ABSTRACT

FACTORS ASSOCIATED WITH VARIATION OF SOLUBLE SOLIDS IN THE FRUIT OF THE CONCORD GRAPE, VITIS LABRUSCA L.

By Darrell Sparks

Soluble solids of Concord grapes in Michigan vary widely from year to year, but the fruit from some vineyards is consistently low or high regardless of seasonal variation. This indicates that "permanent" factors are present within a vineyard which affect soluble solids in a consistent manner.

Experiments were conducted in 1962, 1963, and 1964 to determine the effect of various levels of shade and time of shading on the production of soluble solids. In 1962, one-half of the clusters per vine was removed to study increased leaf to fruit ratio singly and in combination with shade. The effect of shoot tipping (to stop terminal shoot growth) was also studied.

A vineyard survey was conducted in 1962 and 1963 in southwestern Michigan to determine vineyard and cultural practices associated with variation in fruit soluble solids. Leaf petioles, shoot tips and berries were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, boron, and zinc. Soil samples were rated as to texture and analyzed for available phosphorus, potassium, calcium, and magnesium; cation exchange capacity; percent saturation of potassium, calcium, magnesium; and percent base saturation. Foliage density was visually estimated and notes were made as to row direction, soil management, spacing, trellis height, and clusters per vine.

Two nitrogen studies were initiated in 1963 and 1964 to determine the effect of nitrogen on production of soluble solids. One study involved

growers' vineyards under a wide range of conditions. One pound of ammonium nitrate was applied per vine and number of shoots per vine, growth per shoot, rate of growth and days of shoot growth were recorded. Foliage density was estimated and leaf area per pound of fruit calculated. A second study was conducted at the Sodus Horticultural Farm. The vines were balance pruned and there was little variation in soil or general vine condition. One pound of ammonium nitrate in combination with various levels of sawdust was applied per vine. The weight of pruned material per vine was recorded in the winter of 1963. In both studies, yield and number of clusters per vine were recorded and soluble solids samples were taken at harvest.

Shading lowered production of soluble solids; whereas, shoot tipping had no effect. Thinning clusters increased soluble solids only if the vines were not shaded. This indicated the leaf to fruit ratio was limiting soluble solids, but was dependent on the exposure to sunlight.

The survey revealed that the major factors associated with low soluble solids were: (1) shading due to high foliage density, and (2) low leaf to fruit ratio. There was a negative correlation of soluble solids with foliage density and clusters per vine, and between soluble solids and soil cation exchange capacity. The correlation was positive between soluble solids and square feet of soil surface per vine.

With added nitrogen in commercial growers' vineyards, variations in leaf area per pound of fruit and foliage density accounted for a high percentage of the total variation in soluble solids. The effect of foliage density on soluble solids was greater than the leaf area per pound of fruit. Growth per shoot, rate or days of growth were not inversely related to soluble solids. Thus, the effect of foliage density on soluble solids was not due to growth *per se*. That the effect of foliage density was due to shading was indicated by altering the trellis to provide better exposure, resulting in higher soluble solids. Foliage density had less effect in 1963 than in 1964 due to differences in climatic conditions.

Applications of nitrogen had no effect on soluble solids, yield per vine or growth in the growers' vineyards. However, at the Sodus Farm, applications of nitrogen increased growth when measured as pruned weight removed. There were more buds per vine in 1964 with greater foliage density and lower soluble solids. The difference was probably due to balanced pruned vines and less soil variation at Sodus.

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Mr. and Mrs. Fred Sparks

whose determination will always

be a source of inspiration.

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INTRODUCTION

Grapes constitute an important segment of the fruit industry of Michigan. Most of the approximately 50,000 - 60,000 tons normally produced on 22,000 acres in southwestern Michigan are processed as juices, wine and other products. The predominant variety is Concord (Vitis labrusca L.).

A major problem associated with production is variation of fruit soluble solids. Data from 72 vineyards obtained over a five year period, 1957-61, by a Michigan processor revealed soluble solids varied widely from year to year with some vineyards being consistently high or low regardless of seasonal variation, Table 1.

Table 1. Variation of soluble solids between years and vineyards.

Soluble solids class	Year 1957	1958	1959	1960	1961
	Soluble solids - %				
High	17.4	16.5	17.6	16.7	16.4
Intermediate	16.5	16.1	17.0	16.0	16.0
Low	15.8	15.6	16.9	15.6	15.3
Means	16.7	16.2	17.2	16.1	16.0

The variation of soluble solids between vineyards is of economical importance, especially during years of relatively low average soluble solids. In such years, the soluble solids in the grapes from consistently low vineyards may be below the commercially acceptable minimum of 15.0 percent. Variation, during years of a relatively high average, is also of economical importance since the market price increases with the soluble solids content, in the range of 15.0 to 18.0 percent.

The fact that some vineyards are consistently high or low in soluble solids, indicates that there are "permanent" factors within vineyards which influence soluble solids.

LITERATURE REVIEW

Introduction

Percent soluble solids in grape juice is used as an indirect measure of the total sugar content. The measurement is usually made with a refractometer or a Balling or Brix hydrometer. All three methods give essentially identical results (69). The relationship of soluble solids and total sugars is usually assumed to be linear.

In a 4 year study involving about 40 varieties of American bunch grapes and 208 observations, the correlation coefficient of total sugars and total soluble solids was .925 (66). A similar correlation (.917) was found for the Concord variety. This correlation was calculated from data reported in a 3 year study by Kertesz (32). The slope of the line for regression of total sugars on soluble solids was .957. These correlations for the grape are in close agreement with the correlation (.923) found for the sour cherry (60).

The sugars in grape juice are predominantly glucose and fructose with small and variable amounts of sucrose (4, 14, 67, 70). Since sucrose has been found (58) to be the translocated sugar in the Concord variety, glucose and fructose presumably result from its hydrolysis. The site of hydrolysis appears to be in the berry since invertase activity has been detected in extracts of ripe berries (4).

Winkler (70) has assumed that glucose predominates during the growth of the berry; at maturity, the proportions of glucose and fructose are about equal, and in over-ripe berries fructose is the major sugar.

Apparent Relation of Fruit Growth and Sugar Accumulation

The growth curve of fruit from seeded and seedless varieties of American (12, 43) and European (18, 71) grapes, like stone fruits (20, 22, 39, 40, 60), is a double sigmoid curve. This curve is usually divided into three distinct periods of growth: period one, with a rapid rate of berry enlargement; period two, with only a slight rate of growth; and period three, with an intermediate growth rate. In seedless grapes the second period is sometimes not as distinct as in seeded varieties, but it becomes very distinct if growth is plotted as rate (18).

The level of sugars in the grape berry remains relatively low and constant until the second period of growth. At this time the rate of sugar accumulation rises sharply, almost on a certain day, and in some varieties reaches a maximum rate within 10 days. After the rate of sugar accumulation begins to increase, the third stage of growth becomes evident. The maximum growth rate of the third period is preceded a few days by the maximum rate of sugar accumulation (9, 18, 71).

On the basis of the correlation of sugar accumulation and fruit growth during the third period, Coombe (18) and Winkler (70) have suggested that the third stage of growth is due to the accumulation of sugar followed by the influx of water in response to diffusion pressure deficits. This suggestion is supported by the work of Winkler and Williams (71) who found that the insoluble solids of the berry remained approximately unchanged during the third period. Also, Crane and Brown (20) found that 72 percent of the total dry weight of the fig fruit, 89 percent of the total sugar content, and 60 percent of the total moisture was accumulated during the third stage.

Various hypotheses have been proposed to explain the decrease in fruit growth during the second period. These, in general, have favored a competition between the seed and the pericarp or between the fruit and other parts of the plant.

The hypothesis of competition between seed and pericarp is supported by Nitsch (42) and by the correlation found between embryo abortion and earliness in stone fruits (60). However, as has been pointed out by Winkler (39), this hypothesis does not account for the growth of seedless fruits.

Dorsey and McMunn (21), working in Illinois, suggested that the second growth stage of the peach fruit may be due to competition from growth in the tree and not primarily to food substances used in forming the stone. Later (22) these workers reported that shoot growth accelerated during the second period of fruit growth. However, the reported change in rate was not large, and their data was inconsistent. Also, Lilleland (38), in a similar study with peaches, found that shoot growth was over before the second period began. Furthermore, a wide variation in yield did not alter the growth rate of the second period.

Winkler and Williams (71), working in California, found that shoot growth and trunk circumference of the grape had practically ceased by the inception of the second period. Also, the storage of starch and sugar in the canes continued through the major period of berry growth. In addition, removal of 90 percent of the original leaf area at the inception of the second period of growth did not prevent the third period, despite renewed vegetative growth. They stated that these results pointed to an increasing supply of available nutrients rather than to a sudden decrease. These workers concluded that whatever the nature of the slow berry growth during the second period, it did not appear to be the result of nutritional competition within the vine itself. Winkler (70) decided, on the basis of the rapid accumulation of sugar in the fruit (9, 18), that the rate of movement is too rapid to result simply from a change in competition for carbohydrates.

Lilleland (39), in California, has shown that the time the apricot fruit remained in the first period and the time to maturity appear to be independent of shoot growth. He increased the night temperature of the fruit and shoots on four percent of the tree, and the remainder of the tree served as a control. An increase in night temperature of about 20 degrees for eight weeks, from March 19, shortened the duration of the first period by 22 days. The fruit ripened 21 days earlier than the control. There were no differences in final fruit size, but there was an advance in shoot growth. In another experiment shoot growth was not advanced, and the fruit emerged from the second period 28 days earlier than the control. He concluded that shifting the periods of growth of individual fruits, independent of the time of maximum vegetative growth, minimized the probability of any inter-relation between the initiation of the second period of fruit growth and the time of maximum shoot extension. He further concluded that if the second period of fruit growth is due to competition, that competition comes more likely from within the fruit than from other parts of the tree. He explained that the growth of the fruit during the first period is a response to its environment. Thus, synchronism of all the fruits on a tree can be ascribed to their response to the same identical environment.

Tukey (61), in Pennsylvania, increased the average diurnal temperature of the Concord grape by altering the night temperature for the 13 days after full bloom. The rate of berry enlargement was increased, up to a limit, in proportion to the temperature increase. At harvest the size of the berry and its soluble solids content were increased in the same proportion. Similarly, Clore and Bryant (16) associated abnormally high minimum temperatures in May and June with high soluble solids at harvest.

Climatic Factors Associated with Variation of Soluble Solids of Grapes

Amerine and Winkler (3) concluded, from a study of climatic data, that temperature was the only predominant climatic factor influencing the quality of wine. Winkler (69) found that the effect of temperature, expressed as a summation of degree days above 50 degree F, can be used to predict the maturity of table grapes in California with a deviation of ± 2 days. Maturity was measured as degrees Balling.

The California grape industry was divided into 5 geographical regions based on the amount of heat received from April to October (3). The regions range from 2,500 degree days in Region 1 to more than 4,000 in Region 5. Late maturing varieties are not recommended for Regions 1 and 2 since they fail to ripen in cool seasons.

Between regions, the time of maturity is inversely related to the rate of accumulation of degree days. For example, the Thompson Seedless variety develops from bloom to a maturity of 18 degrees Balling in the Coachella Valley - a hot desert region - in approximately 68 days (69) and the ripening period is about 21 days. At Davis, a moderately warm region, 90 or more days are required, and the ripening period covers 30 days. However, in both regions 2,000 degree days, ± 2 days, are required for this variety.

Caldwell, in New York, (14) reported in a five year study involving 66 varieties of American grapes, that the climate has a marked effect on the sugar content during a particular year. He considered that the effect was masked, but that the dominant factor was the amount of sunshine received during the period, March to September. The years of maximum sunshine during this period were associated with maximum or next-to-maximum sugar content of the juice in a majority of all varieties; the years of minimum sunshine had the lowest or next-to-lowest sugar content, and the years of intermediate sunshine had intermediate sugar content. However, his results were confounded to some extent with sampling dates.

Partridge (46), working in Michigan, reported that the average summer temperature had a marked effect on the sugar content and quality of the grape. He considered that the variations in temperature due to differences in elevation, character of the soil, direction of the slope, and protection from the wind were enough to account for the local success or failure of vineyards in doubtful zones of production. He concluded from temperature records and other data that the Concord variety appeared to require an average mean temperature of at least 65.5 degrees F from May to September and a growing period of more than 160 days for successful production.

