36, 38). As Birshtein states, stage III of acclimation involves "the influence of molecular surfaces oversurrounding water by creating a

higher degree of order among water molecules" (15). Induction of this stage occurs at the low temperature range between -20 and -60 degrees centigrade and enables plants to withstand temperatures down to -96 degrees centigrade (95, 127). The reduced intermolecular distance and thermal motion (128) of low temperatures are what make this submicroscopic reorientation into quasi-crystalline structures possible. Such structures are readily reconverted by the fluctuations of environmental temperatures (43, 85, 127, 136), thus accounting for the quick oscillations between stages II and III during the winter months.

Increasing air and soil temperatures are most important in triggering deacclimation and bud break once the chilling requirements has been met (116). Dehardening during a late winter thaw can be rapid with as much as five to ten degrees centigrade of hardiness lost per day (93). However, rehardening requires much more time. When the soil has warmed sufficiently, the roots resume growth (60) and increase in moisture uptake and content (125). At the same time, bud succulence increases and cytokinin and auxin levels increase (82, 125).

Grape Hardiness, Productivity and Maturation

To insure consistent viticultural success, grape growers in temperate zones must culture to maximize the maturity of their vines

as well as the maturity of their fruit. Buds and canes must mature and develop tolerance to cold so that shoot and flower primordia and the vascular system which feeds them will survive the winter to produce the next year's crop. As Siminovitch, et al., state, the development of such tolerance, is the result of many independent and additive events (113). To optimize these different processes, research toward increasing cold hardiness has centered around breeding, weather modification, mechanical protection, attempts to slow autumn growth, and hormonal control (136). Of these, breeding has probably been relied upon the most. Its impact, however, can be felt only upon single cultivars. The manipulation of cold hardiness potential by cultural means which is applicable to any cultivar, has received less attention. Therefore, this study will focus on the cultural techniques available to influence cold tolerance.

Being a perennial, a grape vine by definition must be able to survive from year to year. The rates, timing and magnitudes of environmental change interact with the genetic potential and preconditioning of a grape vine to determine whether it will survive. Latitude, the effects of the prevailing winds and ocean currents, and the proximity to large bodies of water largely determine gross climatic conditions important to the growth and survival of the grape vines.

Temperature variations throughout the year influence a grape vine the most of any climatic condition (140). The rate of

photosynthesis and metabolism and therefore, the rate of growth and maturation are determined by the temperature of the environment. The grape vine can accumulate carbohydrates only above 12°C. (140). Therefore, heat summation or growing degree days determined by the average temperatures above twelve degrees centigrade of the growing season and its length has been used to ascertain whether a particular variety will be able to produce enough carbohydrates in a particular environment to survive and to produce sufficient yield and quality of fruit to be economical (25, 47, 101, 103, 105, 111). Temperature also affects the balance of sugar to acid and the volatile constituents of the fruit (140), but this will be discussed further in a later section.

Fall temperatures affect the onset of acclimation through their initiation of stage II of the hardening process (45, 48, 79, 80, 120, 132). Spring temperature fluctuations and their rates of change are important to the survival of the vines which are ready to emerge from quiescence, and especially critical to the coming season's yield of fruit. Winter minimum temperatures which fall too low can cause local tissue damage to trunks, canes, buds, or can kill whole vines (33, 103, 105).

The other major environmental factor affecting grape vine growth is the availability of water. As in any plant, grape vines require a certain range of precipitation and humidity to survive. A minimum amount of water is required for metabolic activity and to

dissipate heat. However, too much rain at bloom time can cause poor set (140), rain near harvest can cause splitting and disease of the fruit (33, 92, 140). Snow cover can insulate the trunk and roots, and reduce injury due to cold air temperatures (33, 92).

Superimposed upon the macroclimate are the variations of microclimate due to local topography, soils, vegetation, and bodies of water. Such local climatological variations occur close to ground in the space occupied by low grouping vegetation like grape vines (31), and thus have a great effect on viticultural practices.

The movement of air during the winter is critical in temperate zone viticulture. Cold air, being heavier than warmer air, remains close to the ground and accumulates in low spots in the landscape. Establishing vineyards on slopes facilitates the drainage of cold air away from the vines which can then be replaced by the warmer air above it (25, 33, 73, 92, 105, 111). Care should be taken that this drainage not be blocked by trees or other physical obstructions below the vineyard (25). Obstructions above the vineyard, however, can divert cold air away from the vines (25).

Decreased air temperatures cause increased cold hardiness, so grapevines in low sites develop greater cold hardiness (123). However, the greater fluctuations of temperatures in low sites increases the probability of vine damage (123). Grapevines on higher sites harden to a lesser degree and also fluctuate more in hardiness

during hardening and dehardening with respect to the living bark and the primary and secondary buds (123). Therefore, low sites tend to be more productive in severe winters (123).

Large bodies of water also enhance air circulation due to their heat retaining ability (25, 92, 103, 111). Warmed air rising from the water's surface pulls the cooler air from the surrounding land toward the water. Warmer air from above can then replace it. Since water has a high thermal capacity, specific heat, and heat of fusion, the temperature of a large body of water changes much slower than the air (73); therefore, local moderating of seasonal change is experienced. The decreased rates of temperature change surrounding large bodies of water increases the probability of viticultural success.

As well as adequate air drainage requirements, well drained soil favors grapevine growth (33, 103, 105, 111). Increased soil aeration due to water drainage enables grape roots to spread wide and deeply into the soil to obtain the nutrients necessary for growth (103). A deep root system also enables the grapevine to withstand the stress of droughts. Six feet or more of well drained soil is considered to be necessary for optimal vine growth and production (105). Deep fertile soils give high vigor and yields, but produce a lower quality wine (140). Shallow soils lower in fertility yield less fruit, but produce a higher quality vine (140).

Soil fertility is not as important as soil texture, however (140).

Transfer of heat between soil and the air depends on the differences between the temperatures of both, the conductivity of each, and the state of the boundary layer of air (73). Soil compaction and moisture level are directly proportional to heat transfer to and from the soil. Compact moist soil therefore absorbs more heat during the day and releases more during the night, thus protecting the vines from possible frost damage (25, 73, 92). Weed or cover crops interfere with this heat transfer by increasing the size of the insulating air boundary layer (25, 73, 92). Therefore, weeds should be cultivated and cover crops mowed before times when frosts are a danger. However, the effect of plowing or discing is much like mulching or use of plastic films in that a heat and water barrier is established (73). This could keep the vines dormant longer in the spring by keeping the soil cool, but increases the hazard of frost in the fall (73).

Since there are so many factors to consider, the vineyard must be established on the basis of the geographical site and the desired varieties (25, 103, 104). The site is a complex ecosystem composed of above ground and root environments and the topography (103), many factors of which have already been discussed. Varities of grapes differ widely in their growing condition optimums in such

factors as tolerance to cold, heat, drought, soil and air moisture, soil composition, the many diseases and pests afflicting grapes and in the timing of senescence, bud break, bloom, and maturation of their fruit and wood (25, 32, 92, 140). A particular site can therefore accommodate only a fraction of the total number of potential cultivars. Likewise, one cultivar can be grown only in some of the many possible grape sites. Although there is usually a range of cultivars which can be grown on a given site, environmental or soil factors can severely limit cultivar choice. Breeding programs are therefore essential in combining genetic adaptions to various environmental factors with the many desirable fruit characteristics of grape vines.

Since grape maturity, vine maturity, and cold hardiness are all related to the vines' carbohydrate status (101, 104), regular vineyard practices can not be separated from hardiness promoting practices (41). Therefore, cultural practices must be weighed on the basis of vine size, maturation, and winter hardiness as well as fruit maturation and yield measurements.

The grapevine, as in any photosynthetic organism, derives its energy from the sun. Overcrowding due to close spacing or large vine size, poor trellising, and poor shoot positioning cause shading and can greatly effect the efficiency of the vine's leaf surface (110). Leaves need at least five hundred foot candles of light to

achieve maximum photosynthesis (102). Internal or shaded leaves may get less than one hundred foot candles of light (102). Defoliation can be used to demonstrate the loss of photosynthetic capacity due to shading (78, 123) which can cause reduced total sugar production (123), fruit maturity (55, 56, 78, 117, 119, 123), total yields (78, -07, 110, 115, 123), yield per node (fruitfulness (123), cluster weight (123), number of berries per cluster (78, 123), fruitfulness the following year (20, 77, 78, 123), and vine size (123). The overall carbohydrate deficiency also results in poor wood maturation and reduced cold hardiness (101, 104, 123).

The priority of vine carbohydrate distribution is demonstrated by the effect of defoliation on successive vine parts. Root, berry, shoot, and then trunk dry weights (19) are decreased, or culturally, fruit maturation, yield, vine size, and then hardiness (123) are decreased in that order. Correct trellising, spacing, and shoot positioning are thus critical to efficient vineyard management. To capture the most light, grapevine rows should be planted in a north-south direction (114). Exposure on southern slopes insures warmer winter minimum temperatures, but can be dangerous if buds break too soon in the spring (25). High, well filled trellises also best utilize incoming solar radiation (114). High trained vines are exposed to a warmer winter environment and may be less cold hardy (123). Although full trellis coverage is good, excessive vine size can lead

to increased shading. To combat the deliterious effects of shading, and to allow the vigorous growth of such cultivars as Baco noir, a trellis system called the Geneva Double Curtain was developed by Shaulis (102). Two wires equidistant from the ground support two curtains of grape vegetation so that each vine actually receives more light than it would have if trained to any of the conventional single curtain systems (114). The use of the Geneva Double Curtain trellising system results in up to ninety percent increase in yields (27, 102) with no decrease in soluble solids, but with increased cluster size and fruitfulness, and better vine maturation (104). The Geneva Double Curtain is also more adaptible to mechanical harvesting (27).

Another major factor in fruit and vine maturation and cold hardiness is pruning practices. A low pruning severity such as 60 + 10 can increase simple yield (72, 123, 126), and has improved berry set due to increased pollen germinability (90, 108, 139), and increased the number of clusters per bud retained (123, 126). However, the resultant increased crop stress decreases cluster weight (123, soluble solids (90, 100, 123, 133, 134, 135), color (133), the following year's fruit production (138), vine growth (133, 134, 135, 138), vine vigor (21, 72, 126), and increases acidity (4, 92, 133, 134, 139). If excessive, low pruning severity can deplete carbohydrate reserves (133, 134, 135, 138), and decrease cold hardiness (23, 41, 104, 123).

High pruning severity causes the reverse of the above vine characteristics with the exception that as the vine vigor increases due to high pruning severity, vegetative growth may be prolonged into autumn and result in delayed acclimation (104, 105, 123). The correct intermediate pruning severity balances vegetative growth with crop load and will result, when other cultural practices are optimal, in the maximum potential cold hardiness. The correct pruning severity, or the number of buds retained, can be determined from the vigor of the vine expressed as vine size, and can be measured as the weight of pruned canes (90). Late pruning may cause delayed bud break in the spring (92, 105, 140). Also, leaving multiple trunks increases the probability that one trunk will survive the winter cold (25, 103, 104, 105).