In Washington (57) the Concord grape is reported to require at least 1,900 heat units from full bloom to produce a juice with a Brix of 16 or better. In Arkansas (30), at least 2,500 degree days are considered to be necessary for 16.5 percent soluble solids. However, Shaulis and Robinson (54) reported that heat summation units are less likely to be useful for the Concord variety in New York than has been found in California for vinifera grapes. But they concluded that variations between seasons affect the date of maturity (16 degree Brix) more than pruning severity or trellis height variations.

Workers in Washington (16) reported that the maturity of Concord fruit is determined not only by the total heat units but also by the period during the growing season when the most favorable temperature occurs. These workers associated abnormally high minimum temperatures in May and June with early shoot and leaf growth and advanced maturity.

That the optimum temperature may vary with time in the Concord grape is supported by the work of Tukey (61). He found that the optimum diurnal temperature for berry growth decreased with time during the 13 days following full bloom. Also, Brown (10, 11), working in Calfornia, found that the apparent efficiencies of different temperatures in the development of the apricot fruit varied widely with increasing temperature. The time of harvest of the apricots was predicted, with a maximum deviation of $\pm$ 3 days, by use of the number of hours in various temperature classes during the 42 days following full bloom.

Cultural Conditions and Practices Associated with Variation of Soluble Solids

According to Winkler (70), operations (girdling, limiting water, etc.,) that cause the vines to slow down or cease growing will tend to hasten ripening after the fruit reaches the ripening stage. A limited supply of nitrogen will cause the vines to cease growth early, tending to advance ripening, and applications of nitrogen, which cause the vine growth to continue actively, will delay fruit ripening. Also, Bukovac *et al* (13) suggested that vigorous vine growth late in the season may be responsible for slow color development and low sugar content of grapes. Other workers (48, 52, 62) have attributed low soluble solids to vigorous vine growth. However, yield, which usually increases with vigor (1, 8, 45, 50, 52) has also been found to be inversely related to soluble solids (10, 26, 27, 49, 51, 65).

Partridge (48) found that the inverse relationship between yield, in the Concord grape, and soluble solids was apparent whether a sub-division was made based on vigor or whether the population was considered as a whole. There was no definite relationship between soluble solids and vigor when vines of equal production but varied vigor were grouped. Partridge concluded that the apparent inverse relationship of soluble solids with vigor was apparently due to the lower yield of the weak vines. However, in another study involving the Campbell Early grape, there was no consistent relationship between soluble solids and vigor or yield (47).

Shaulis, after considering the relationship of soluble solids, vigor and yield, concluded that soluble solids data without yield and vigor data are of limited value (52).

Upshall and Van Harrlem (62) reported that high vigor Concord vines had lower soluble solids than did low vigor vines although the latter vines produced a slightly greater yield. Part of the difference in vigor was ascribed to five consecutive years of heavy pruning. These workers suggested that over pruning strong vines may reduce both the quality and quantity of the fruit.

Shaulis and Robinson (54) found that pruning severities of 20 + 10, 30 + 10, and 40 + 10* did not appreciably affect maturity over a period of 4 years. However, with the lightest pruning level, there was a tendency towards delayed maturity. Yield increased with decreasing pruning severity.

Kimball and Shaulis (33) found, in a four year study, that soluble solids decreased slightly as pruning severity was decreased from 20 + 10 to 65 + 10. Yield increased with increasing number of buds.

Larsen (36) found that spur pruning of 30 + 10 and conventional pruning of 15, 30 and 45 + 10 did not affect yield or soluble solids. Partridge (47) found that soluble solids, when taken from vines with equal yields, increased with pruning severities from 60 to 30 buds per vine.

Winkler (68) working with the vinifera grape in California, found that yield increased as pruning severity decreased from spur to cane pruning. Non-pruned and cane pruned vines on which the crop was controlled by thinning, had a more abundant supply of available carbohydrates than conventionally spur pruned or severely spur pruned vines. With some varieties the lower available carbohydrates, due to increased pruning severity, were associated with low pollen germination, shot berries, and straggly clusters. The differences in carbohydrates were attributed to differences in number of leaves and the length of the time during which the leaves were active. Pruning not only reduced the total weight of leaves per vine, but delayed the time of maximal leaf area beyond midsummer. Winkler concluded that controlling the crop entirely by thinning, with no pruning, although uneconomical, would produce the largest crop with

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* The first figure, i.e. 20, 30, or 40 refers to the number of buds left on a vine for the first pound of one year old wood removed by pruning; the second figure, 10, indicates the number of buds left for each additional pound removed.

a high sugar content. He explained this would result in a large increase in the number of leaves early in the season resulting in an improvement of the nutrition of the flowers. He found a more economical compromise was to cane prune with flower cluster thinning. This resulted in yields equal to or greater than conventional spur pruning and with a higher sugar content.

Workers generally agree (7, 46, 50, 57, 70) that grapes have a higher sugar content when grown on sandy soils than on "heavy" soils. The delay in maturity on heavier soils is generally attributed to "stronger" vine growth. The fact that heavy soils tend to produce high vigor vines is reflected in the high positive correlation found for growth, measured as pruning weight, and soil organic matter (1, 50), total nitrogen, available moisture capacity, capillary porosity, clay and silt content and total cation exchange capacity of the soil (1). All of these factors often increase as soil texture changes from a sand to clay.

Snyder and Brannon (57) suggested that although extremely light soils present problems in maintaining soil fertility and soil moisture, they may be very desirable in areas where total heat units are low.

Hendrickson and Veihmeyer (29), working in California, found irrigation resulted in lower soluble solids in one year out of seven. This effect occurred the second year of treatment and was associated with increasing vigor and a 30 to 40 percent increase in yield. Other workers in California (63) found that irrigation did not consistently affect the sugar content of the fruit.

Research, in Arkansas, showed that irrigation of one inch per week delayed maturation (30). However, the delay was slight as indicated by difference in soluble solids. These workers did not report any effect of irrigation on yield or vigor.

In Arkansas (19), applications of 30 pounds of nitrogen per acre for eight years did not affect the sugar content of grapes.

Workers in California (17) reported that rates of over 40 pounds of nitrogen per acre reduces color development and delays maturity by a few days.

Partridge (48), found, when comparisons were made between vines of approximately equal production, that addition of 35 pounds of nitrogen per acre the first year of treatment had no effect on soluble solids, but reduced soluble solids the second year of the treatment. He did not report any effect on vigor.

In Ohio (8) applications of 0, 40 and 80 pounds of nitrogen per acre for eight years did not have a consistent effect on soluble solids. However, the soluble solids content of fruit from cultivated vines was consistently higher than fruit from mulched vines. The difference in soluble solids was attributed to the high nitrogen status of the mulched vines as evidenced by weight of prunings removed and leaf petiole nitrogen. It was suggested that a higher level of soluble solids can be anticipated if petiole leaf nitrogen, in early July, is maintained in the range of .85 to 1.30 percent rather than above this range. In general, however, the data showed that the greatest rate of decrease in soluble solids was within the range of .85 to 1.30 percent petiole nitrogen. Beyond 1.30 percent petiole nitrogen, soluble solids appeared to level off.

Shaulis (52) found that 32 to 64 pounds of nitrogen per acre, for five years, was associated with lower soluble solids in proportion to the nitrogen applied. However, since yield and vine vigor increased in the same proportion, he concluded that the data offered no evidence concerning the effects of fertilizer on the soluble solids content of the grape berry.

Low soluble solids have been associated with potassium deficiency (17, 35), but applications of potassium in vineyards having adequate potassium (17, 19, 36, 44) have not affected soluble solids. However, Partridge found (48) that vines which received potassium in combination with nitrogen produced higher soluble solids than nitrogen alone.

Applications of phosphorus (17, 19, 48), magnesium (36) and calcium (48) have not been associated with variations in soluble solids.

Shaulis and Robinson (54) found that low trellised (4 feet) grapes matured more slowly than did high trellised (7 feet) grapes. They suggested that the delay in maturity may have been due to shading of the foliage and thus keeping fruit cooler. A second suggestion was that the delay was due to the inferior leaf exposure on the low trellis.

Kimball and Shaulis (33) found that soluble solids increased in proportion to spacing if vines of equal vigor were compared. They concluded that delayed maturity of large crops in large vines is dependent in part on the inadequate exposure of the large leaf surface.

Conclusions from the Literature Review and Basis for Subsequent Studies

Variation of the climatic environment, especially temperature and/or light intensity, appears to be the most important factor responsible for variation in soluble solids between years. Seasonal temperature and/or light intensity variations appear to alter the rate of fruit development and shoot growth.

Many factors have been suggested as responsible for variation of soluble solids between vineyards within a given year. Usually these factors affect soluble solids by altering vigor and/or yield. However, these two factors usually vary together. The suggestion has been made that the effect of vigor on fruit soluble solids is due to competition for available carbohydrates and in one case to shading.

Experiments were initiated to alter vigor, yield, and light intensity and to observe the effects, singly and in combination, on soluble solids production of the Concord grape. Also, vineyards were surveyed to determine the relative importance of various reported factors on soluble solids production.

MATERIALS AND METHODS

I. Shading Studies

The primary purpose of this experiment was to determine the effect of shading during various parts of the growing season on soluble solids production. Secondary objectives were to determine the effect of reduced yield (thinning clusters) and shoot tip removal on soluble solids production. The shoot tips were removed in an attempt to check vegetative shoot extension.

Procedure: The experiment was conducted for three consecutive summers, 1962, 1963 and 1964, at the Horticulture Farm, East Lansing, Michigan.

In 1962, a split-plot design was used with shading as the main plot and shoot tip removal and thinned clusters as the sub-plot treatment. The experiment was replicated four times with nine vines per replicate.

Two weeks after full bloom (June 20) the total number of clusters per vine were counted and one-half of them were removed from designated vines.

On August 15, the shade treatments, consisting of no shade, 30 percent shade, and 50 percent shade were applied for the five weeks preceding harvest. Woven saran panels were placed over a previously constructed "cradle" so that each panel covered three vines as a modified umbrella, which was one foot above the vines, two feet wide, and dropped five feet along each side. Also, on August 15, approximately six inches were removed from the terminal portion of each shoot on designated vines.

A soluble solids sample was taken from each vine at harvest, September 20. The sample consisted of four apical berries from 16 basal clusters. Percent soluble solids of the expressed juice was determined with a Zeiss hand refractometer immediately after collection. Yield records were obtained at harvest.

In 1963 and 1964, the time of shade application was the main plot and percent shading was the sub-plot treatment. The experiment was replicated twice with 18 vines per replicate.

At full bloom the shade treatments, as described, were applied for either seven weeks following full bloom or later for the seven weeks preceding harvest.

Soluble solids samples, consisting of 100 random berries per vine, were taken at harvest, September 26, 1963 and September 24, 1964. The samples were held at 0°F until fresh weights of the berries and percent soluble solids determinations were made. Yield and number of clusters per vine were recorded at harvest.

A comparison was made in 1964 of fruit soluble solids from fruit on exposed shoots *versus* shaded shoots on the same vine. There were seven shoots per treatment, and yield per shoot was recorded on September 24, 1964.

II. Survey, 1962 and 63

A survey of Concord vineyards in southwestern Michigan was conducted during the summers of 1962 and 1963 to determine factors associated with variation of soluble solids between vineyards.

Procedure: In the spring of 1962, 100 ten vine plots were selected for study in Van Buren and Berrien Counties. The plots were selected in vineyards with variable soluble solids records over the year.

Two plots were generally selected per grower. These plots usually differed in some aspect such as vigor, fruit soluble solids during past years, soil texture, row direction, trellis height, or soil management.

Vine vigor was numerically rated from 1 to 5 by visual observation. Vines with very low vigor and those with high vigor were rated 1 and 5, respectively.

Trellis height and spacing between vines were measured. Square feet of soil surface per vine was calculated as the product of spacing within and between rows. Cubic feet per vine was calculated as the product of square feet of soil surface and trellis height.

During mid-July, the number of clusters on five vines per plot was recorded and a soil, petiole and shoot tip sample was taken from each plot. Soil samples were taken from the surface soil to a depth of six to eight inches. Two cores of soil were taken, one from each side of the vine, at an angle of about 45 degrees to the row and about one foot from the trunk. The cores were thoroughly mixed and one-half pint was saved for analysis.