Suckering is vine pruning done after bud push to eliminate shoots arising from compressed base nodes on the trunk and from the roots. If suckers are not removed from a vine, they can effectively compete for soil nutrients coming from the root system (47, 62). The production of large numbers of suckers may indicate overly severe pruning or winter injury (104, 105, 140). Suckers are valuable for vine renewal, and are used to replace mechanically or cold injured or diseased vines (92, 104, 105).

In some years, high berry set or excessive numbers of clusters per shoot can cause overcropping and reduced fruit maturity. Cluster

thinning can be used in these years to reduce the crop (105). In the production of some French-American hybrid cultivars, even severe pruning can not overcome these vines' propensity to over-produce. Cluster thinning is normally employed in conjunction with pruning to establish the correct balance between fruit and wood production (32, 138). Thinning clusters increases cluster weight (35, 110, 123), reduces time to fruit maturation (35, 58, 105), increases berry proline (58), vine size (58, 110, 123), wood maturity, and degree of cold hardiness (58, 123). Cluster thinning is not usually employed on low to moderately high yielding vines since the decrease of yield (35, 105, 110, 123) causes more economic loss than is offset by the increased fruit maturity. Only on high producing vines where overcropping may kill or severely weaken the fine is cluster thinning commonly used. Girdling, tipping, and growth regulators are also used to improve grape quality of table grapes (140).

The control of weeds in a vineyard can have a great effect on vine growth (150). Spring spray and cultivation treatments should be utilized to afford the grapevines the best growing conditions during their early development (105). Such cultivation should not be to a greater depth than three inches since root injury and excessive erosion may result (105). If continuous cover crop or weed cover is to be used, as with terracing, the cover should be controlled by mowing in the spring. The cover crop can limit the

water supply during the critical late season when excess water can prolong the vegetative state detrimental to optimal acclimation (23, 26, 104). Cover crops also use up soil nutrients which can reduce vine growth in the fall (104, 105). When the cover is disked under, some of the nutrients are returned to the soil and thus can act as a nutrient storage mechanism (111). During the winter, cover crops can hold the snow to aid in vine root insulation (111).

Soil nutrient levels can greatly affect vine and fruit maturity, although there is a wide tolerance to varying nutrient levels (64). Micronutrients are usually at adequate levels in soils, but deficiencies and toxicities do occur. Nitrogen and potassium are the most important macronutrients to the grapevine. Both increase vine growth, yield, and total sugar production (63, 100).

Potassium deficiencies decrease yields (63, 100), fruitfulness (106), and vine size (63, 106), but either too low or too high levels cause decreased cold hardiness (14). High nitrogen levels cause increased vegetative growth (110, reduced yields (84), soluble solids (100, 118), and fruitfulness (10), and increased cold injury to the vine (23, 42, 92, 101, 104). This is also substantiated by observations linking excessive nitrogen application to decreased cold hardiness in many plants (51, 67, 91).

To determine how a particular treatment is affecting the nutrition within a vine, the chemical composition of leaf petioles is

tested. Petiolar composition appears to best reflect both vine growth and deficiency symptoms (106). A random sample of petioles are taken from the youngest mature leaves in the center of the cane beyond the fruit which are well exposed and free from damage and disease (34, 53, 105, 106). The best time to sample is from mid-July to mid-August (53).

Even after the maturity of the vines is established, the extent of cold injury can be affected by controlling the environment within the vineyard. During acclimation and deacclimation, grapevines can be protected from frosts by the use of a sprinkler irrigation system (73, 92, 140). Care must be used to spray enough water so that the vine will not freeze, and not so much that the mass of external ice causes heat loss or mechanical damage (73, 92, 140). Air temperature surrounding the grapevines can be increased by the use of heaters and/or wind machines (73, 140). In marginal climates or where tender varieties are grown in moderately cold climates, the grapevines are covered with soil during the winter to decrease the extent of cold injury (104, 140).

Although cultural practices such as trelising, pruning, suckering, weed control, cluster thinning, and fertilizer application have a great effect on vine maturity (101) and fruit maturity, climatic variation has the greatest effect upon maturation (109). The interrelated factors of light and heat levels influence the

accumulation of photosynthates and the metabolism of organic acids. In full sunlight, labeled carbon dioxide is incorporated mostly into sugars. However, in shade or at low light and heat levels, labeled carbon dioxide is incorporated mostly into organic acids. Also, at higher heat and light levels, malate is dehydrogenated to oxaloacetate which is in turn transaminated to aspartate (57). Tartrate levels are not influenced much by heat. Tartrate is therefore the organic acid found in the highest amount in mature grapes (57). The more light and heat that vines receive during the growing season, the more mature is the fruit at a given date. Thus, red grape maturity is equated with high sugar, color, amino acids, total nitrogen levels, tartrate to malate ratio, and low total acidity, as well as high phosphorus and potassium and low ammonia levels (88, 109). Too much heat, however, can cause grapes to lose the delicacy and richness of their aromatic qualities (140). Balance in aromatics and acid to sugar ratios decline with increased heat, but the oxidation results in grapes that are good for making Port, Sherry or Muscatel (140). Cooler regions produce better balanced, more delicate wines.

In the wine resultant from red wine grapes, the greater the maturity of the grapes, the higher the levels of phosphorus, potassium, total nitrogen, proline, biotin, alcohol, 2,3-butanediols, tannin, extract, volatile acidity, color, and pH are, and the lower

is the total acidity (88, 133, 135). Although vine treatments which affect grape maturity may affect the above qualities, wines made from the differently treated grapes may be rated "the same" numerically by organoleptic evaluation. However, up to a point, the more mature the grapes are, the better the ratings, and the better are the keeping and aging potential of that wine (135).

The quality of a wine must reflect the maturation state of the grapes from which it was made. This in turn is affected by the climatic conditions and cultural techniques under which the grapes were grown. To some extent, wines can be improved and standardized by good enological technique. However, this would defeat the purpose of comparative enology which is used to estimate such differences. Since lab tests alone can not test all facets of a wine, and since small quantitites and perhaps small differences are involved, micro-vinification as used by grape breeders is necessary to completely evaluate cultural treatments applied to a wine grape vine (13). The critical differences between microvinification and commonly used enological technique is the care taken to prevent oxidation where such large surface to volume ratios are involved, and the care to maintain each of the small batches representing a wine treatment under the same conditions (13) so that they can be compared.

Cultural Problems of Baco Noir

Baco noir is an early ripening, moderate to high yielding blue-black grape variety susceptible to cold injury, having medium clusters of small berries, moderately susceptible to powdery mildew, resistant to downy mildew and phylloxera, and resultant from a cross of Vitis riparia Michx. and Folle Blanche (32, 130). The extreme vigor of this cultivar resulting in late season growth may lead to the trunk cankering, cane die-back and bud mortality due to cold injury common to this cultivar (32). Excess vigor has been tied to the unbalanced nutritional state of a low carbon to nitrogen ratio, water supply, weather conditions, grape pests, and crop size (71, 105). The large vine size resultant from excess vegetative growth causes shading and reduced fruitfulness which in turn causes increased vine size (105, 110).

Control of vine nutrition to control excess vigor could result in increased yields and resistance to cold injury. The use of girdling increases the carbon to nitrogen ratio, and affects the increase of berry set and yields only in vigorous vines (71). Resistant rootstocks have been shown to decrease the carbon to nitrogen ratio of the scion and reduce yields, fruitfulness, fruit maturity, cluster weight, and clusters per node, and to increase the number of clusters per vine, and vine size (71, 87) compared with both less vigorous

rootstocks and the own-rooted scion. As previously discussed, high nitrogen levels can cause increased vegetative growth which reduces vine carbohydrate levels, fruit and wood maturation, fruitfulness and yields, and increases cold injury (10, 23, 84, 92, 101, 104, 110, 111). Nitrogen control is therefore a logical choice for controlling vigor, and is best obtained by withholding nitrogen fertilizer, and by establishing a cover crop or natural weed cover to compete for soil nutrients (23, 104, 105). A cover crop established after July will afford the vine full nutrition during the spring growth spurt, and begin to use soil nutrients and water late in the season to reduce detrimental late season growth (23, 26, 104). Cover crops can also reduce erosion, especially in conjunction with terracing.

Although weed cover can counteract high nitrogen levels, it would be more logical economically to convert some of the vines excess energy into more harvestable fruit (71) by pruning less severely. The added carbohydrate sinks might cause an even more imbalanced carbon to nitrogen ratio, however. The added crop may also increase the already high acidity of Baco's fruit. Even so, overly vigorous vines are definitely not balance pruned, and seem to warrant a decrease in pruning severity. Suckering may be useful in decreasing vine vigor without further imbalancing nutrients since they are close to the ground and may usurp soil nutrients (62).

Summary

Baco noir is a very vigorous cultivar characterized by late season vegetative growth. The vines are thus not prepared for cold weather, resulting in trunk cankering, cane die-back, and bud mortality. The purpose of this research is to define some cultural options for controlling vigor and subsequent hardiness problems of Baco noir without reducing the quality or quantity of the fruit produced. Pruning severity, suckering, and weed control will be the variables imposed to control vigor.

MATERIALS AND METHODS

The experimental plots were established at the Tabor Hill Winery which is located in southwestern Michigan in Berrien county. Three rows of fifty, six year old Baco noir grape vines planted in a North-South direction in rows spaced nine feet apart and vines spaced eight feet apart were used as the test vines. The Bellefontaine sandy loam (137) soil slopes down into a weed covered depression to the east. The plot is otherwise surrounded by vineyards on lands sloping up to the north, and level with the experimental plot to the west and south. The test vines were supported by the Geneva Double Curtain trellising system with the center wire 76 cm (2.5 feet) and the top two wires 183 cm (6 feet) above the ground level.

Treatments were applied to the vines in a split plot design with four replicates of 24 vines each, blocked against a North-South slope. Weed control was split with half of the plots receiving monthly applications of one half pound per acre paraquat plus .03 percent surfactant (x - 77) applications using a hand held portable sprayer. The weeds were sprayed as soon as they began to grow in the spring and until just before harvest. The other half of the

plots were mowed just before harvest. Each weed plot was separated by a buffer vine.

Eighteen species of weeds were identified from the weed plots. These were quackgrass (Agropyron repens (L.) Beauv.), brome-grass (Bromus carinatus H. & L.), annual blue-grass (Poa annua L.), yellow foxtail (Setaria glauca Beauv.), red sorrel (Rumex acetosella L.), common chickweed (Stellaria media (L.) Vill.), yellow rocket (Barbarea vulgaris R. Br.), field peppergrass (Lepidium campestre R. Br.), rough cinquefoil (Ponteneilla norvegica L.), wild carrot (Daucus carota L.), common milkweed (Asclepias syriaca L.), red dead-nettle (Lamium purpureum L.), common mullen (Verbascum thapsus L.), buckhorn plantain (Plantago lanceolata L.), bracted plantain (Plantago aristata Michx.), chickory (Cichorum intybus L.), horseweed (Conyza canadensis (L.) Cron.), spiny sowthistle (Sonchus asper Hill), dandelion (Taraxacum officinale Weber), and alsike clover (Trifolium hybridum L.).