The soil samples were analyzed by the Soil Testing Laboratory of the Soil Science Department for pH; available phosphorus, potassium, calcium, magnesium; cation exchange capacity; percent saturation of potassium, calcium, magnesium; and percent base saturation. The laboratory also rated the samples from one (clay loam) to five (sand). Percent organic matter of the soil was determined by combustion (23).

Petiole samples, consisting of 80 petioles, eight per vine, were taken from the most recent "mature" leaves on fruiting shoots. Shoot tip samples of 30 shoot tips, three per vine, were taken at random. The length of the shoot removed ranged from four to ten inches depending on the number of immature leaves. The petioles and shoot tips were free of insect, disease, and mechanical injury.

After sampling, the petiole and shoot tip samples were dried at room temperature for two weeks, then dried at 174°F for 72 hours and ground in a Wiley mill with a 20 mesh screen. The samples were analyzed for 11 nutrient-elements by the Plant Analysis Laboratory in the Department of Horticulture. Potassium determinations were made with a flame photometer, nitrogen by use of the Kjeldahl method, and calcium, magnesium, phosphorus, manganese, iron, copper, boron, and zinc by photoelectric spectrometer analysis (31).

A soluble solids sample was taken of the 4 apical berries from 25 basal clusters from each plot just before harvest, September 12 and 13. On the day of sampling, the berries were macerated in either a Waring or Lourdes blendor and percent soluble solids of the expressed juice were made with a Zeiss hand refractometer.

Approximately 100 grams of macerated berries were saved from each soluble solids sample for nutrient analysis. Due to difficulties in drying, the berries were analyzed on a fresh rather than on a dry weight basis.

Soluble solids samples were taken of fruit on September 16 from the top and bottom wire of the trellis at 20 locations. The sample consisted of four apical berries from 25 basal clusters.

In 1963, due to a late spring freeze, only 49 of the original 100 plots were used in the survey. Vine vigor was rated numerically from 1 to 5 and the percent of the trellis filled with foliage was visually[1/]

1/ "Percent of the trellis filled with foliage" will be referred to as "foliage density."

estimated. These estimates were made twice during the growing season, July 22 and September 22[1] and averaged for the final estimate. The vigor rating was found to be more closely correlated with foliage density (.940**) than with average shoot growth (.738**). This indicated that the vigor rating was a better estimate of foliage density than growth per shoot. Thus, vigor is herein considered to be a measure of foliage density and not of growth.

During mid-July, petiole and soil samples were taken and analyzed. A soluble solids sample of 150 berries, 15 per vine, was taken at random from each plot just before harvest, September 21 and 22. The samples were harvested onto dry ice and held at 0°F until fresh weights of the berries were recorded, and percent soluble solids were determined with a Zeiss hand refractometer. All soluble solids samples, in subsequent studies, were processed in this manner.

III. Nitrogen Study - Growers' Vineyards

This experiment was initiated to determine the effect of increased nitrogen on the growth and fruit soluble solids from vineyards of varying degrees of vigor.

Procedure: In the spring of 1963, 20 vineyards[2] were selected from the original 100 for this study. The vineyards represented wide ranges in fruit soluble solids, vigor, soil type, and cultural practices.

The experimental design was a restricted randomized block with two

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1/ The estimate of foliage density on July 22 and September 22 was positively correlated (.907**). This correlation indicates the estimate was repeatable.

2/ Due to damage from a late spring freeze, ten of the vineyards were later dropped from the study.

replicates per location and 10 vines per replicate. The treatments of no nitrogen and one pound of ammonium nitrate per vine (about four times normal rate), were applied in mid-April in addition to any fertilizer application made by the grower. The experiment was conducted during 1963 and 1964.

Petiole samples, eight per vine, were collected June 14 and July 22 in 1963, and June 15 and July 13 in 1964. In the June sampling, the first petiole beyond the last cluster was sampled; and in the July sampling, the most recent mature petiole was selected. The samples were analyzed for nitrogen by use of Kjeldahl method. The purpose of the two sampling dates was to determine if plant response was more closely associated with the petiole nitrogen content in June or July.

On July 16, 1963, 10 shoots per plot were marked and weekly growth measurements were made until growth stopped. The weekly growth measurements were plotted and the rate of growth per shoot was calculated from the straight portion of the curve. The date at which shoot extension stopped was recorded for each vineyard. Average shoot growth per vine was obtained by the product of average rate of shoot growth with days of growth. Total shoot growth per vine was determined by the average shoot length per vine times the number of shoots per vine.

In 1964, 20 to 25 shoots were measured per plot to obtain average shoot growth per vine. Total shoot growth per vine was calculated as the average shoot growth times average number of shoots per vine.

In 1963, leaf area was determined by pressing and tracing the area of 52 leaves onto square centimeter graph paper. The area per leaf was related to the length of the central vein of the leaf as per the equation in Figure 1. From the equation, square meters of leaf area per shoot were estimated by determining and summing the area of all leaves per shoot. Square meters of leaf area per shoot were related to the length of the shoot by the equation in Figure 2. The equation was derived from 36 observations. Each observation was an average of 2 to 5 single observations.

Total leaf are per vine was obtained by the average leaf area per shoot times the average number of shoots per vine. The leaf area per pound of fruit was obtained by dividing leaf area per vine by yield per vine.

A fruit sample, consisting of 100 berries taken at random per basic plot, was taken September 21, 1963 and September 15, 1964.

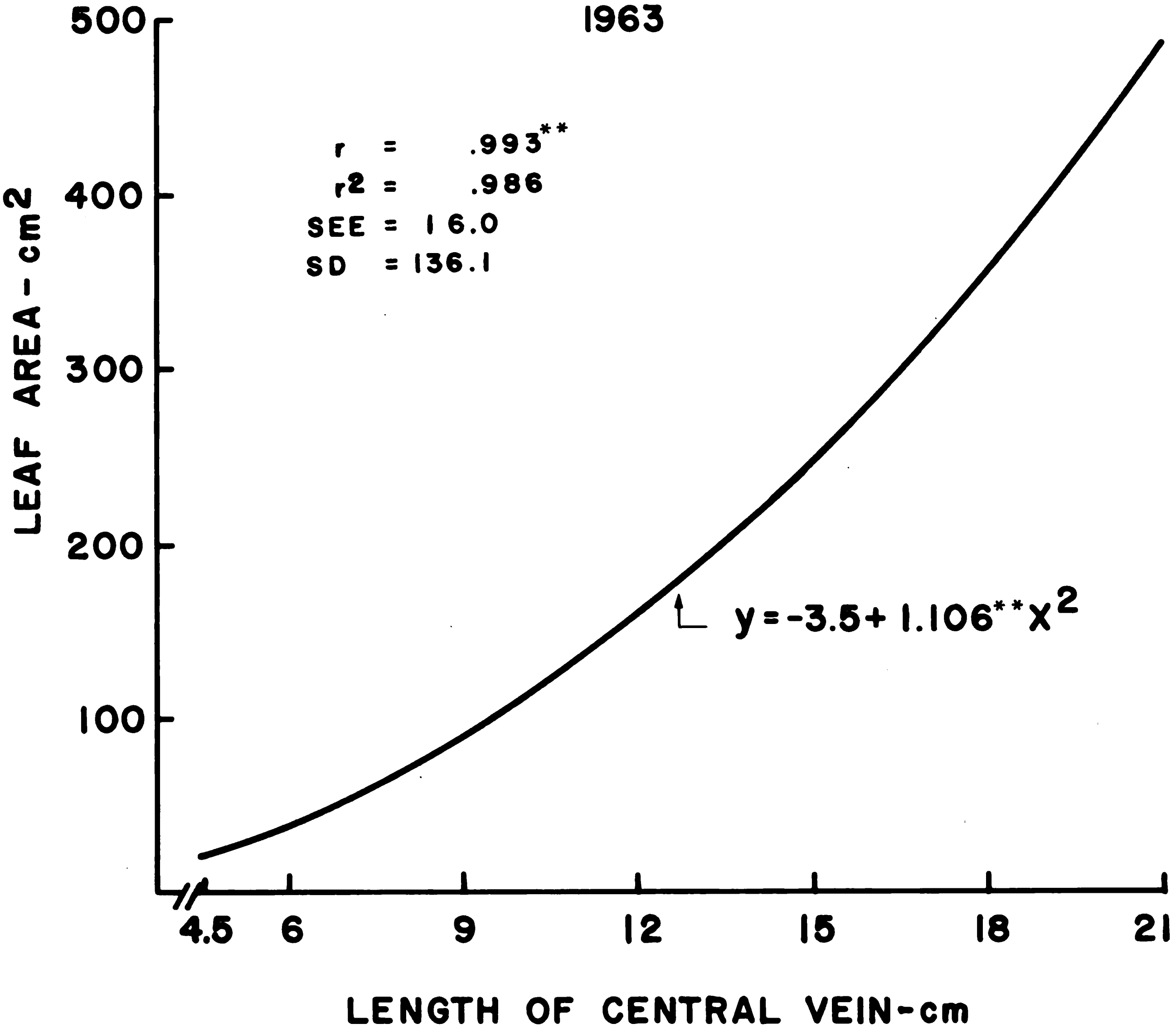
Yield and number of clusters per vine were recorded at harvest. Weight per cluster was obtained by dividing yield per vine by clusters per vine. Berries per cluster were calculated by dividing weight per cluster by average berry weight.

IV. Nitrogen Study - Sodus

The primary objective of this experiment was to modify vigor by altering the levels of nitrogen available to the vines and to observe the effects on soluble solids. Unlike the nitrogen experiment in growers' vineyards, factors such as soil type, microclimate and cultural practices would be constant.

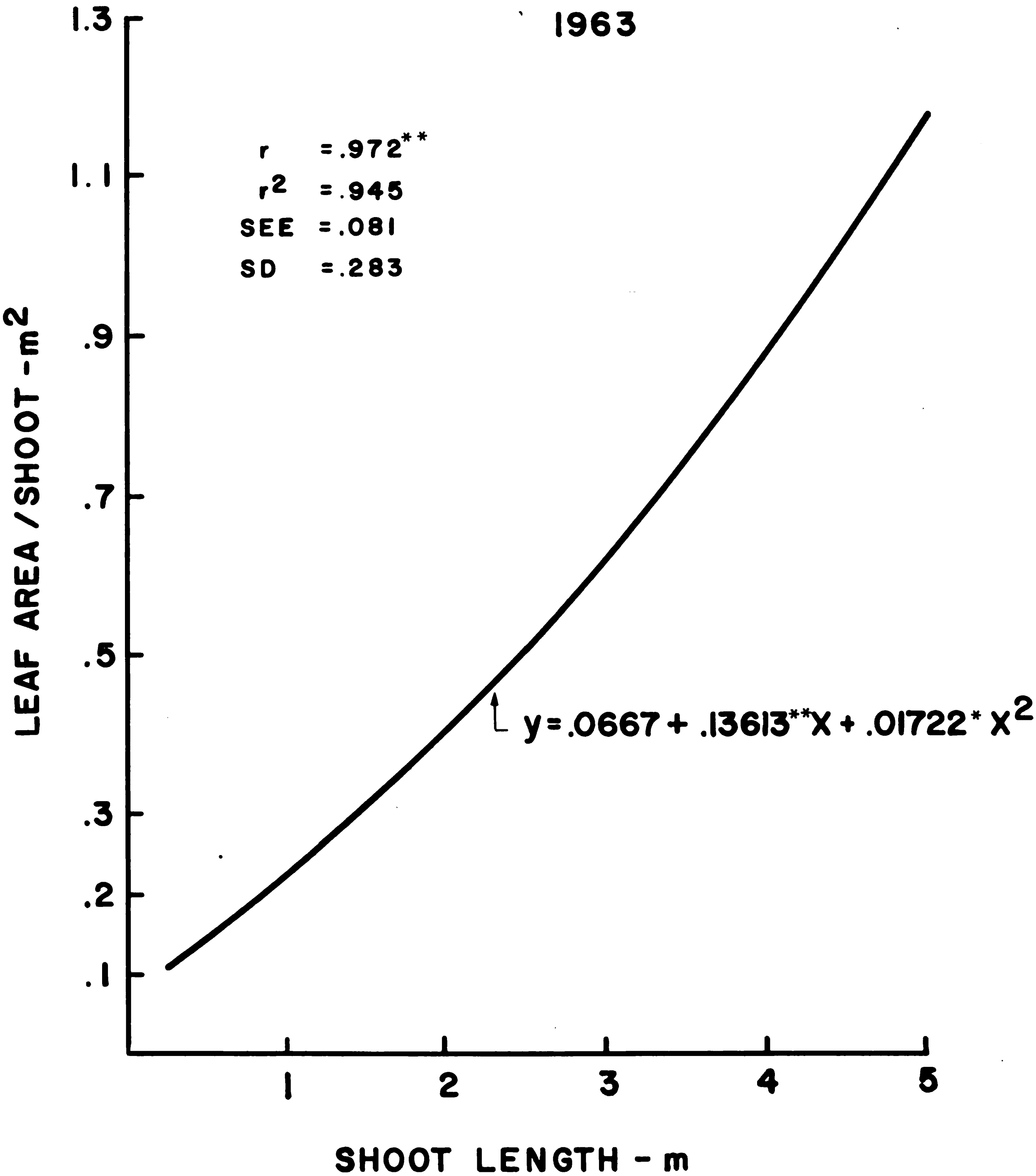
Secondary objectives were to reduce yield, by thinning clusters at two dates during the growing season, to determine the critical period for soluble solids production; to study possible interactions of yield and vigor with soluble solids; and to study the effect of the previous years'

Figure 1. The relationship of leaf area to the length of the central vein, 1963.