The other two treatments, pruning severity and suckering were randomly assigned to the grapevines within each weed control plot. Vines were pruned using the formulas of 30, 50, and 70 buds retained for the first pound of pruned one year old canes, and ten buds were left on the vine for each successive pound of one year old prunings. The number of buds retained and the weight of the first year pruned canes were recorded for each vine.

After the first year of the experiment, the 70 + 10 vines showed a greatly reduced vine size and increased dieback during the winter. These vines were determined to be over stressed and were pruned using a 10 + 10 formula the following year. Each pruning year took place in the early spring. After the vines began to develop new shoots, base nodes on each trunk and newly developing suckers were removed from the roots on thevvines to be suckered. On the other half of the vines, suckers and base shoots were allowed to develop.

The grapes from each vine were harvested and tested separately for yield, 50 berry weight from the apical portion of five clusters, number of clusters, soluble solids, total acidity, and pH according to the methods described by Amerine (2). The fifty berry samples were frozen and latter analyzed for soluble solids, pH, and total acidity in the lab. The grapes from all eight similarly treated vines were then combined, crushed, and tested for pH, soluble solids, and total acidity. The acidity was not adjusted as it could have been so that any treatment differences could be measured. One hundred ppm sodium meta bisulfite was then added to each of the twelve musts. After two days, one tenth gram Montrachet yeast was added per gallon, and the must was allowed to ferment on the skins in ten and twenty gallon food grade plastic containers at 20°C. for ten days in 1974, and for five days in 1975. The twelve batches of wine were pressed in a five gallon capacity basket wine press after which sucrose was

added to bring the total soluble solids up to 22° Brix and a final alcohol of 12%. Wine from each treatment was placed in two, three gallon glass carboys and allowed to undergo secondary fermentation under water seal at 20°C.

After fermentation had ceased, the wines were allowed to settle and were then racked. Total acidity and pH were tested, and the acids were chromatographed to determine whether malo-lactic fermentation had occurred (2). All of the wines were cold stabilized at -2°C. for three months to precipitate excess potassium acid tartrate. Afterwards, the wines were racked and tested for free sulfur dioxide which was adjusted to 25 ppm at this time, and the wines were bottled.

Laboratory analysis of the wines consisted of testing total acidity by titration, pH measured on a Beckman Zeriomatic pH meter, soluble solids by hydrometer, volatile acidity with a Cash Volatile Still and subsequent titration, and color with a Beckman Recording Quartz Spectrophotometer, model DUR with a tungston filament light bulb at 420mμ, 520 mμ, and the dominant wavelength, each as described by Amerine (2). Organoleptic evaluation was performed by a test panel consisting of Dr. G. Stan Howell, associate professor of Horticulture, Michael Byrne, David Johnson, and James Wolpert, graduate research assistants, Stephen Stackhouse and Henry Nelson, laboratory technicians, and Tim Mansfield, undergraduate. All wines were

evaluated on Amerine's twenty point scale (3) in repeated blind tastings for color, appearance, aroma, bouquet, acescence, body, flavor, astringency, acidity, sweetness, and general quality. Triangular and paired comparisons were also used to determine replication differences and to detect the widest range of differences between treatment and productivity parameters of 1975 wines.

The effect of the various treatments on vine cold hardiness was evaluated by taking periodic samples of canes and subjecting them to controlled freezing tests. The effect of position on a cane was tested in terms of node distance away from the cordon to determine whether random sampling of unequal node positions would produce similar results. Hardiness of nodes three through thirty were not significantly different when sampled so random sampling of cane tips and whole canes were utilized. Cane sampling otherwise was stratified to reduce variability. Unless physically impossible, the canes were selected for maturity where the canes were well exposed to the sun and as dark brown as possible, and the diameter of medial size. Single node stem sections cut at the midpoint of each internode from the mid portion of each cane were sealed in plastic bags in the field and transported to laboratory. After being labeled, samples were stored for not more than 48 hours at 1°C. while awaiting testing. Aluminum foil was used as a heat sink by wrapping the samples in it before placing them in vacuum flasks.

The Revco two stage freezer was precooled to -75 $\pm$ 15°C. according to the mass of the samples to be frozen and the temperature to be attained inside of the vacuum flasks so that a uniform rate of drop could be maintained between controlled freezer tests. The temperature was monitored inside of the flasks by inserting a 26 gauge copper-constantan wire thermocouple into the pith of the inner-most cane sample. Each thermocouple wire was attached to a rotary switch which allowed up to twenty-four separate flask temperatures to be monitored on the temperature read out. Freezing occurred at a rate of 3 $\pm$ 1°C. per hour to a predetermined temperature at which time the flasks were removed from the freezer. Flasks were thawed at ambient temperature for 12 to 18 hours at which time the samples were removed from the flasks. The samples were then placed in two gallon glass jars for 7 days during which time they were aerated periodically with high humidity air.

Each controlled freezer test consisted of five temperature intervals, 5°C. apart plus an unfrozen control which was stored at 1°C. Two cane sections with single buds replicated four times were used to evaluate each of the twelve vine treatments. The living bark plus the primary, secondary, and tertiary buds were evaluated by a browning test. The tissues were considered alive if green, and dead if fruit clusters and/or other bud tissue was brown and if the living bark was dark brown all the way through the phloem and cambium to the

xylem. Browning was initially compared to regrowth in a mist bench for evaluating Baco noir canes and buds, and was used due to the shorter time required to obtain results through this method (124). The temperature at which 50 percent of the canes or buds were killed, the T_{50}, was determined with the use of the Spearman-Karber probit analysis equation as adapted for use in temperature stress evaluations by Bittenbender (16).

The effects of the aforementioned treatments on vine growth were measured in the early winter of 1975. Measurements were taken on the two longest canes on each vine, and included total cane length and node number, length and number of nodes of the tip of the cane that failed to produce periderm, the length of node numbers three through thirteen, and the diameter of two axis midway between node numbers four and five. A cross sectional area was computed using the formula $A - r_1 r_2 \pi$ since the canes are elipsoidal. Vine size, expressed as the weight of one year old canes pruned off each of three years, was also used as an estimate of vine growth.

The effect of the treatments on the nutritional status of each vine was determined by collecting and analyzing a sample of the leaf petioles in early August (53). Petioles from undamaged well exposed leaves apical to nodes bearing fruit were collected resulting in a composite sample from two vines for each of 48 replicate treatments. The petioles were dried in a forced air oven and ground in a Wiley

mill. Each sample was tested for nitrogen, potassium, phosphorus, calcium, manganese, magnesium, zinc, copper, iron, and boron.

RESULTS AND DISCUSSION

Vine Growth and Nutrition

The treatments imposed upon the test vines were designed to reduce excess vegetative growth and create a better utilization of photosynthates. Measurements were taken, therefore, to ascertain how the treatments affected vine growth and nutrient balance. As in the rest of the results sections, only those treatment means which are less than or equal to 5% probability will be discussed unless otherwise stated. All mean comparisons are based on the studentized range tables of Tukey Q values.

Figure 1 represents the treatment effects on vine size from 1974 through 1976 as given in Table 14. Vine size means were not significantly different in the spring of 1974 when the experimental treatments were applied. Treatments were therefore applied across randomly variable size vines. The most obvious difference in vine sizes is the large drop between the pruning weights of 1974 and 1975, and the reestablishment of large vine size of several treatments in 1976. This can be partially explained by the fact that the Baco noir vines were being pruned at 10 + 10 or greater pruning severity previous to 1974. All of the pruning treatments of this experiment were

pruned less severely and could account for the large drop in vine size between 1974 and 1975. Climate could also account for the vine size changes. Although the degree days from bloom to harvest were almost identical in 1974 and 1975 at approximately 2500, degree days for the whole season were 2677 and 3064 respectively. Also the mean daily maximum temperatures averaged almost one degree higher in 1975. These climatic conditions along with the fact that the crop was harvested one month earlier in 1975 could have resulted in more of the photosynthetic capacity being utilized to produce and mature wood after the harvest in 1975. This offers one explanation to account for the gross year to year variations which were observed in the experimental vines. The fact that no fertilizer applications were made in the Tabor Hill vineyard during the experiment also probably had an effect on vine size as well as other growth factors of the Baco noir vines.

Table 1 displays the treatment main effects on vine size. The establishment of the pruning severity treatment by the number of buds left after pruning is shown to be significantly different. The effects of the pruning severity on vine size do not become significant, however, until after the spring of 1975 when the 70 + 10 vines were pruned with a 10 + 10 formula. By the spring of 1976 vine size became significantly different with vine size directly proportional to the severity of these pruning treatments used in this experiment.

In other words, with increasing buds left on a vine for each pound of pruning wood, not only are there more growing points among which the vine can spread its nutrients, but the vine is less capable of producing new canes. Of the nutrients assayed, pruning severity only affected vine nitrogen and calcium at the 10% level, however, as shown in Table 3.

Weed control only affected vine size at the 10% significance level in 1976 as shown in Table 1. The absolute difference, however, is just as great as effects on vine size caused by pruning severity. The weed control effect is considered less significant because of the fewer degrees of freedom resulting from the split plot design. Therefore, weed control treatment differences of 10% or less will be discussed in the following text. When the difference between the weed control and weed cover plots are compared over the two year period, a trend is shown toward increasing vine size within weed control plots. Perhaps this will become more statistically significant in the future. It is more importantly viticulturely significant. Weed control also affected other vine growth factors, but also only at the 10% level. Table 2 shows that weed cover results in shorter cane length and less nodes per cane as well as a larger percentage of nodes which developed periderm by the date of measurement. However, the die-back data in the same table indicates that just as much winter kill occurs in weed control and weed cover plots. The weed control

plots, which resulted in more vine growth also resulted in the most wood surviving the winter. Also, weed cover caused a decrease in nitrogen and increased potassium content in petiole samples at the 5% significance level. Although the samples were collected in early August, and are therefore inconclusive as far as nitrogen fertilizer recommendations (100), they are useful in determining the effect of the various treatment combinations on the Baco noir vines.

The effect of weed cover on the content of phosphorus is significant only at the 10% level, but is an absolute difference of almost 50%. This may be of importance since percent phosphorus is highly negatively correlated with wood weight, cane length, and internode length. Weed cover appears to increase phosphorus which is in opposition to previous nutrition data on phosphorus in the range of these samples (14, 140). The weed cover affected the nutritional status of the vines which may have resulted in the growth effects. However, nutritional status of the vines is confounded with other factors such as soil moisture depletion by weeds. Since no measurements were taken on soil moisture, this must be considered as an equally possible explanation of experimental results.

The effect of suckering on vine size as shown in Table 1 was significantly different in 1975. Vines which were not suckered on the average had higher vine sizes. This was probably due to the growth in sucker weight as opposed to the count node weight. The

suckers could actually have reduced the growth of the upper portions of the vines. Suckering of the vines also resulted in higher petiole nitrogen levels as shown in Table 3. This could be responsible for the decrease in percent nodes which formed periderm and in the percent length of periderm formed on the end of the canes as shown in Table 2.

Also shown in Table 2 is the length of node numbers three through thirteen and their internode lengths which represents the early growth of the canes. Leaving the suckers on the vines results in increased cane growth in the early part of the season. The presence of suckers at the end of the season is also beneficial in that fewer nodes and less length of the canes lack periderm.