1963
r = .993**
r2 = .986
SEE = 16.0
SD = 136.1
y = -3.5 + 1.106** X2
500
400
300
200
100
LEAF AREA - cm2
4.5
6
9
12
15
18
21
LENGTH OF CENTRAL VEIN-cm

Figure 2. The relationship of leaf area per shoot to shoot length, 1963.



1963
r =.972**
r2 =.945
SEE =.081
SD =.283
y=.0667+.13613**X+.01722*X2
LEAF AREA / SHOOT - m2
SHOOT LENGTH - m
1.3
1.1
.9
.7
.5
.3
.2
.1
1
2
3
4
5

yield on soluble solids production.

Procedure: The experiment was conducted during the summers of 1963 and 1964 at the Sodus Horticultural Farm in Berrien County, Michigan.

The design was a factorial split-plot replicated four times with 36 vines per replicate. The basic unit consisted of two vines.

The main plots were two levels of ammonium nitrate, 0 and 1 pound per vine and three levels of sawdust, 0, 23, and 45 pounds per vine. (After drying a sample of sawdust to a constant weight of 150°F, the actual amount applied was found to be 0, 10, and 20 pounds.) The sawdust was applied in an attempt to reduce available soil nitrogen. (Ten pounds of sawdust per vine based on broadcast application will reduce the availability of nitrogen approximately 45 pounds per acre (41).)

In 1963, the sub-plot treatments consisted of (a) no cluster thinning, (b) one-third of the clusters per vine removed five days (June 20) after full bloom and (c) one-third removed 50 days (August 5) after full bloom. At the latter date the berries had completed the first stage of growth and the precent soluble solids was 4.0.

Petiole samples, 15 per vine, were collected on June 20 and July 27 in 1963, and June 15 and July 15 in 1964. In the June sampling, the first petiole beyond the last cluster was taken; and in the July sampling, the most recent mature petiole was selected. The samples were analyzed for nitrogen.

A fruit sample, consisting of 60 berries selected at random per basic plot, was taken September 30, 1963 and September 23, 1964.

Yield and number of clusters per vine, berries per cluster and berry weight were obtained in the manner previously indicated. Pounds of prunings removed per vine were obtained in the winter of 1963.

RESULTS

I. Shading Studies

In 1962, shading for five weeks preceding harvest or removing the terminal portion of grape shoots to stop linear growth had no significant effect on fruit soluble solids (Table 2). Thinning one-half of the clusters per vine resulted in significant increase in soluble solids only when the vines were not shaded. Removing one-half of the total number of clusters per vine decreased yield by approximately one-half. There was no effect on weight per cluster. The interactions of shade x shoot tip removal and shade x cluster thinning were not significant.

In 1963, shading during the early part of the season had no significant effect on soluble solids production, but 50 percent shading for seven weeks preceding harvest reduced soluble solids (Table 3). In 1964, shading to 30 or 50 percent during both periods decreased soluble solids, but the effect was greater during the latter part of the season. The degree or time of shading or the interaction of shade with time had no significant effect on yield, berry weight, or berries per cluster in 1963 or 1964.

Exposed shoots produced fruit with higher soluble solids than did shaded shoots on the same vine. There was no significant effect on yield per shoot, berry weight, or berries per clusters (Table 4).

II. Survey, 1962 and 63

In approximately one-half of the 1962 vineyards surveyed, the growers were using a complete fertilizer (200-500 pounds per acre). The fertilizer

Table 2. - Effect of shading, shoot tip removal and cluster thinning on soluble solids, yield per vine and weight per cluster. Shading studies, 1962.

Effect on soluble solids

Treatment	Shade - % 0	30	50	Ave.
	Soluble solids - %			
Check	15.3 a	15.1 a	14.8 a	15.0 a
Shoot tips removed	15.3 a	14.9 a	14.6 a	14.9 a
Clusters thinned	16.6 b**	15.8 a	15.3 a	15.9 b**
Average	15.7	15.3	14.9 n.s.	

Effect on yield and weight per cluster

Treatment	Yield - lbs./vine	Wt./cluster - lbs.
Check	14.4 a	.22 a
Shoot tips removed	14.0 a	.21 a
Clusters thinned	7.8 b**	.22 a
Shade - %		
0	14.4 a	.21 a
30	11.8 a	.22 a
50	10.5 a	.24 a
Shade x shoot tip removal and cluster thinning	n.s.	n.s.

Means followed by the same letter are not significantly different.
* Statistically significant at the 5 percent level.
** Statistically significant at the 1 percent level.
n.s. not significant

Table 3. - Effect of shade and time of shade application on soluble solids, yield per vine, berries per cluster and berry weight. Shading studies, 1963 and 64.

Effect on soluble solids

	Time of shade, 1963		Time of shade, 1964	
	6/17 to 8/7	8/7 to 9/26	6/19 to 8/7	8/7 to 9/24
Shade - %	Soluble solids - %			
0	14.9 a	15.6 a	16.2 a	16.8 a
30	14.5 a	14.1 a	15.5 b	13.5 b
50	15.6 a	13.5 b**	15.4 b*	13.8 b**
Average	15.0	14.4 *	15.7	14.7 n.s.

Effect on yield, berries/cluster and weight/berry

	1963			1964		
Treatment	Yield - lbs./vine	Berries/ cluster	Wt./berry gms	Yield - lbs./vine	Berries/ cluster	Wt./berry gms
Shade - %						
0	6.8 a	32 a	3.1 a	10.1 a	25 a	3.1 a
30	7.6 a	35 a	3.0 a	10.2 a	23 a	3.0 a
50	5.6 a	35 a	2.8 a	7.0 a	23 a	2.9 a
Time of shade						
7 wks. f.b.1/	7.9 a	29 a	2.8 a	9.0 a	25 a	3.0 a
7 wks. p.h.2/	5.4 a	38 a	3.1 a	9.2 a	23 a	3.2 a
Time x shade	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

1/ f.b. = following bloom

2/ p.h. = preceding harvest

Table 4. - Effect of leaf exposure within vines on soluble solids. Shading studies, 1964.

Shoot	Soluble solids - %	Yield - gms/shoot	Weight/ berry - gms	Berries/ cluster
Exposed	16.8	202	3.15	24.8
Shaded	15.8	229	2.97	26.4
	*	n.s.	n.s.	n.s.

grade varied somewhat but was primarily 12-6-24 and 12-12-12. Other growers were using nitrogen singly and in combination with potassium. The nitrogen was usually applied in the form of ammonium nitrate at the rate of 80 to 200 pounds per acre. Potassium, as muriate of potash, was applied at a rate of 150 to 500 pounds per acre. Some growers were applying manure and lime in addition to the above fertilizer.

Trashy cultivation was practiced to some extent in an attempt to reduce vegetative growth and increase fruit soluble solids. Clean cultivated vineyards were often planted to a cover crop of rye in late July or early August. Weed control within the row was by cultivation or herbicides.

The vines were trained to a four-arm Kniffin or Umbrella system. The Kniffin system predominated. Balance pruning was practiced to some degree by about half of the growers. The number of canes per vine averaged about five, but there was a wide variation in number of canes per vine as well as the length of canes.

Yield of the vines and denseness of the foliage varied greatly and low vigor vineyards appeared to be in an alternate bearing cycle. In vineyards with heavy foliage, much of the leaf surface was subjected to shade during a large portion of the growing season. In very high vigor vineyards, leaves in the interior of the vine often turned yellow and dropped before harvest.

In 1962, the period from full bloom to harvest was 4 days longer than in 1963. The mean percent soluble solids in 1962 was 16.6 ± 1.14 and 15.4 ± 1.13 in 1963. Between years, the relative position of the vineyards, with respect to soluble solids, remained fairly constant. This was indicated by the correlation (.605**) of soluble solids in 1962 versus 1963.

Petiole potassium was negatively correlated with soluble solids, and other nutrients in the petioles, shoot tips or berries were either inconsistently correlated between years or were not related to soluble solids (Table 5).

Soluble solids were positively correlated with soil texture (increasing sand content) and percent saturation of the exchange complex with magnesium, and negatively correlated with cation exchange capacity and available calcium. All other soil properties were inconsistently correlated between years or were not related to soluble solids (Table 6).

The relationship of soluble solids to magnesium saturation and available calcium was apparently indirect. This was indicated by lack of a correlation of these factors with soluble solids when the effect of cation exchange capacity or soil texture was held constant (Table 7). Soluble solids were correlated with soil texture or cation exchange capacity regardless of any effect due to magnesium saturation or available calcium. Neither cation exchange capacity or soil texture were

Table 5.-Relationship of soluble solids to nutrient content of petioles, shoot tips and grape berries. Survey vineyards, 1962 and 1963.

Soluble solids - % vs.	1962 Petioles	1962 Shoot tips	1962 Berries	1963 Petioles
	Correlation coefficient			
Nitrogen	-.326**	-.110	-.337**	-.071
Potassium	-.280**	-.041	-.228*	-.303*
Phosphorus	.123	-.022	.056	.050
Calcium	-.067	.181	-.115	-.009
Magnesium	.272**	.287*	.136	.186
Manganese	.088	.016	-.040	.080
Iron	.200	.134	-.110	-.007
Copper	-.020	-.043	-.187	.086
Boron	-.130	-.040	-.106	-.105
Zinc	-.172	-.043	---	-.117

Nutrient	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
N - %	.74	.13	2.70	.28	.193	.028	1.09	.16
K - %	1.47	.60	1.96	.21	.319	.045	2.19	.68
P - %	.225	.10	.420	.05	.023	.004	.292	.08
Ca - %	1.03	.15	.63	.08	.015	.004	1.06	.17
Mg - %	.40	.16	.23	.03	.008	.001	.46	.17
Mn - ppm	396.0	309.0	82.0	52.0	2.7	2.6	265.0	230.0
Fe - ppm	55.0	21.0	104.0	57.0	5.6	1.6	68.0	25.0
Cu - ppm	47.0	51.0	48.0	57.0	2.3	1.6	50.0	61.0
B - ppm	26.0	3.6	24.0	2.8	3.8	.9	31.0	3.9
Zn - ppm	35.0	8.4	31.0	7.9	---	---	72.0	22.0

1962, P.05 = .205, P.01 = .267; 1963, P.05 = .288, P.01 = .372

S. D. = Standard deviation (±)

Table 6. - Relationship of soluble solids and various soil properties. Survey vineyards, 1962 and 63.