Productivity and Maturity

It is difficult to interpret the precise effect of the pruning severity treatments on the vines which were changed from 70 + 10 to 10 + 10 in the spring of 1975. This is especially true of the effect on productivity since the fruitfulness, or yield per bud retained, is affected by the various climatic and cultural factors of the previous year. Therefore, the first year's data on the 70 + 10 pruned vines and second year's data on the same vines pruned 10 + 10 will be considered as separate single year experiments. For the same reason,

the 1975 data will be given more weight than that from 1974 in the subsequent discussion.

When 1975 yield is compared to vine size as measured in the spring of 1976 in Figures 1 and 2, yield is shown to be inversely proportional to vine size and pruning severity. This is due to the fact that when the vines are pruned severely as in the 10 + 10 pruning severity treatment, many of the compressed base nodes on the cordons will develop shoots which otherwise would not have grown. This is due either to the increased availability of nutrients, the increased availability of growth-promoting hormones, or the decreased inhibition resulting from the reduction in production of growth inhibiting hormones. More of the secondaries and tertiaries also will develop which causes increased fruit production per node. Although the fruitfulness of each node retained is much greater with increasing pruning severity, the yield per vine is greater with decreasing pruning severity due to the increasing number of buds retained. The same is true of the 1974 data as shown in Table 4.

The same relationship exists for the number of clusters per vine and the clusters per node where increased pruning severity results in more clusters per node, but fewer clusters per vine. This again is the effect of non-count nodes which are similarly related to pruning severity since it would be expected to be an inverse relationship. It appears that the more fruit sinks that are present, the

less energy the vine will put into the shoot sinks. This also could be due to the repression of the less fruitful base shoots. Thus the low pruning severity treatment of 50 + 10 which is applied by leaving the most buds per vine produces vines with high numbers of fruit clusters. The increased number of fruit sinks utilize more of both available photosynthates and fertilizer so that less nutrients are used to produce canes resulting in lower vine size (21). Total carbohydrate production in a given year expressed as fruit yield in 1974 and 1975 plus pruning brush in 1975 and 1976 is inversely related to pruning severity. This confirms previous findings that increasing the number of fruit sinks stimulates photosynthesis and results in higher total carbohydrate production even though vine size is lower (21). The question remains whether the fruit sinks are taking too much nutrients away from the root sinks. It appears not, but more time is needed to determine this effect since the roots were not measured.

The 1975 effects of pruning severity on grape maturity are surprisingly slight considering the large vine size and yield differences. The largest acidity difference is 0.02%; the largest pH difference is 0.07%; the largest Brix difference is 0.81%; and the largest Brix/acid difference is 0.82% as shown in Table 5. 1974 differences were similarly small. Although these are small viticulturally, the difference in soluble solids could make a slight

difference to the winemaker in the achievable alcohol percentage or amount of sugar to be added. However, this difference has much less variance than is experienced between vintages.

In 1975, suckering had no effect on any productivity factors. However, when calculated for only weed controlled plots, the presence of suckers was shown to decrease yield. This suggests two possibilities: weed control may exert more effect on productivity than does suckering, but suckers reduce growth if weeds are not present. In 1974 suckering affected only the number of clusters produced and clusters per bud. This was probably a non-count node development phenomenon which resulted in a slightly higher yield per vine. This is shown in Table 4. Unfortunately, the point of origin and fruitfulness for each cane was not evaluated, so this is only conjecture.

The effect of weed control on productivity in 1975 clearly illustrates the chain of events in the effect of stress on productivity of Baco noir. Controlling weeds results in a 5% level of significance in the number of clusters and the number of clusters per bud which increase. This could be a non-count node development phenomenon, or due to the increased fruitfulness of the buds which developed under less stressful conditions during the previous year, but is most likely due to the increased vine size and number of buds. Whatever the cause, the increased number of clusters causes an increase in yield, yield per bud, and total sugar, but only at the 10% level

because these are indirect effects of the less stressful conditions. There are no significant effects on fruit maturation due to weed control in 1975. In 1974, weed control did result in a significant rise in soluble solids and Brix acid ratio, however.

When percent total acidity and Brix are compared between the initial fifty berry sample and the must data, there is little difference in 1974, but there is both a drop in Brix and a rise in total acidity. This can be seen when Tables 4, 5, and 6 are compared. The consistency in the difference of about 1.0% Brix and 0.10% total acidity in 1975 probably means that this is a bias in sampling toward riper fruit when selecting the fifty berries. The fact that this did not occur in 1974 with the same samplers, however, could indicate that the fruit ripened more uniformly in 1974.

Wine Quality

The data on the wines made from the Baco noir grapes harvested in 1974 is shown in Table 7. As a group, these wines were relatively high in acidity with an overall average of 0.815%. They were slightly low in tannin, but were dark, full flavored wines with a vinous aroma, being uncharacteristic of Baco. When tasted "blind," the wines were rated at between fifteen and sixteen on Amerine's twenty point scale (3). Treatment differences could not be discerned by the panel of tasters in this manner. Paired comparisons of the extremes of

treatment effects on vine size, yield, and theoretical stress were also analyzed. By this method it was established that there were no preferential differences in 1974 wine qualities due to treatment effects on either vine size or theoretical stress. There was a preference for the wines from vines with lower yields which in this case was a difference between 7.32 and 11.55 kilograms per vine. The actual difference between these wines was very slight, however.

From the results of the laboratory tests on the 1974 wines displayed in Table 7, it is shown that after the cessation of fermentation, the acidities were significantly different, being inversely proportional to pruning severity and lower in suckered vines. Cold stabilization not only reduced the acidities on the average of 0.15%, but also greatly reduced the differences between treatments. Thus, in the treatment effect on grape maturity, pruning severity did have an effect, but the acidities in the resulting wines did not manifest these differences. This conclusion is substantiated by the fact that the percent extract is also affected by pruning severity as well as by weed control. Slightly higher bodied wines resulted from the highest pruning severity and weed control. Other "significant" differences shown in Table 7 are not viticulturally or enologically important.

Paired comparisons of wines resultant from 1975 vine treatment extremes showed marked preference (five out of five) for high stress,

high yield, and low vine size. The actual yield difference was between 3.18 and 10.09 kilograms per vine. In each case the wines from vines of reduced vigor and increased crop load were preferred. However this could have been due to the indirect effect of crop load as it interacted with excessive rain in August just before harvest (see Table 15). On vines pruned the most severely, not suckered, and not weed controlled, the crops were reduced. Thus, there was less volume of fruit in which to distribute the excess rain water absorbed by the roots. These fruits were also probably more mature and more susceptible to splitting, which they did. This is probable since volatile acidity was shown to be inversely proportional to yield as can be seen by comparison of Table 5 and Table 8. It was probably this increase in volatile acidity with decreased cropping stress which resulted in the lower taste panel preference for such wines. Other factors such as increased extract, pH, and color intensity support the hypothesis that decreased cropping stress increased fruit maturation. Therefore, in a year with less August rain, taste panel preferences may have been different if not opposite.

Table 8 displays the results of laboratory tests on the 1975 wines. Pruning severities decreased acidity in the order of 30 + 10, 50 + 10, and 10 + 10. However, other indicators of fruit maturity such as the percent extract, color intensity, and dominant wavelength show the 10 + 10 pruning severity to be slightly superior. Suckering

also benefited wine quality by decreasing acidity, increasing the percent extract, and lengthening the dominant wavelength. Weed control increased the percent extract and lengthened the dominant wavelength, but decreased the color intensity and caused the hue to be more blue which was considered a negative attribute.

Hardiness

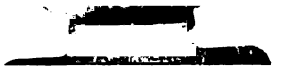
The discussion of Baco noir hardiness will be in terms of the negative °C. temperatures at which 50% of the canes, and the primary, secondary, and tertiary buds are still alive, otherwise known as the T_{50}. This is not necessarily the T_{50} which would occur under field conditions since factors such as evaporative cooling, heat of fusion, snow cover, time of exposure, rate of temperature change, wind dessication, and others would effect the survival of vine tissues. However, it is an accurate comparison of the relative sensitivities to cold stress as a result of the various treatments. Since only one T_{50} was obtained per treatment, no statistics could be computed other than the Spearman-Karber "S" statistic (16), which is a slope and variance around the T_{50} estimate.

In the winter of 1974-1975, all treatment vines attained approximately the same hardiness level by the beginning of deacclimation. This is shown in Table 10. Rather, the differences between treatments occurred as delayed or accelerated acclimation. Both

suckering and weed control caused a delay in the onset of acclimation as shown in Table 9. This is also shown in Table 2 as a delay in periderm formation. The delayed vines gradually caught up to the others as can be seen across the dates in Tables 9 and 10. As well as sucker and weed stress, cropping stress caused an acceleration in acclimation as shown in the effect of pruning severity on hardiness in Table 9. Unlike the presence of suckers and weeds, however, the effect of pruning severity on hardiness completely reversed by the time maximum hardiness was attained. The vines which acclimated first due to the pruning severity treatments were not able to attain as great a hardiness by two degrees centigrade. By the onset of de-acclimation, the vines were all equally hardy. The treatment effects on hardiness during the winter of 1975-1976 were also similar to the previous year. The hardiness levels for 1975-1976 are shown in Table 11. The order of hardiness of the tissues from the highest to lowest appears to be cane, tertiary, secondary, primary. This is probably the reverse order of economical significance, although no studies have been done on the relative fruitfulness of the various buds of Baco noir. The cane is usually considered less important since it is often the hardiest tissue and is therefore less often limiting to fruit production than are the more cold sensitive buds (123), although the buds can not survive without the cane.

The slope and variance around the T_{50} or Spearman-Karber "S" statistic (16) given in Tables 9, 10, and 11, show a fairly consistent effect of treatment stress. The less stressful treatments produce slopes which have a larger range around the T_{50} values. This would probably result in more tissue survival for two otherwise equal T_{50} values. For example, in Table 9, on March 25, 1975, all of the T_{50} values are almost identical except for the very large differences in S values. For less stressful treatments, S values are higher. Primary bud S values are also higher than cane, or secondary and tertiary buds.

Figure 3 shows the degree of hardiness of non-treatment Baco noir grape tissues throughout the winter of 1975-1976 as compared to the air temperature maximums and minimums. Although the minimum temperatures of March 3rd and 4th went below the level of the T_{50} values, very little bud and cane kill resulted. This reveals the conservative and relative nature of the T_{50} values given. A multiple regression analysis of the cane and each bud versus the maximum and minimum air temperatures, zero through fourteen days prior to twelve sampling dates produces conflicting results. However, the hardiness of the cane and each bud as well as the mean of the cane and three buds' hardiness regressed on the average daily temperatures zero through fourteen days prior to the sampling date reveals highly consistent results. Each tissue has the highest correlation with the average air temperature three, nine, and twelve days prior to the sampling



date (see Figure 4). Such consistent results, each with a correlation coefficient of over .780 are most probably not artifacts. It appears that the mechanism at work in the hardiness maintenance of Baco noir operates on a three day cycle with both short and long range sensing ability, although the long range control appears more important. This would be sound evolutionarily since the vine could respond to changes relatively quickly, but not unless the weather trend were in the right direction. More research is needed to determine the veracity of this suggestion.