Soluble solids - % vs.	Correlation coefficient		1962		1963	
	1962	1963	Mean	S.D.	Mean	S.D.
Soil texture	.440**	.340*	3.68	1.20	3.98	1.28
pH	.248*	.084	5.87	.63	6.10	.72
P - lbs./acre avail.	-.168	.366**	105.0	45.0	103.0	50.0
K - lbs./acre avail.	-.299**	-.135	192.0	115.0	232.0	177.0
Ca - lbs./acre avail.	-.269*	-.296*	950.0	597.0	1010.0	618.0
Mg - lbs./acre avail.	-.098	.022	122.0	67.0	117.0	67.0
CEC - m.e./100 gms	-.430**	-.354*	5.07	2.83	5.89	3.57
K - % saturation	.162	.151	5.33	2.94	5.50	4.03
Ca - % saturation	.114	.014	49.6	21.7	47.8	23.5
Mg - % saturation	.268**	.304*	9.7	6.4	9.0	6.7
Percent base saturation	.159	.070	63.4	25.9	61.3	28.5
Organic matter - %	-.475**	.176	2.87	1.28	3.00	1.80

1962, P.05 = .205, P.01 = .267; 1963, P.01 = .288, P.01 = .372

Table 7. - Relationship of soluble solids to various soil properties, petiole potassium and vigor. Survey vineyards, 1962.

Soluble solids - % vs.	r	Constant effect	Partial r
Mg - % saturation	.268**	CEC - m.e./100 gms	.109
CEC - m.e./100 gms	-.430**	Mg - % saturation	-.364**
Mg - % saturation	.268**	Soil texture	.086
Soil texture	.440**	Mg - % saturation	.371**
Ca - lbs./acre avail.	-.269**	CEC - m.e./100 gms	-.042
CEC - m.e./100 gms	-.430**	Ca - lbs./acre avail.	-.351**
Ca - lbs./acre avail.	-.269**	Soil texture	-.047
Soil texture	.440**	Ca - lbs./acre avail.	-.364**
CEC - m.e./100 gms	-.430**	Soil texture	-.174
Soil texture	.440**	CEC - m.e./100 gms	.200
Petiole K - %	-.280**	Vigor	-.176
Vigor	-.524**	Petiole K - %	-.487**

P.01 = .267

Partial r or partial correlation coefficient measures the correlation between the dependent factor (soluble solids) and each of the several independent factors (cation exchange capacity, soil texture, etc.,) while eliminating any tendency of the remaining independent factor (s) to obscure the relation. For example, there was a significant positive correlation (r) between soluble solids and soil magnesium. However, when either cation exchange capacity or soil texture were taken into consideration (constant effect), there was no significant correlation between soluble solids and soil magnesium.

correlated with soluble solids if the effect of one or the other was held constant. This indicates that the effect of the soil is reflected to the same extent by either soil texture or cation exchange capacity.

The apparent relation of soluble solids to petiole potassium was indirect as indicated by the lack of a correlation of soluble solids and petiole potassium when the effect of vigor was held constant (Table 7).

Vigor, as determined by a vigor rating, was inversely related to soluble solids (Table 8). The 1963 foliage density and 1962 yield, as indicated by number of clusters per vine, were negatively correlated with soluble solids. Soluble solids did not vary consistently with spacing within or between the row nor with trellis height, but were consistently correlated with square and cubic feet per vine. When the effect of vigor was held constant, square feet per vine was not correlated with soluble solids. Soluble solids were not related to row direction, position of the shoots on the trellis or soil management.

Thus, in summary, the factors associated with variation of soluble solids were cation exchange capacity and/or soil texture, square feet of soil surface per vine, vigor and/or foliage density and clusters per vine. The relation of these factors to soluble solids is shown in Figures 3 - 7. The relation of cation exchange capacity (Figure 3) and soil texture (Figure 4) to soluble solids was slightly greater in 1962 than in 1963. The relation of square feet of soil surface per vine was slightly greater in 1963 than in 1962 (Figure 5).

III, Nitrogen Study -- Growers' Vineyards

Application of one pound of added ammonium nitrate per vine substantially increased petiole nitrogen compared to vines receiving none (Table 9). Vines receiving the additional nitrogen in 1963 had eight percent higher petiole nitrogen in June than the check vines and 13 percent more in July. The reverse occurred in 1964 with an 18 percent increase in June and a 13 percent increase in July. The nitrogen application had no effect on yield per vine, clusters per vine, berries per cluster, leaf area per pound of fruit, shoot growth, foliage density or soluble solids in 1963 or 1964. The interaction of applied nitrogen

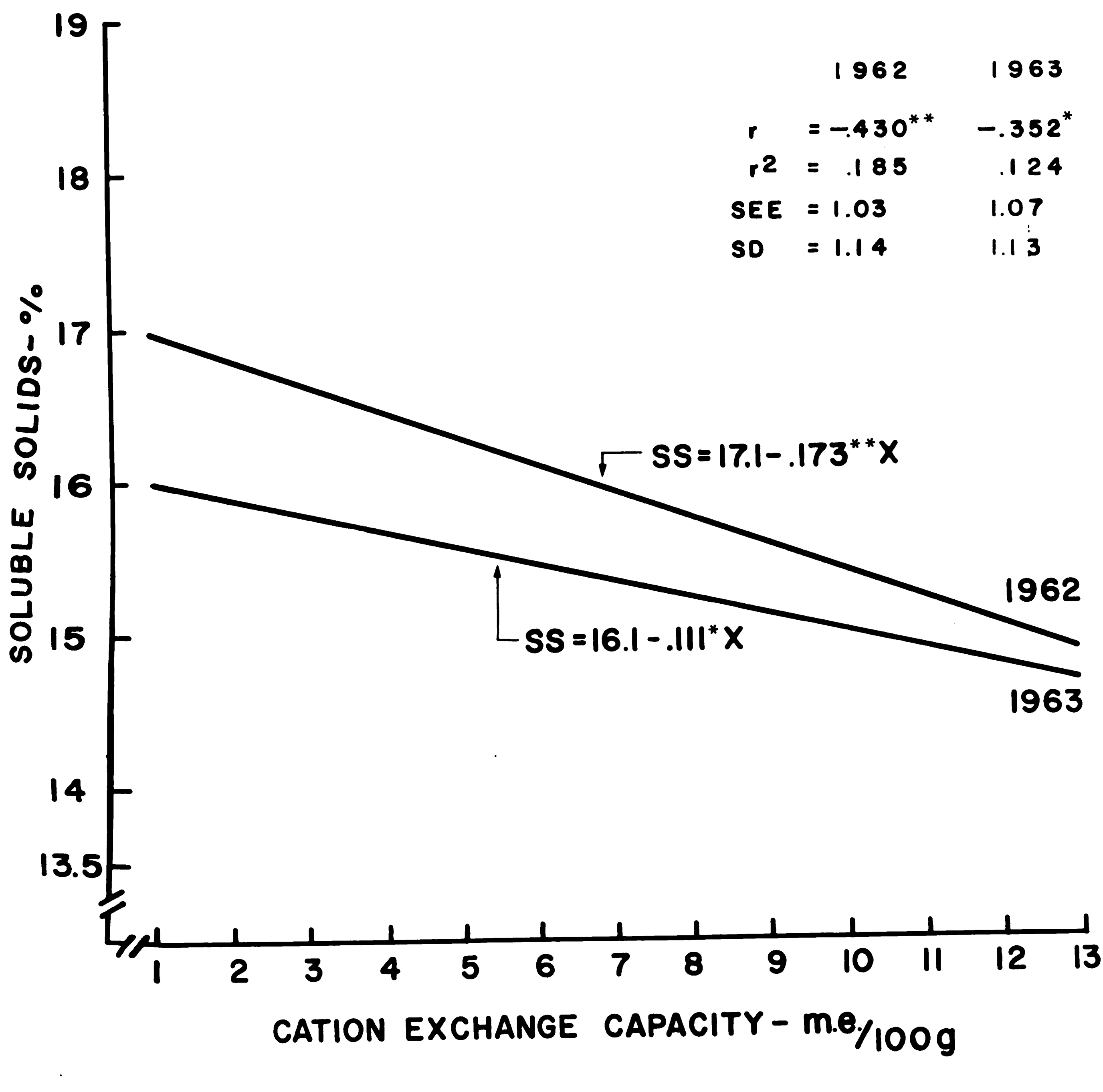
Table 8. - Relationship of soluble solids to vigor, foliage density, clusters per vine and cultural practices. Survey vineyards, 1962 and 63.

Soluble solids - % vs.	1962 r	1962 Mean	1962 S.D.	1963 r	1963 Mean	1963 S.D.
Vigor rating	-.524**	3.36	.88	-.733**	3.26	.94
Foliage density - %	.---	.---	.---	-.803**	57.1	23.0
Clusters/vine	-.425**	94.0	25.0	.---	---	---
Spacing						
within - ft.	.117	8.9	1.2	.300*	8.9	1.1
between - ft.	.233**	9.2	.78	.054	9.4	.69
Trellis height - ft.	.046	4.72	.35	-.187	4.67	.35
Square feet/vine	.247*	82.0	12.0	.308*	83.0	12.0
Cubic feet/vine	.237*	387.0	66.0	.289*	386.0	65.0
Square feet/vine + constant foliage density effect	.183	.---	.---	.136	---	---

Factor	Soluble solids - %
Row direction	
north	16.7 n.s.
south	16.2
Position	
top wire	16.9 n.s.
bottom wire	16.6
Soil management	
clean cultivation	16.5 n.s.
trashy cultivation	15.9

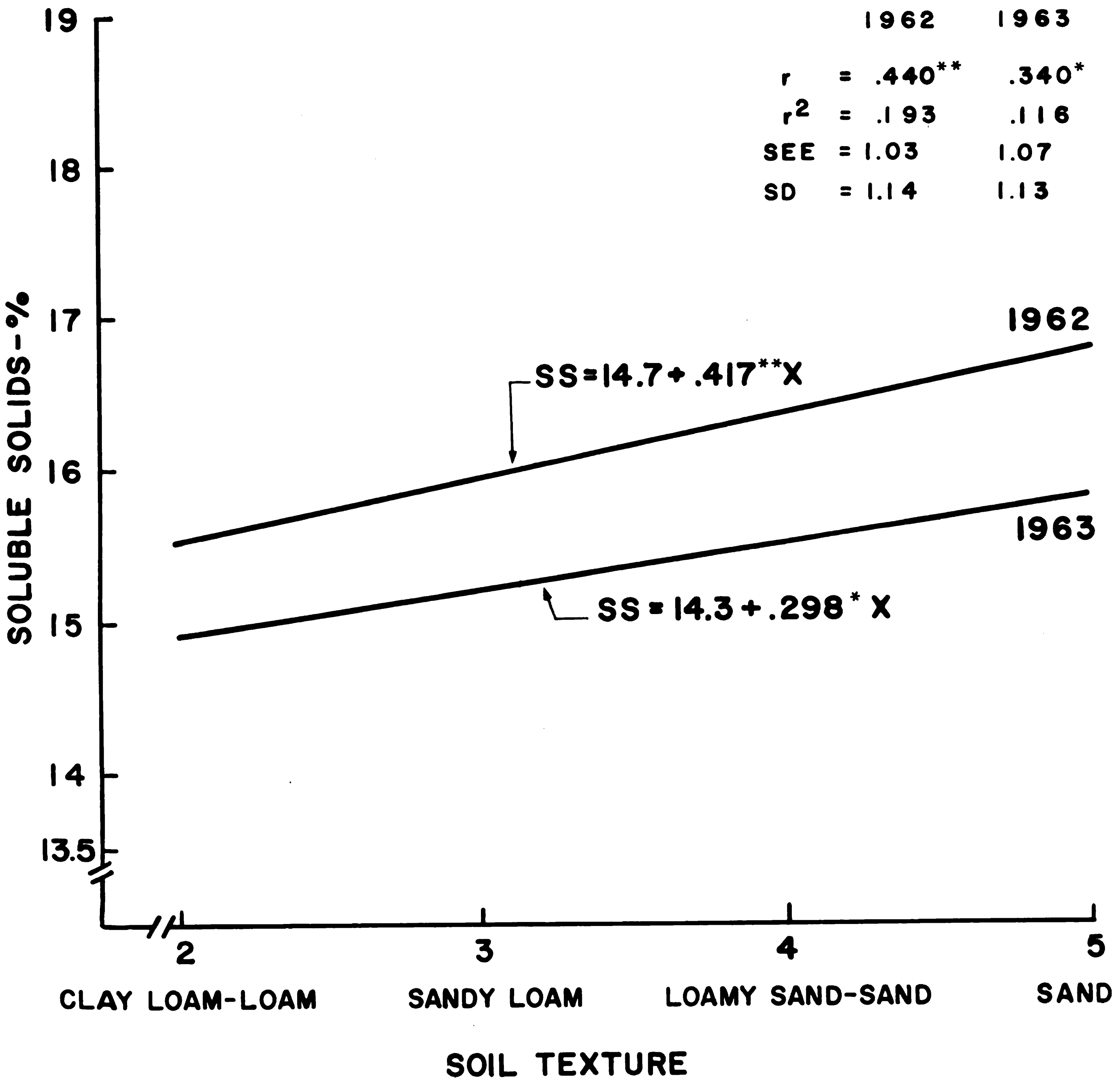
1962, P.05 = .205, P.05 = .267; 1963, P.05 = .288, P.01 = .372

Figure 3. The relationship of soluble solids to cation exchange capacity. Survey vineyards, 1962 and 63.