Air temperatures in the spring of 1976 began a warming trend in late February. There was an especially warm period for two weeks in mid April followed by cold weather which killed much of the fruit crop in Michigan. The temperature dropped only to -2°C., however, at Tabor Hill. The Baco noir buds had begun to push and were between swell and five centimeter development, and depending on the extent of development, the buds were variously damaged. One week after the frost an evaluation of damage to the buds was made on normally pruned five noded canes and on the first five nodes of unpruned vines. As can be seen in Table 16, the first five nodes on the pruned spurs developed faster than those on the unpruned canes and therefore sustained more damage increasingly from the basal to the fifth node. Although the pruned vines will probably bear a normal crop, this observation on spring frosts should not be ignored.

Summary and Conclusions

The suckering treatment resulted in decreased vine size and higher vine nitrogen levels, delayed periderm formation, and delayed acclimation. Suckering did slightly increase the number of clusters and yield per vine, and also improved the extract and color of the resultant wine. The effects of the presence of suckers on the reduced yield and wine quality are so slight, however, that the beneficial effects on periderm formation and accelerated acclimation overshadow these drawbacks. A compromise could be struck where the compressed base nodes on the trunk are stripped off, but the shoots arising from the roots are allowed to develop for multiple trunk renewal. This is also logical since the trunks and cordons of Baco noir need replacing often.

Weed control and the resultant lack of weed competion with the vines caused increased vine size, longer canes, and more nodes per cane. The increased vine size was correlated with increased vine nitrogen, reduced vine potassium and phosphorus, and less periderm formation. Weed control also resulted in an increase in the number of clusters per node and per vine, fruitfulness, total sugar, and a large increase in yield. Fruit maturation was not reduced by the increased productivity, and wine quality was even improved in acid, pH, volatile acidity, extract, and color, and overall taste panel preference. The resultant slight delay in acclimation should

therefore be ignored and all weeds should be removed from the vineyard. If some cover crop is necessary to reduce erosion, a plant which will compete the least with the vines should be chosen. Potassium is not a problem under such conditions.

For the four pruning severities used in this experiment, as the pruning severity increased, and the number of buds left on the vine decreased, vine size increased along with vine nitrogen. Also increased were fruitfulness and the number of clusters per node, but yield, the number of clusters, and total sugar were reduced. Increasing pruning severity increased fruit maturity, and probably as a result decreased wine quality by increasing volatile acidity due to splitting. Extract, pH, and color were benefited by the increased pruning severity even though preference by the taste panel was lowered. Thus, it is tentatively concluded from this experiment that the pruning severity of Baco noir should be 50 + 10 which will increase yields while maintaining a constant vine size, will not cause any important decrease in fruit maturation or wine quality, and will accelerate acclimation while only reducing the maximum hardiness level slightly. More years of data need to be collected before this tentative conclusion can be accepted with confidence.

It is also suggested from this study that Baco noir could have a mechanism which operates on a three day cycle for detecting changes in air temperature, and for establishing and maintaining the

correct level of hardiness. It is recommended that Baco noir and other cultivars be pruned either late or double pruned when there is the possibility of frost damage in the spring.

TABLES

Table 1. Treatment main effects on 1974, 1975, and 1976 vine size. Values are given in pounds of first year pruning brush per vine. Numberical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Astierisks indicate between 5 and 10% level of significance.

Table 1

Measurements → / Treatments ↓		1974		1975		1976	
		Pounds Pruned Brush	#Buds	Pounds Pruned Brush	#Buds	Pounds Pruned Brush	#Buds
Pruning	30 + 10	3.17	49.7	1.34	11.3	2.30	44.8
	50 + 10	3.34	73.2	1.37	44.0	1.86	58.1
	70 + 10	2.89	86.2 (10+10)	1.23	14.0	3.32	33.8
Not Suckered		3.01	70.0	1.48	31.0	2.71	46.8
Suckered		3.27	69.3	1.14	29.8	2.28	44.3
Weed Cover		3.36	72.7	1.21	28.3	1.81	39.8
Weed Control		2.91	66.7	1.41	32.6	3.17	51.3
Tukey Comparison Level	Pruning		9.64		5.50	0.881	8.41
	Suckering			0.302			
	Weeds					*	
	W X P			*			
	W X S			1.964	19.23		
	P X S					*	*
	W X P X S						

Table 2. Treatment main effects on 1975 vine growth. Vine growth was measured in November of 1975 and cane dieback was measured in March of 1976 with each measurement made on the longest two canes of each vine. Numerical values given in the lower portion of the Table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 2

Treatments \ Measurements		Total Length (m)	# Nodes 11/75	# Nodes Non-Per.	% Nodes Non-Per.	Length Non-Per. (cm)	% Length Non-Per. (cm)	Length Nodes 3-13 (cm)	Mean Inter. Length 3-13 (cm)	Area Cross Sec. (mm^2)	# Nodes 3/76	# Nodes Die Back
Pruning	30 + 10	4.48	43.66	6.03	13.98	55.41	13.20	83.11	8.31	46.27	36.50	7.16
	50 + 10	4.71	47.86	6.38	13.24	57.82	12.53	79.53	7.96	46.68	40.13	7.73
	10 + 10	4.97	48.00	6.88	13.71	67.43	13.46	81.33	8.21	50.94	39.98	8.39
Not Suckered		4.75	45.64	6.04	12.43	55.35	11.33	84.25	8.48	48.41	38.39	7.52
Suckered		4.69	46.73	6.81	14.85	65.09	14.80	78.40	7.84	47.52	39.35	8.00
Weed Cover		3.83	39.99	5.29	12.50	50.59	12.77	78.11	7.87	42.42	33.23	7.29
Weed Control		5.61	52.38	7.56	14.79	69.85	13.36	84.55	8.45	53.51	44.51	8.23
Tukey Comparison Level	Pruning											
	Suckering			*	2.151	*	2.460	5.252	0.516			
	Weeds	*	*	*							10.905	
	W X P		*									
	W X S											
	P X S											
	W X P X S							*				

Table 3. Treatment main effects on 1975 vine nutrition. Measurements were made on composite samples of leaf petioles collected on August 1, 1975 by Kehldal and spectroscopic analysis. Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 3

Treatments \ Measurements		% K	% N	% P	ppm Na	% Ca	% Mg	ppm Mn	ppm Fe	ppm Bo	ppm Zn
Pruning	30 + 10	1.230	0.867	0.235	586.4	1.954	0.583	375.1	84.34	44.07	182.7
	50 ± 10	1.213	0.829	0.202	643.0	1.892	0.677	403.3	57.59	40.17	164.4
	10 + 10	1.246	0.926	0.219	580.1	1.664	0.595	339.5	45.72	35.36	162.8
Not Suckered		1.257	0.839	0.226	578.8	1.867	0.606	375.8	67.81	43.31	174.9
Suckered		1.203	0.909	0.211	627.5	1.806	0.631	369.4	57.29	36.42	165.0
Weed Cover		1.378	0.813	0.260	617.3	1.869	0.595	391.0	58.99	38.71	176.8
Weed Control		1.082	0.935	0.177	588.9	1.804	0.642	354.2	66.11	41.03	163.1
Tukey Comparison Level	Pruning		*			*					
	Suckering		0.0487								*
	Weeds	0.1189	0.0497	*							
	W X P										
	W X S	0.2121	*								
	P X S	*	*								
	W X P X S										

Table 4. Treatment main effects on 1974 productivity. Productivity measurements were made on October 3, 1974. Total acidity, pH, and Brix measurements were performed on the fifty berry samples over the next few months. Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 4

Treatments \ Measurements		Yield	# Clusters	Grams / Cluster	Grams / Berry	Berries / Cluster	Fruitfulness	Clusters / Bud	% Acid	pH	% Brix	Brix / acid	Total Sugar (kg)
Pruning	30 + 10	7.88	136.8	55.99	1.01	55.91	163.3	2.81	1.361	3.21	19.81	14.71	1.53
	50 + 10	9.59	173.0	55.43	0.97	58.10	136.2	2.46	1.337	3.19	19.47	14.72	1.86
	70 + 10	9.60	77.0	55.10	0.97	57.29	112.6	2.08	1.370	3.16	19.46	14.32	1.86
Not Suckered		9.42	173.2	54.86	0.98	56.38	142.2	2.62	1.363	3.20	19.45	14.37	1.83
Suckered		8.63	151.3	56.15	0.99	57.83	132.5	2.28	1.349	3.18	19.41	14.79	1.67
Weed Cover		9.20	168.1	54.36	0.97	57.15	137.1	2.47	1.380	3.16	19.00	13.91	1.73
Weed Control		8.86	156.4	56.66	1.00	57.05	137.6	2.43	1.332	3.21	20.16	15.26	1.78
Tukey Comparison Level	Pruning	1.55	23.75				28.05	0.352					0.282
	Suckering		16.13					0.239					
	Weeds								*		*	*	
	W X P								*				
	W X S	*							0.1025		*	1.901	
	P X S	*	52.10										
	W X P X S												

Table 5. Treatment main effects on 1975 productivity. Productivity measurements were made on September 6, 1975. Total acidity, pH and Brix measurements were performed over the next few months. Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range of Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 5

Treatments \ Measurements		Yield/Vine	# Clusters	Grams/Cluster	Grams/Berry	Berries/Cluster	Fruitfulness	% Acid	pH	% Brix	Brix/Acid	Total Sugar/Vine (kg)	
Pruning	30 + 10	6.02	96.3	60.14	1.20	50.3	178.0	2.86	1.209	3.23	17.55	14.77	1.04
	50 + 10	7.04	111.7	61.73	1.18	52.3	151.1	2.37	1.226	3.21	17.26	14.26	1.22
	10 + 10	3.58	66.5	51.17	1.18	43.1	256.0	5.03	1.206	3.28	18.07	15.08	0.64
Not Suckered		5.18	86.8	57.33	1.19	48.1	187.4	3.31	1.222	3.23	17.64	14.56	0.91
Suckered		5.91	96.3	58.03	1.18	49.1	202.7	3.53	1.205	3.25	17.62	14.85	1.02
Weed Cover		4.25	76.5	53.13	1.17	45.5	167.2	3.16	1.190	3.24	17.81	15.17	0.75
Weed Control		6.84	106.5	62.23	1.21	51.7	222.9	3.68	1.237	3.25	17.45	14.24	1.18
Tukey Comparison Level	Pruning	1.44	20.0	6.220		5.42	47.85	0.824		0.05	0.540	0.239	
	Suckering												
	Weeds	*	30.14		0.023		*	0.396					*
	W X P	5.188							*				*
	W X S	*	75.79		*								*
	P X S								0.1725	*			
	W X P X S												

Table 6. Treatment main effects on 1974, and 1975 wine musts. Measurements were made on composite batches of musts prior to the first fermentation. No statistical evaluation was performed since the measurements could not be replicated.

Table 6

Treatments \ Measurements	1974 % Acid	pH	Brix	Brix/Acid	Liters Must		1975 % Acid	pH	Brix	Brix/Acid	Liters Must
Pruning 30 + 10	1.329	3.14	19.72	14.83	44.5		1.404	3.23	16.6	11.83	38.8
Pruning 50 + 10	1.441	3.30	19.75	13.78	50.8		1.386	3.22	16.53	12.01	41.8
Pruning 70 + 10	1.373	3.23	19.44	14.25	49.8	(10+10)	1.320	3.25	16.75	12.09	24.3
Not Suckered	1.425	3.21	19.81	13.95	49.8		1.395	3.23	16.69	12.01	33.1
Suckered	1.337	3.23	19.46	12.95	48.3		1.389	3.24	16.56	11.96	36.9
Weed Cover	1.384	3.27	19.80	14.40	49.8		1.341	3.23	16.68	12.46	25.1
Weed Control	1.378	3.18	19.47	14.14	48.3		1.443	3.24	16.58	11.50	44.9

Table 7. Treatment main effects on 1974 wines. Total acidity and pH were measured after cessation of fermentation and before cold stabilization, (columns one and two) and in the final product after bottling (columns three and four). Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 7

Treatments \ Measurements →		% Acid Before Cold Stab.	pH Before Cold Stab.	% Acid Final	pH Final	% Volatile Acid	% Extract	Color Intensity (420+520)	Hue (420/520)	Dominant Wavelength	% Alcohol
Pruning	30 + 10	0.913	3.51	0.816	3.45	0.0415	2.91	1.222	3.049	586.1	11.93
	50 + 10	0.988	3.47	0.823	3.42	0.0413	2.74	1.210	3.081	585.6	11.99
	70 + 10	0.994	3.43	0.806	3.39	0.0424	2.77	1.195	3.163	585.4	12.19
Not Suckered		0.981	3.43	0.827	3.39	0.0409	2.80	1.206	3.023	586.0	12.03
Suckered		0.950	3.41	0.803	3.46	0.0426	2.81	1.212	3.171	585.4	12.05
Weed Cover		0.956	3.48	0.813	3.37	0.0404	2.75	1.196	3.101	585.6	12.10
Weed Control		0.974	3.46	0.817	3.48	0.0431	2.86	1.221	3.093	585.8	11.98
Tukey Comparison Level	Pruning	0.0417	0.023		0.036		0.062			*	
	Suckering	0.0276	0.015	0.0164	0.024				0.0119	0.46	
	Weeds				0.085	0.00274	0.053				
	W X P		0.216	0.0534	0.125		0.136				
	W X S	*	0.130				0.073		0.4026		
	P X S		0.041		0.064	*	0.110	0.0626	0.3201		
	W X P X S	0.1048	0.097		*		0.147	0.0880	0.4907		

Table 8. Treatment main effects on 1975 wines. Total acidity and pH were measured after cessation of fermentation and before cold stabilization (columns one and two), and in the final product after bottling (columns three and four). Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison. Asterisks indicate between 5 and 10% level of significance.

Table 8

Treatments \ Measurements		% Acid Before Cold Stab.	pH Before Cold Stab.	% Acid Final	pH Final	% Volatile Acid	% Extract	Color Intensity (420+520)	Hue (420/520)	Dominant Wavelength	% Alcohol
Pruning	30 + 10	0.822	3.57	0.706	3.69	0.0636	2.94	3.835	1.246	634.6	13.56
	50 + 10	0.825	3.58	0.730	3.64	0.0531	2.91	3.839	1.150	629.2	13.79
	10 + 10	0.862	3.68	0.776	3.74	0.1061	3.13	4.475	1.207	642.8	13.80
Not Suckered		0.863	3.59	0.751	3.68	0.0796	2.94	4.043	1.198	633.0	13.64
Suckered		0.810	3.63	0.724	3.69	0.0689	3.04	4.057	1.204	638.0	13.79
Weed Cover		0.833	3.61	0.745	3.70	0.0854	2.94	4.219	1.205	639.1	13.63
Weed Control		0.839	3.61	0.730	3.68	0.0631	3.05	3.881	1.196	631.9	13.80
Tuken Comparison Level	Pruning	0.0397	0.012	0.0233	0.015	0.01299	0.068	0.1463	0.0358	2.69	0.050
	Suckering	0.0263	0.008	0.0155	0.010	0.00861	0.045			1.79	0.033
	Weeds					0.01845	*	*		2.23	
	W X P	0.1020	0.049	0.1003	0.050	0.02720	0.247	0.6692	0.1534	4.84	0.551
	W X S		0.060		0.058		0.294	0.8282		3.84	0.967
	P X S		0.022	0.0418	0.027	0.02325	0.122	0.2618	0.0641	4.83	0.090
	W X P X S		0.425	*		0.03266	0.221		0.1283	5.11	0.382

Table 9. Treatment main effects on 1974 winter hardiness. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}) on October 31, 1974, and December 17, 1974. The Spearman-Karber "S" statistic is given for each T_{50} (16).

Table 9

Treatments		Measurements →	Cane		Primary		Secondary		Tertiary	
			T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S
October 31, 1974	Pruning	30 + 10	10.0	.850	7.8	.730	8.4	.570	8.3	.780
		50 + 10	10.8	1.170	9.9	.755	9.9	.770	10.1	.850
		70 + 10	10.7	1.200	9.7	.755	9.8	.950	9.5	.795
	Not Suckered		10.7	.930	9.6	.800	9.7	.900	9.9	.885
	Suckered		10.8	1.220	8.6	.625	8.8	.935	8.7	.735
	Weed Cover		11.1	.820	9.9	.650	10.1	.650	9.8	.715
	Weed Control		9.9	1.330	8.4	.770	8.7	.875	8.6	.890
December 17, 1974	Pruning	30 + 10	18.1	1.145	16.5	1.380	20.1	1.505	19.5	1.380
		50 + 10	17.1	1.450	16.6	1.225	18.8	1.340	17.6	1.160
		70 + 10	18.2	1.550	17.9	1.425	19.2	1.395	18.3	1.215
	Not Suckered		18.1	1.490	17.3	1.200	19.6	1.160	18.5	1.115
	Suckered		17.5	1.275	16.7	1.485	19.1	1.665	18.4	1.385
	Weed Cover		17.8	1.295	17.5	1.060	20.5	1.265	18.9	.985
	Weed Control		17.8	1.470	16.5	1.625	18.3	1.560	18.1	1.515

Table 10. Treatment main effects on March 25, 1975 winter hardiness. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}). The Spearman-Karber "S" statistic is given for each T_{50} (16).

Table 10

Measurements → / Treatments ↓		Cane		Primary		Secondary		Tertiary	
		T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S
Pruning	30 + 10	17.4	.365	17.2	.795	17.5	.100	17.4	.195
	50 + 10	17.2	.195	17.2	.835	17.3	.530	17.4	.315
	70 + 10	17.4	.640	17.0	1.245	17.1	.810	17.2	.355
Not Suckered		17.3	.315	17.0	.980	17.2	.430	17.2	.355
Suckered		17.4	.485	17.3	.920	17.4	.530	17.4	.485
Weed Cover		17.4	.315	17.3	.865	17.2	.430	17.4	.240
Weed Control		17.4	.485	17.3	.985	17.4	.530	17.2	.595

Table 11. Treatment main effects on 1975-1976 winter hardiness. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}) on December 10, 1975, and March 2, 1976. The Spearman-Karber "S" statistic is given for each T_{50} (16).

Table 11

	Measurements → / Treatments ↓	Cane		Primary		Secondary		Tertiary	
		T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S
December 10, 1975	30 + 10	24.4	.700	22.1	.195	22.5	.000	22.5	.000
	50 + 10	23.6	.600	22.2	.195	22.2	.195	22.5	.000
	10 + 10	24.1	.725	22.1	.195	22.4	.100	22.4	.100
	Not Suckered	24.6	.705	22.0	.195	22.4	.065	22.4	.065
	Suckered	23.5	.740	22.2	.195	22.3	.130	22.5	.000
	Weed Cover	24.8	.820	22.0	.195	22.3	.130	22.4	.065
	Weed Control	23.2	.530	22.2	.195	22.4	.065	22.5	.000
March 2, 1976	30 + 10	19.0	1.395	17.1	1.535	17.6	1.325	17.7	1.045
	50 + 10	19.5	1.050	17.1	1.620	18.1	1.300	17.9	1.215
	10 + 10	20.2	.725	17.2	1.590	17.9	1.215	17.9	1.205
	Not Suckered	19.8	1.015	17.2	1.645	17.8	1.295	17.8	1.190
	Suckered	19.4	1.100	17.1	1.515	18.0	1.265	17.8	1.120
	Weed Cover	19.6	1.135	17.3	1.620	18.0	1.255	18.1	1.175
	Weed Control	19.5	.975	17.0	1.545	17.7	1.305	17.6	1.135

Table 12. Treatment main effects on 1974-1975 winter hardiness replicated over time. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}). Three measurements were used as replication over time to obtain statistical data for hardiness evaluations. Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison.

Table 12

Treatments \ Measurements	Cane		Primary		Secondary		Tertiary		Average	
	T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S
Pruning 30 + 10	15.1	.785	15.2	.985	13.8	.725	15.3	.785	14.8	.810
Pruning 50 + 10	15.0	.940	15.0	.940	14.6	.880	15.3	.790	15.0	.890
Pruning 70 + 10	15.0	1.130	15.4	1.110	14.9	1.050	15.4	.905	15.2	1.050
Not Suckered	15.2	.910	15.4	.975	14.6	.830	15.5	.785	15.2	.875
Suckered	14.9	.995	15.1	1.010	14.2	1.045	15.1	.870	14.8	.980
Weed Cover	15.4	.810	15.4	.860	14.9	.780	15.9	.645	15.4	.775
Weed Control	14.7	1.095	15.0	1.025	13.9	.990	14.8	1.000	14.6	1.055
10/31/74	9.3	1.075	10.5	.715	9.1	.920	9.4	.810	9.6	.880
12/17/74	18.5	1.385	17.8	1.345	17.0	1.415	19.4	1.250	18.2	1.350
3/25/75	17.3	.400	17.3	.925	17.1	.480	17.3	.420	17.3	.555
Tukey Comparison Levels: Dates	2.91		2.47		4.69		2.89		2.86	

Table 13. Treatment main effects on 1975-1976 winter hardiness replicated over time. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}). Two measurements were used as replication over time to obtain statistical data for hardiness evaluations. Numerical values given in the lower portion of the table indicate significance at the 5% level using the studentized range or Tukey mean comparison.

Table 13

Treatments \ Measurements		Cane		Primary		Secondary		Tertiary		Average	
		T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S	T_{50}	S
Pruning	30 + 10	21.7	1.050	19.6	.865	20.1	.750	20.1	.575	20.4	.880
	50 + 10	21.6	.825	19.7	.910	20.1	.750	20.2	.610	20.4	.775
	10 + 10	22.1	.725	19.6	.895	20.1	.660	20.1	.605	20.5	.720
Not Suckered		22.2	.860	19.6	.920	20.1	.680	20.1	.630	20.5	.775
Suckered		21.4	.870	19.6	.855	20.1	.700	20.2	.560	20.3	.745
Weed Cover		22.2	.980	19.6	.910	20.2	.695	20.2	.620	20.6	.800
Weed Control		21.4	.755	19.6	.870	20.1	685	20.1	.570	20.3	.720
12/10/75		24.0	.575	22.1	.195	22.4	.100	22.5	.035	22.7	.250
3/2/76		19.6	1.060	17.1	1.580	17.9	1.280	17.8	1.155	18.1	1.270
Tukey Comparison Levels	Weeds									0.08	
	Dates	9.31		3.55		2.57		3.52		0.08	

Table 14. Treatment effects on 1974, 1975, and 1976 vine size. Values are given in pounds of first year pruning brush per vine. 5% Tukey levels of significance are given for comparison of the same and different weed control treatments.