1962 1963
r = -.430** -.352*
r2 = .185 .124
SEE = 1.03 1.07
SD = 1.14 1.13
SS=17.1-.173**X
SS=16.1-.111*X
1962
1963
SOLUBLE SOLIDS-%
19
18
17
16
15
14
13.5
1
2
3
4
5
6
7
8
9
10
11
12
13
CATION EXCHANGE CAPACITY - m.e./100g

Figure 4. The relationship of soluble solids to soil texture. Survey vineyards, 1962 and 63.



1962 1963
r = .440** .340*
r2 = .193 .116
SEE = 1.03 1.07
SD = 1.14 1.13
1962
SS=14.7+.417**X
1963
SS=14.3+.298*X
SOLUBLE SOLIDS-%
19
18
17
16
15
14
13.5
2
3
4
5
CLAY LOAM-LOAM
SANDY LOAM
LOAMY SAND-SAND
SAND
SOIL TEXTURE

Figure 5. The relationship of soluble solids to square feet of soil surface per vine. Survey vineyards, 1962 and 63.

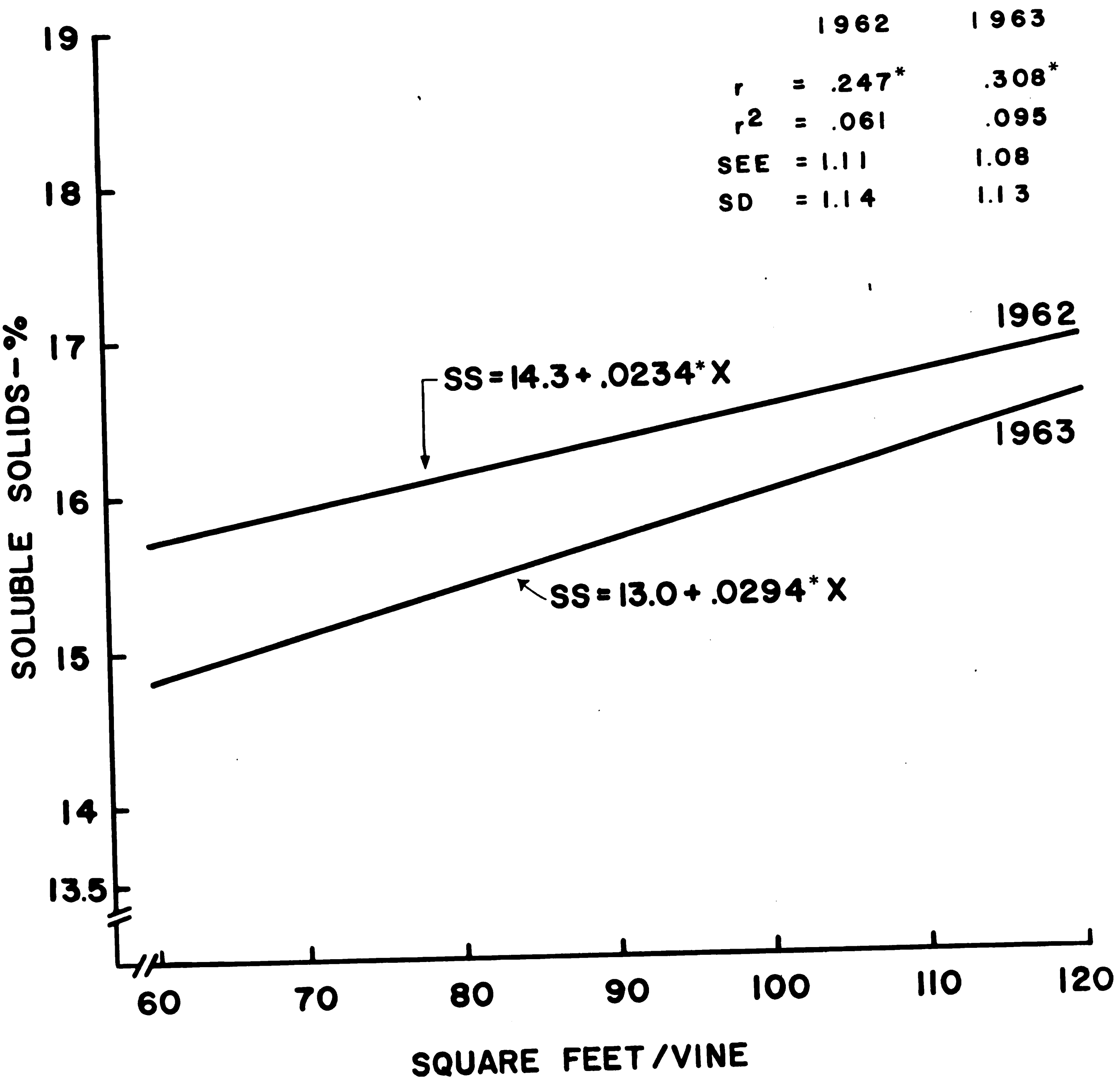

1962 1963
r = .247* .308*
r2 = .061 .095
SEE = 1.11 1.08
SD = 1.14 1.13
1962
1963
SS = 14.3 + .0234* X
SS = 13.0 + .0294* X
SOLUBLE SOLIDS – %
19
18
17
16
15
14
13.5
60
70
80
90
100
110
120
SQUARE FEET/VINE

Figure 6. The relationship of soluble solids to number of clusters per vine. Survey vineyards, 1962.

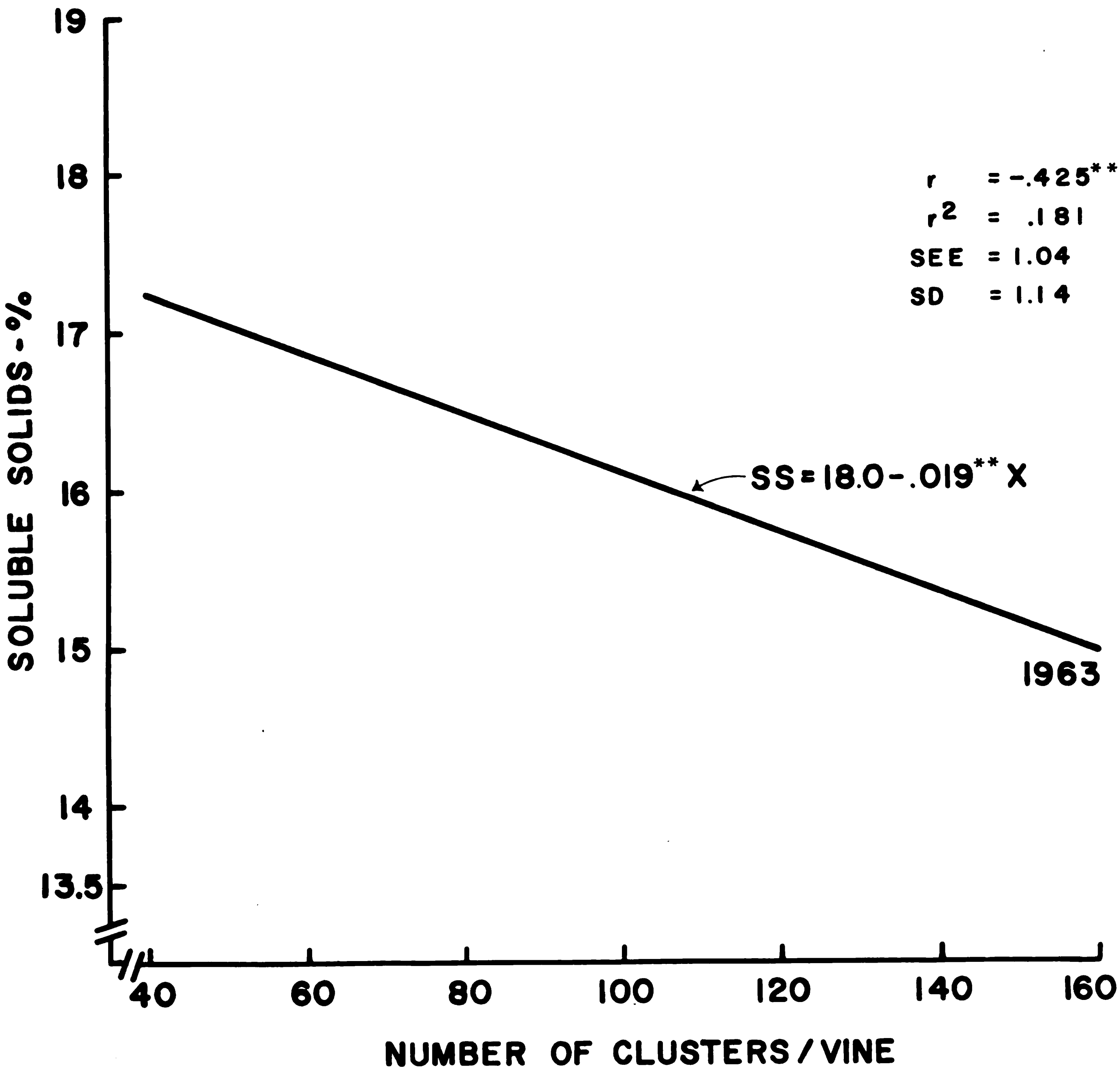
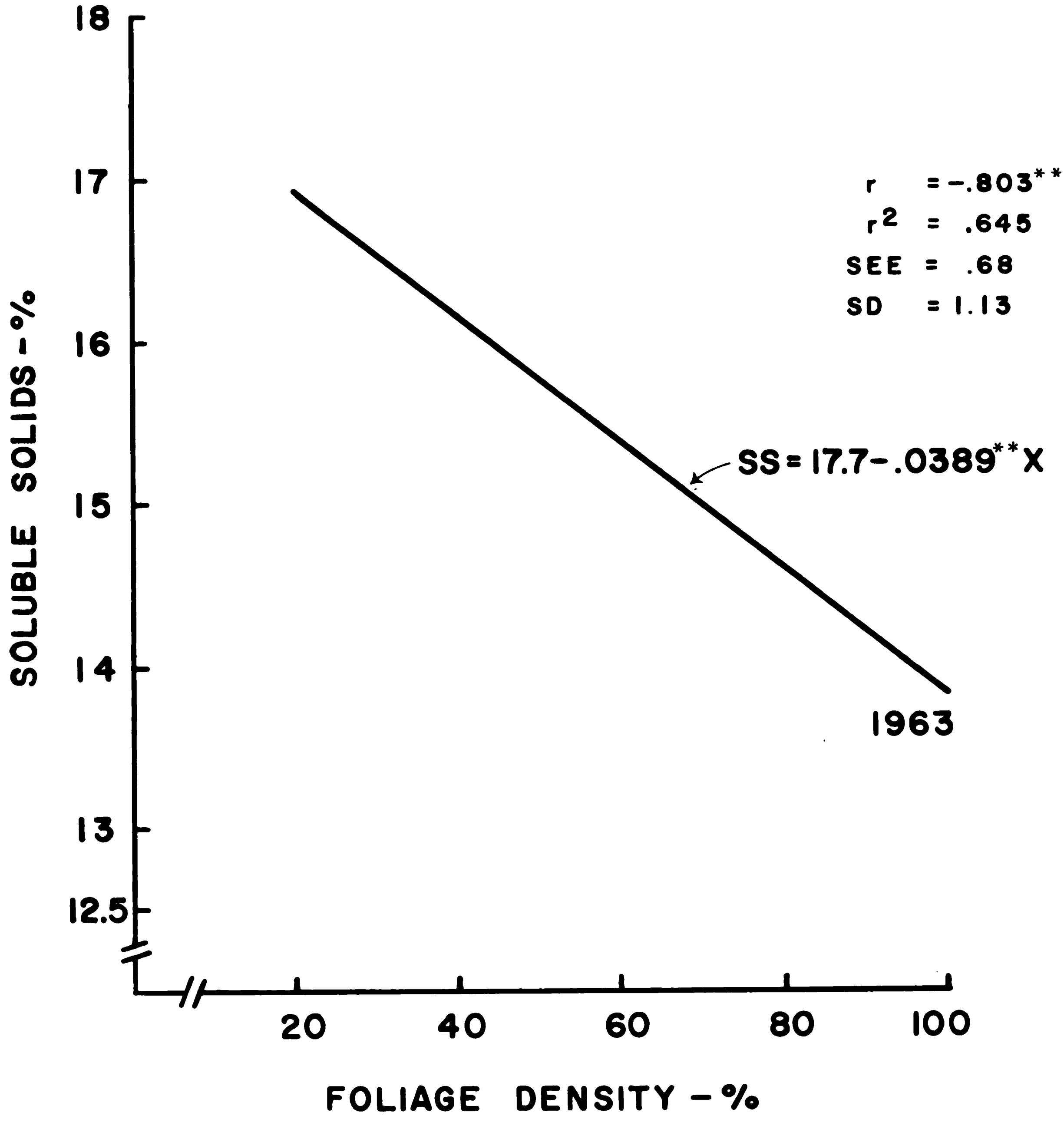