10 = 10 + 10 pruning severity
30 = 30 + 10 pruning severity
50 + 50 + 10 pruning severity
70 = 70 + 10 pruning severity

S = suckers present
S̸ = suckers absent

W = weed cover
W̸ = weed control

Table 14

Measurements / Treatments	1974 Vine Size (lbs.)	1974 #Buds	1975 Vine Size (lbs.)	1975 #Buds	1976 Vine Size (lbs.)	1976 #Buds	
30 S W	3.00	47.5	1.44	33.3	1.75	40.4	
50 S W	3.53	86.9	1.91	45.1	1.41	52.4	
70 S W	3.09	87.5 (10)	1.34	14.8	3.22	32.9	
30 S W	2.63	43.9	1.53	34.1	2.69	47.1	
50 S W	3.09	68.5	1.22	44.0	2.41	60.9	
70 S W	2.69	86.0 (10)	1.47	14.8	4.78	48.0	
30 S W	3.63	53.0	0.66	28.1	1.16	35.4	
50 S W	3.94	74.9	1.06	36.9	1.56	58.0	
70 S W	3.00	86.4 (10)	0.88	11.5	1.78	19.9	
30 S W	3.44	54.3	1.72	37.5	3.59	56.3	
50 S W	2.81	62.6	1.28	50.0	2.06	61.0	
70 S W	2.78	84.8 (10)	1.25	15.0	3.50	35.3	
Tukey Comparison Levels	1.864	23.54	1.085	13.44	2.153	20.55	Same Weed
	2.564	38.170	1.480	24.85	2.808	38.85	Different Weed

Table 15

Tabor Hill Precipitation*

	Month	1974	1974 Deviation	1975	1975 Deviation	Average
1.	January	3.17	0.90	3.21	0.94	2.27
2.	February	1.77	0.02	2.39	0.64	1.75
3.	March	5.21	2.84	2.99	0.62	2.37
4.	April	3.13	-0.68	4.15	0.34	3.81
5.	May	5.40	1.77	5.59	1.96	3.63
6.	June	4.08	0.28	3.56	-0.24	3.80
7.	July	0.96	-2.42	2.38	-1.00	3.38
8.	August	2.12	0.72	5.72	4.32	1.40
9.	September	3.24	-0.01	1.31	-1.94	3.25
10.	October	2.05	-1.17	1.07	-2.15	3.22
11.	November	2.95	0.11	3.07	0.23	2.84
12.	December	2.62	0.18	3.49	1.05	2.44
13.	Total	36.70	1.10	38.93	3.33	35.60

*As measured in inches at the Eau Claire weather observatory.

Deviations from the average precipitation and the average since 1920 at Eau Claire are also given.

Table 16

Spring Frost Survival of Pruned

Versus Unpruned Vines*

Node Number	Basal	1	2	3	4	5
Percent Survival...						
Pruned	100	88	72	36	8	0
Not Pruned	100	90	80	70	60	40
Development...						
Pruned	S-B	B	B	3-5cm	3-5cm	3-5cm**
Not Pruned	S	B	B	B	B	B

*The first five nodes of 100 canes on vines pruned to five node canes in March 1976 were compared with the same nodes on unpruned vines after a four hour period of -2°C. on April 26, 1976. Both degree of development and percent of survival are given. Measurements were taken on May 4, 1976.

**S=Swell B=Burst

FIGURES

Figure 1. Treatment effects on 1974, 1975, and 1976 vine size.

Values are given in pounds of first year pruning brush.

10 = 10 + 10 pruning severity
30 = 30 + 10 pruning severity
50 = 50 + 10 pruning severity
70 = 70 + 10 pruning severity

S = suckers present
Ø = suckers absent

W = weed cover
Ø = weed control

Two different 5% Tukey levels of significance are given for each year. One is to be used for comparisons of the same weed treatments (W, W or Ø, Ø) and the other for comparisons of different weed treatments (W, Ø).

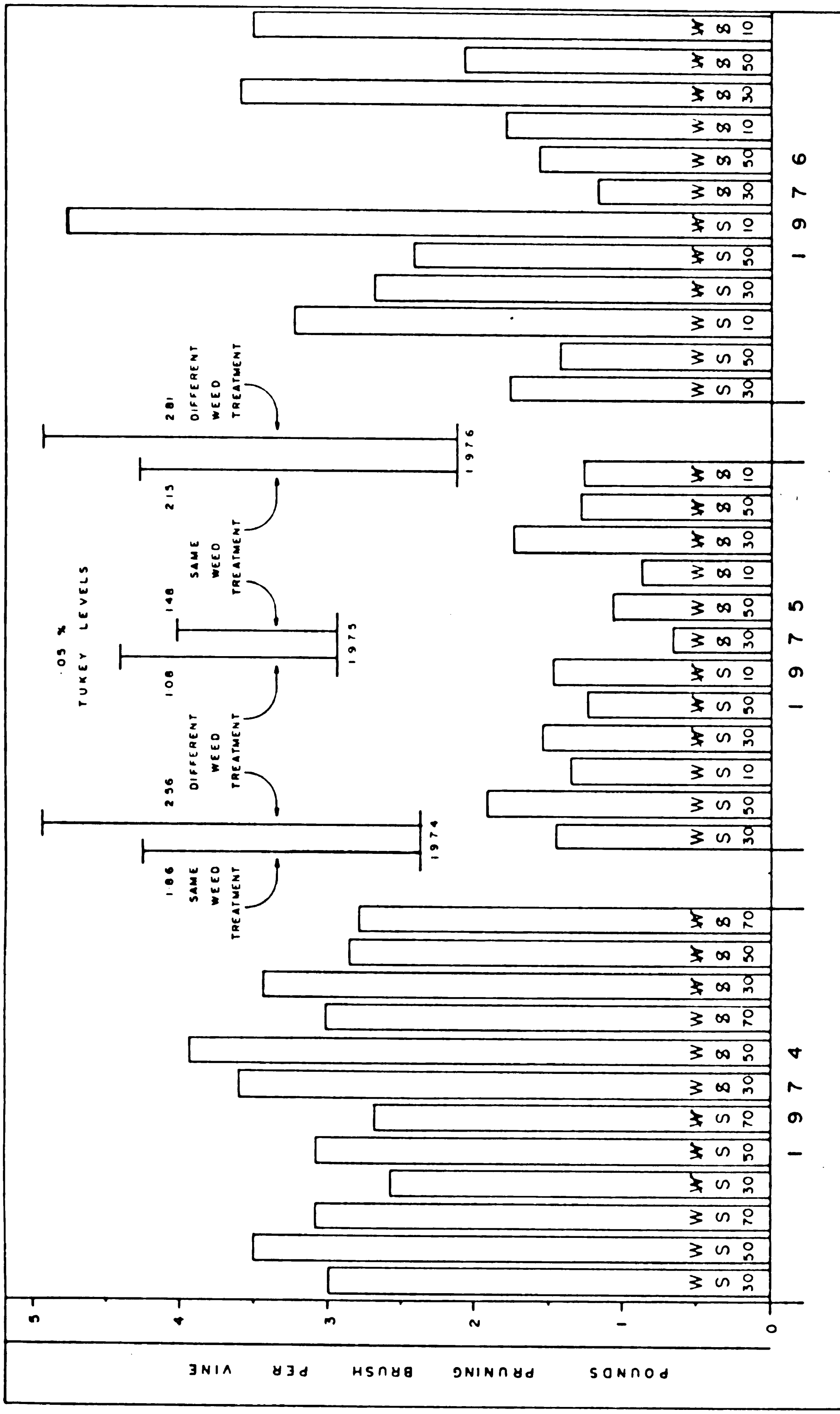

POUNDS PRUNING BRUSH PER VINE
.05 % TUKEY LEVELS
1.86 SAME WEED TREATMENT
2.56 DIFFERENT WEED TREATMENT
1.08
1.48 SAME WEED TREATMENT
2.15
2.81 DIFFERENT WEED TREATMENT
1974
1975
1976

FIGURE I

Figure 2. Treatment effect on 1974 and 1975 yield. Measurements were made on October 3, 1974, and September 4, 1975.

10 = 10 + 10 pruning severity
30 = 30 + 10 pruning severity
50 = 50 + 10 pruning severity
70 = 70 + 10 pruning severity

S = suckers present
Ø = suckers absent

W = weed cover
Ø = weed control

Two different 5% Tukey levels of significance are given for each year. One is to be used for comparisons of the weed control treatments (W,W or Ø,Ø) and the other for comparisons of different weed control treatments (W,Ø).

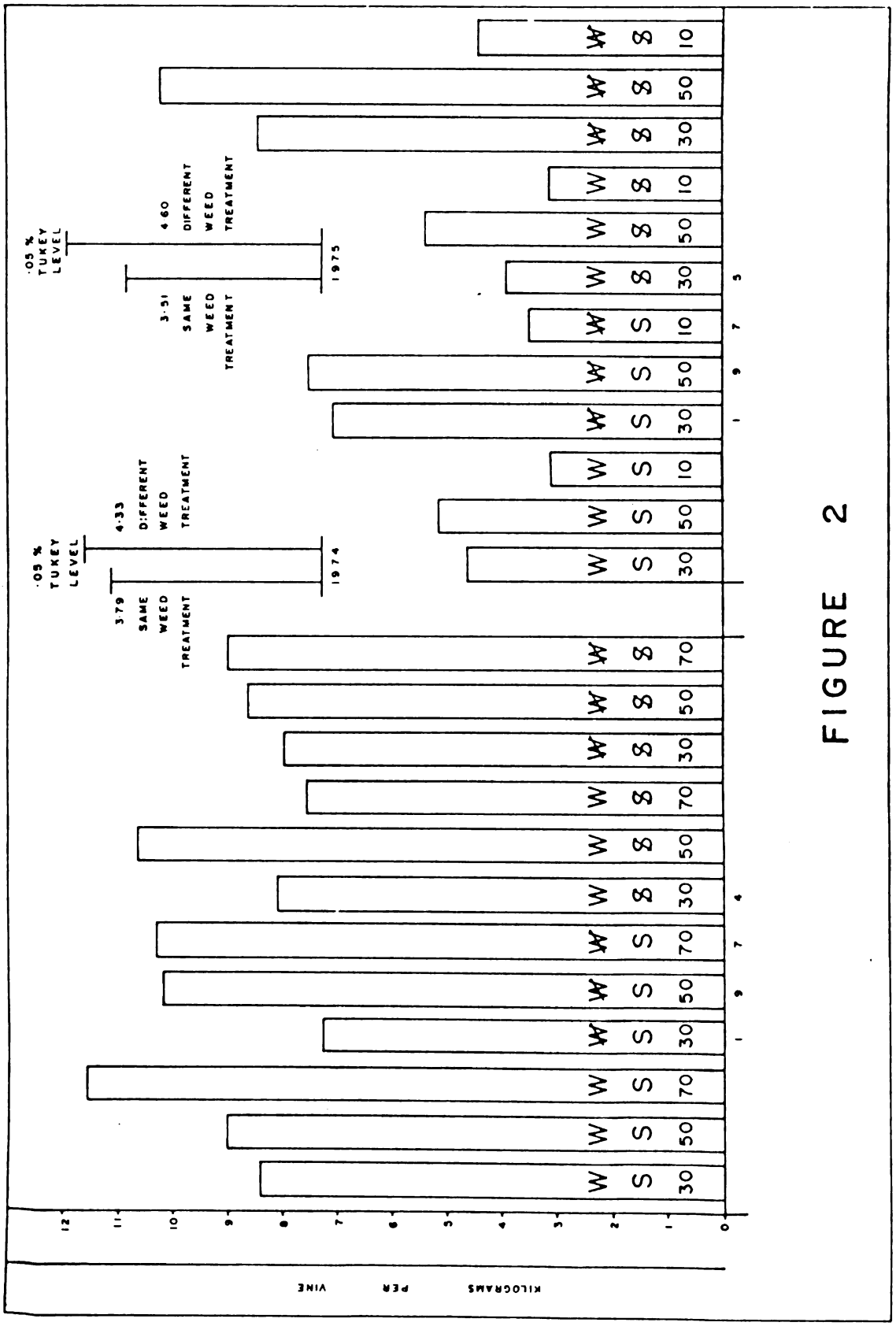

KILOGRAMS PER VINE
0
1
2
3
4
5
6
7
8
9
10
11
12
W S S W 30
W S S W 50
W S S W 70
W W S S 30
W W S S 50
W W S S 70
W W S S 10
W W S S 30
W W S S 50
W W S S 10
W W S S 30
W W S S 50
W W S S 10
W W S S 30
W W S S 50
W W S S 70
W W S S 30
W W S S 50
W W S S 70
W W S S 30
W W S S 50
W W S S 70
W W S S 10
.05 % TUKEY LEVEL
3.79 SAME WEED TREATMENT
4.33 DIFFERENT WEED TREATMENT
1974
.05 % TUKEY LEVEL
3.51 SAME WEED TREATMENT
4.60 DIFFERENT WEED TREATMENT
1975

FIGURE 2

Figure 3. 1975-1976 hardiness of nontreatment Baco noir grapevines. Values indicate the negative °C. temperature at which 50% of the tissue survived (T_{50}) at twelve times during the winter of 1975-1976 (lower portion of graph).

o———————o = Cane T_{50}

o— — — — — o = Primary Bud T_{50}

o- — - — -o = Secondary Bud T_{50}

o---------- o = Tertiary Bud T_{50}

The upper portion of the graph represents the daily air temperature maximums and minimums between September 22, 1975 and April 6, 1976 as measured by the M.S.U. weather station at Tabor Hill Vineyard in Berrien County.

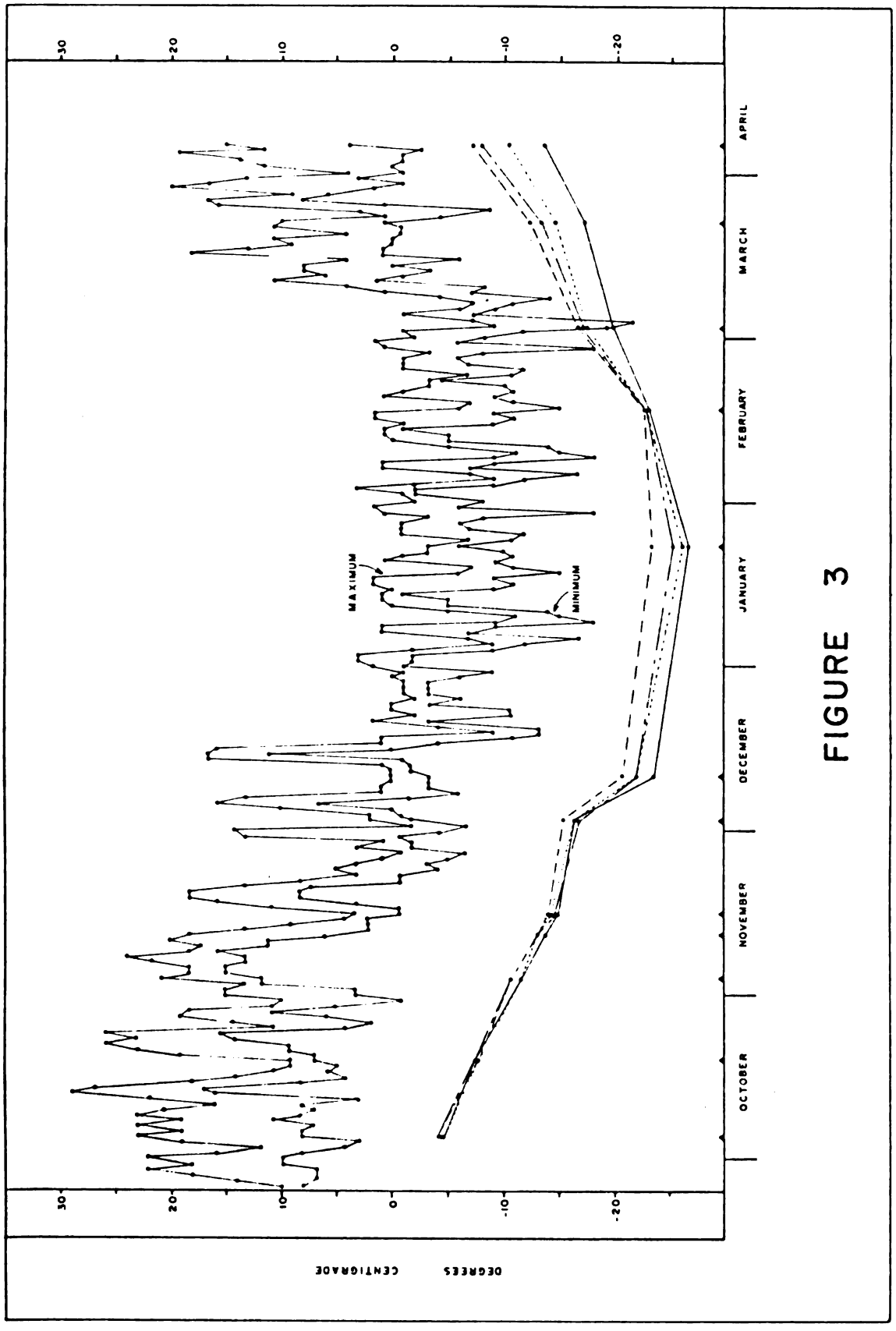

30
20
10
0
-10
-20
DEGREES CENTIGRADE
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAXIMUM
MINIMUM

FIGURE 3

Figure 4. The effect of air temperature on the degree of tissue hardiness. Measurements are given for zero to fourteen days prior to sampling on twelve dates during the winter of 1975-1976 and computed as the simple correlations of the mean of the primary, secondary, and tertiary buds and the cane versus the air temperature on a given day. The 1% level of significance occurs at .708 for 10 degrees of freedom.

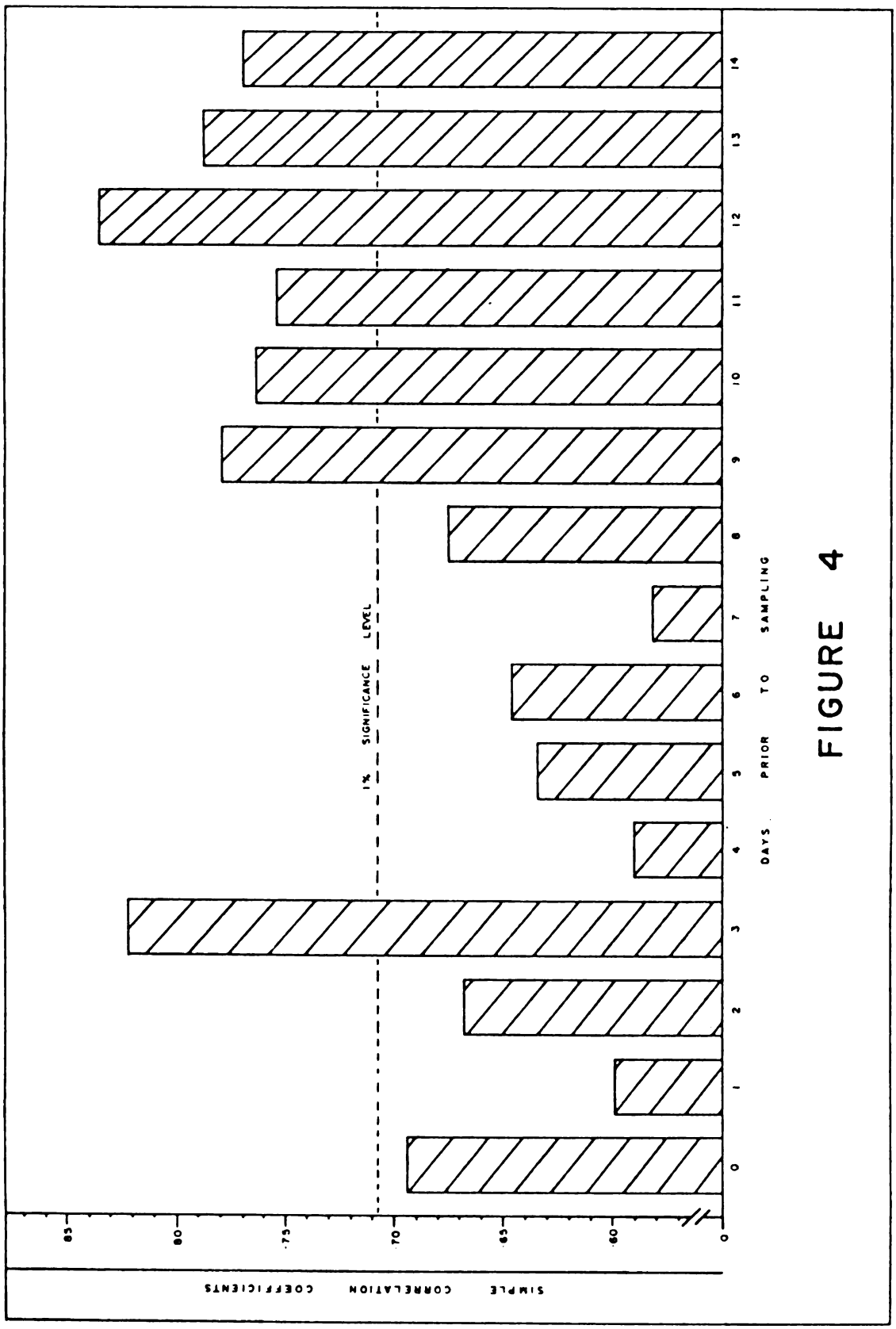

SIMPLE CORRELATION COEFFICIENTS
.85
.80
.75
.70
.65
.60
0
1% SIGNIFICANCE LEVEL
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS PRIOR TO SAMPLING

FIGURE 4

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