19
18
17
16
15
14
13.5
SOLUBLE SOLIDS - %
r = -.425**
r2 = .181
SEE = 1.04
SD = 1.14
SS = 18.0 - .019** X
1963
40
60
80
100
120
140
160
NUMBER OF CLUSTERS / VINE

Figure 7. The relationship of soluble solids to foliage density. Survey vineyards, 1963.



18
17
16
15
14
13
12.5
SOLUBLE SOLIDS - %
r = -.803**
r2 = .645
SEE = .68
SD = 1.13
SS = 17.7 - .0389** X
1963
20
40
60
80
100
FOLIAGE DENSITY - %

Table 9. - Effect of nitrogen application on petiole nitrogen, yield per vine, clusters per vine, berries per cluster, weight per berry, leaf area per pound of fruit, shoot length, foliage density and soluble solids of Concord grapes. Nitrogen study - growers' vineyards, 1963 and 64.

Factor	1963 Check	1963 N	1964 Check	1964 N
Petiole N - % dry wt.				
June	1.56	1.69**	1.26	1.54**
July	1.08	1.24**	1.17	1.35**
Yield - lbs./vine	16.1	15.0	19.3	19.3
Clusters/vine	80.0	76.0	111.0	114.0
Berries/cluster	29.7	29.0	26.6	25.2
Wt./berry - gms	2.99	3.02	2.94	2.97
Leaf area/lb. of fruit -m^2	1.12	1.15	.91	.94
Shoot length - m	2.05	2.13	1.73	1.73
Foliage density - %	55.0	58.0	53.5	62.4
Soluble solids - %	15.7	15.7	16.3	16.2

with locations was significant for berry weight in 1964. All other interactions were not significant in 1963 and 1964.

The petiole nitrogen content, from the check plots, was positively correlated with growth and leaf area per shoot regardless of the time or the year the petioles were sampled. Growth and leaf area per shoot were more highly correlated in 1963 with the nitrogen content of petioles collected in June than in July. The correlations did not differ with date of sampling in 1964. Soluble solids were not correlated with petiole nitrogen at any sampling date or year (Table 10).

Since there was no effect of applied nitrogen on any of the factors studied except petiole nitrogen and berry weight, the data for nitrogen treatments were pooled for both years. The pooled data were subjected to correlation and regression analysis (24) in order to study the relationship of soluble solids to foliage density, growth and yield. There were 20 observations per comparison.

Table 10. - Relationship of growth and leaf area per shoot and soluble solids to petiole nitrogen. Nitrogen study - growers' vineyards, 1963 and 64.

Petiole N - % vs.	Date petiole sampled 6/14/63	7/22/63	6/15/64	7/13/64
	Correlation coefficient			
Growth/shoot - m	.618**	.488*	.681**	.687**
Leaf area/shoot - m^2	.554*	.453*	.705**	.670**
Soluble solids - %	-.231	-.199	-.076	-.293

P.05 = .444, P.01 = .561

Soluble solids were negatively correlated in 1963 as indicated by simple correlations with foliage density, shoot growth per vine, shoots and yield per vine. They were not correlated with rate or days of growth. Soluble solids were correlated with foliage density only in 1964 (Table 11). The negative correlation of soluble solids to shoot growth per vine in 1962 was indirect and apparently due to the influence of shoot growth on foliage density. This was indicated by the lack of a correlation of soluble solids with shoot growth per vine when the effect of foliage density was held constant. Soluble solids were found to be positively correlated with days of growth when the masking effect of foliage density was removed. As indicated by simple and/or partial correlation, soluble solids were negatively related to yield in 1963 but not in

Table 11. - Relationship of soluble solids to foliage density, growth, yield per vine and leaf area per pound of fruit. Nitrogen study - growers' vineyards, 1963 and 64.

Soluble solids - % vs.	1963 Simple r	1963 Constant foliage, Partial r	1964 Simple r	1964 Constant foliage, Partial r
Foliage density - %	-.870**		-.600**	
Shoot growth/vine - m	-.687**	.260	-.104	.110
Shoots/vine	-.749**	-.580**	.081	-.079
Growth/shoot - m	-.429	.346	-.178	-.271
Shoot growth/wk. - cm	-.396	.329	---	---
Days of shoot growth	.054	.622**	---	---
Yield - lbs./vine	-.711**	-.604**	-.392	-.453
Leaf area/lb. of fruit -m^2	-.107	.491*	.215	.486*

Simple r, P.05 = .444, P.01 = .561; Partial r, P.05 = .456, P.01 = .575

1964. Leaf area per pound of fruit was not correlated with soluble solids in either year as indicated by simple correlation. However, there was a positive correlation with soluble solids in both years when the masking effect of foliage density was removed.

The relationship of foliage density to leaf area per shoot and number of shoots per vine in 1962 and 1963 is shown in Table 12. Foliage density increased in 1963 with increasing leaf area per shoot and number of shoots per vine. These two factors were associated to about the same

Table 12. - Relationship of foliage density to leaf area per shoot and shoots per vine. Nitrogen study - growers' vineyards, 1963 and 64.

1963

Foliage density (%) = $-24.6 + 73.0^{**}X_1 + 1.62^{**}X_2$

where:

X_1 = leaf area/shoot - m^2

X_2 = shoots/vine

R = .844 Beta wt.$_1$ = .597 S.E.E. = 13.6

R^2 = .713 Beta wt.$_2$ = .563 S.D. = 24.0

1964

Foliage density (%) = $17.8 + 146.2^{**}X_1 - .25X_2$

where:

X_1 = leaf area/shoot - m^2

X_2 = shoots/vine

R = .669 Beta wt.$_1$ = .641 S.E.E. = 15.3

R^2 = .447 Beta wt.$_2$ = .124 S.D. = 19.5

R = Multiple correlation

R^2 = Coefficient of multiple determination and represents the proportion of the total variation in the dependent factor (foliage density) which can be explained by, or is associated with, variation in the independent factor or factors (leaf area per shoot and shoots per vine).

Beta wt. = Beta weight and measures the relative importance of each of the independent factors in explaining or predicting variation in the dependent factor.

S.E.E. = Standard error of the estimate and measures the closeness with which the estimated values of foliage density agree with the actual values of foliage density.

S.D. = Standard deviation of foliage density.

degree with foliage density. This is indicated by the beta weights which were essentially equal. The R^2 value multiplied by 100 indicates that leaf area per shoot and number of shoots per vine accounted for about 71 percent of the total variation in foliage density. Only leaf area per shoot was significantly related to foliage density in 1964 and accounted for about 45 percent of the total variation. The effect of leaf area per shoot in foliage density was greater in 1964 than 1963. This is indicated by the difference in the beta weight for leaf area per shoot between the two years.

The two factors directly associated with variation of soluble solids were leaf area per pound of fruit and foliage density (Figure 8). Variation of foliage density and leaf area per pound of fruit accounted for 81.5 percent of the total variation in soluble solids in 1963 and 49.1 percent in 1964. These percentages were obtained by multiplying the R^2 values by 100. Although the percentage of the total variation in soluble solids that could be explained on the basis of these two factors varied between years, the total association of soluble solids to foliage density and leaf area per pound of fruit was the same in both years. This is shown by the lack of a difference in the standard error of the estimate for the two years. The standard error of the estimate in 1963 was .60 as compared to .52 in 1964. However, the degree to which soluble solids were associated with each factor varied between years.

Variation in foliage density in 1963 had a greater effect on soluble solids than did variation of leaf area per pound of fruit (Figure 8). This is indicated by the beta weights. The beta weight for foliage density was about three and one-half times greater than that

Figure 8. The relationship of soluble solids to leaf area per pound of fruit and foliage density. Nitrogen study - growers' vineyards, 1963 and 64.

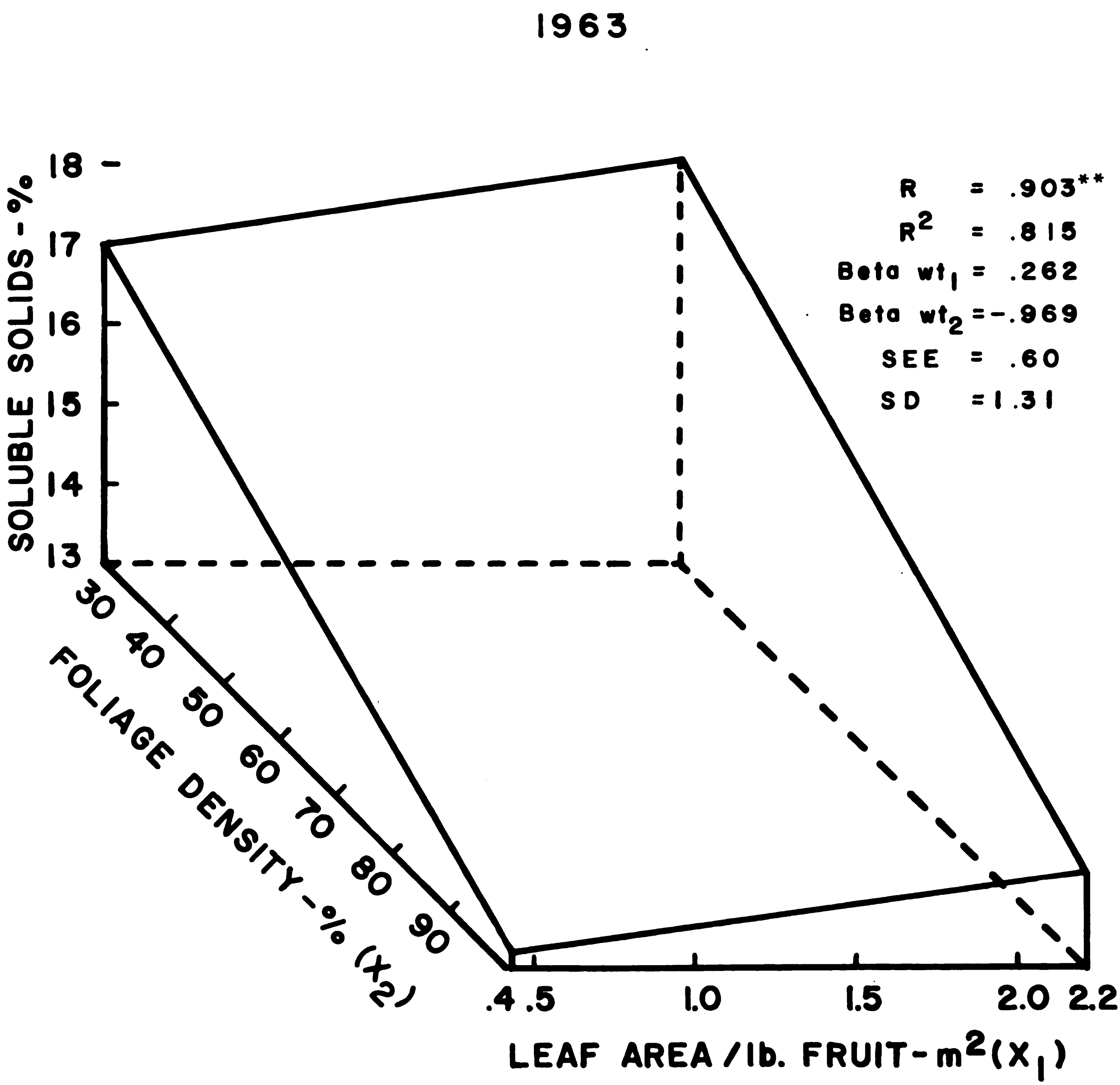
The figures were constructed according to the following equations:

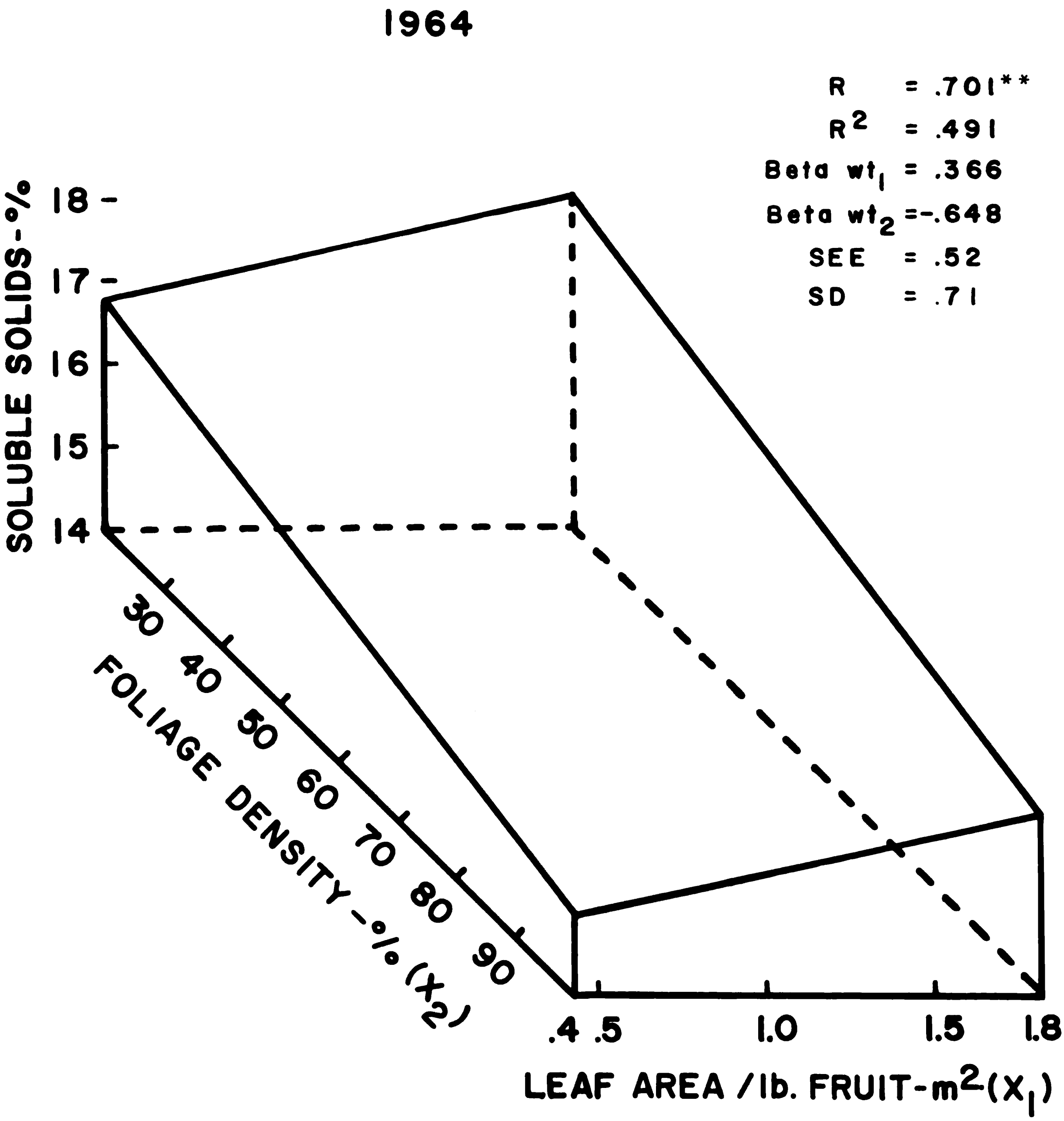
<u>1963</u>

$$\text{Soluble solids} = 18.20 + .5756^{*}X_1 - .0531^{**}X_2$$

<u>1964</u>

$$\text{Soluble solids} = 16.86 + .8606^{*}X_1 - .0235^{**}X_2$$


1963
SOLUBLE SOLIDS - %
18
17
16
15
14
13
R = .903**
R2 = .815
Beta wt1 = .262
Beta wt2 = -.969
SEE = .60
SD = 1.31
30
40
50
60
70
80
90
FOLIAGE DENSITY - % (X2)
.4
.5
1.0
1.5
2.0
2.2
LEAF AREA / lb. FRUIT - m2 (X1)


1964
R = .701**
R2 = .491
Beta wt1 = .366
Beta wt2 =-.648
SEE = .52
SD = .71
SOLUBLE SOLIDS-%
18
17
16
15
14
30
40
50
60
70
80
90
FOLIAGE DENSITY-% (X2)
.4
.5
1.0
1.5
1.8
LEAF AREA / lb. FRUIT-m2 (X1)

for leaf area per pound of fruit. The effect of foliage density on soluble solids in 1964 was greater than the effect of leaf area per pound of fruit. This is shown by the difference in the beta weights. A comparison of the portion of the plane due to foliage density in each year shows that this factor had less effect in 1964 than 1963. This further supported by the difference in beta weight for foliage density. The beta weight for foliage density was -.969 in 1963 as compared to -.648 in 1964. Leaf area per pound of fruit had slightly more effect on soluble solids in 1964 than 1963. In either year, the highest soluble solids were associated with low foliage density and high leaf area per pound of fruit; whereas, the lowest soluble solids were associated with high foliage density and low leaf area. An increasing leaf area per pound of fruit was associated with an increase in soluble solids only if the foliage density remained fairly constant.

Mean soluble solids were slightly higher in 1964 than in 1963, and soluble solids variability in 1964 was about one-half that of 1963. Mean foliage density did not differ between years. Leaf area per pound of fruit and leaf area per shoot were higher in 1963 than in 1964; whereas, yield per vine and number of shoots per vine were less. The variation of all these factors, except shoots per vine, was greater in 1963 than in 1964 (Table 13).

Climatic and phenological data for 1963 and 1964 are shown in Table 14. The number of heat units accumulated above 50°F before full bloom was essentially the same in 1963 and 1964. Days from full bloom to harvest was 101 in 1963 and 99 in 1964. Heat units accumulated during the first 30 days, second 30 days and residual days were greater

Table 13. - Variation of soluble solids, foliage density, leaf area per pound of fruit and per shoot, yield per vine, number of shoots, rate of shoot growth and days of growth. Nitrogen study - growers' vineyards, 1963 and 64.

Factor	1963 Mean	1963 C.V. - %	1964 Mean	1964 C.V. - %
Soluble solids - %	15.7	8.3	16.2	4.4
Foliage density - %	59.2	40.5	58.0	33.8
Leaf area/lb. of fruit - m^2	1.14	52.6	.91	33.0
Leaf area/shoot - m^2	.44	47.7	.37	27.0
Yield - lbs./vine	15.5	43.2	19.3	29.0
Shoots/vine	36.1	23.0	47.2	23.0
Shoot growth/wk. - cm	16.4	52.4	---	---
Days of shoot growth	64.1	15.0	---	---

C.V. = Coefficient of variation

for each period in 1964 than in 1963. The difference in heat units was greater during the first two periods.

Average soluble solids, adjusted for differences in leaf area per pound of fruit and days from full bloom to harvest, were greater in 1964 than in 1963.

Total rainfall during the period from full bloom to harvest was greater in 1963 than in 1964. The rainfall in 1963 was less during the first 30 days, and greater in the second 30 days and the remaining days before harvest than in 1964.

Table 14. - Phenological and climatic variation. Nitrogen study - growers' vineyards, 1963 and 64.

Phenological variation

Year	(a) Bloom date	(b) Harvest date	Days - (a to b)	Soluble[1/] solids - %
1963	6/13	9/21	101	15.3
1964	6/9	9/15	99	16.6

Climatic variation

Year	Heat units - degree days[2/] (bloom to harvest): Heat units to bloom	1st 30 days	2nd 30 days	Residual days	Total
1963	616	524	667	575	1772
1964	621	718	738	582	2036
		Rainfall[3/]			
1963		.60	5.38	1.91	7.89
1964		2.75	.67	.83	4.25

1/ Adjusted for differences in leaf area per pound of fruit by equations in Figure 8. Adjusted for differences in days from full bloom to harvest by adding .2 percent units per day difference.

2/ Obtained by accumulating daily average and minimum temperatures minus 50°F base temperature (Paw Paw Station).

3/ Paw Paw Station

IV. Nitrogen Study - Sodus

Application of one pound of ammonium nitrate per vine increased petiole nitrogen compared to vines receiving no additional nitrogen. The increase was evident at both sampling dates in 1963 but only for the June sampling in 1964 (Table 15). Vines receiving the additional nitrogen in

Table 15.- Effect of nitrogen application on petiole nitrogen, yield per vine, clusters per vine, berries per cluster, weight per berry, number of buds, pruning weight, foliage density and fruit soluble solids. Nitrogen study - Sodus, 1963 and 64.

Factor	1963		1964	
	Check	N	Check	N
Petiole N - % dry wt.				
June	1.09	1.25**	1.24	1.61**
July	.90	1.06**	1.27	1.32
Yield - lbs./vine	18.3	16.7	20.4	21.6
Clusters/vine	143.0	132.0	106.0	114.0
Berries/cluster	37.4	37.9	27.3	26.4
Wt./berry - gms	3.18	3.14	3.24	3.24
Pruning wt. - lbs./vine	3.5	4.3**	---	---
Buds/vine	48.9	47.1	53.6	62.7*
Foliage density - %	---	---	54.0	64.0*
Soluble solids - %	16.6	16.5	16.4	16.0*

Table 16.- Effect of thinning clusters on petiole nitrogen, yield per vine, clusters per vine, berries per cluster, weight per berry, pruning weight, buds per vine, and fruit soluble solids. Nitrogen study - Sodus, 1963.

Factor	Clusters thinned		
	Check	6/29/63	8/5/63
Petiole N - % dry wt.			
June	1.19	1.16	1.16
July	.99	.98	.97
Yield - lbs./vine	21.4 a	17.3 b	13.7 c**
Clusters/vine	186.0 a	112.0 b	115.0 b**
Berries/cluster	33.1 a	43.6 b	36.6 a**
Wt./berry - gms	3.12 a	3.28 b	3.07 a**
Pruning wt. - lbs./vine	3.7	4.1	3.7
Buds/vine	45.7	51.8	46.5
Soluble solids - %	15.9 a	16.7 b	17.0 b**

1963 had 13 percent higher petiole nitrogen in June than the check vines and 15 percent higher in July. There was a 23 percent petiole nitrogen increase in June 1964. The nitrogen application had no effect on yield, clusters per vine, berries per clusters, or berry weight in 1963 or 1964. The nitrogen application in 1963 resulted in an increase in pruned weight, but this was not associated with a change in soluble solids. The greater pruned weight in 1963 due to the nitrogen application resulted in a larger number of buds per vine after pruning in the spring of 1964. This larger number of buds was associated with greater foliage density and lower fruit soluble solids in 1964.

Application of sawdust and the interaction of sawdust and nitrogen did not have a significant effect on any of the factors studied.

Removing one-third of the total number of clusters per vine on either 6/20/63 and 8/5/63 reduced yield, but the difference was greatest when the clusters were thinned early. Thinning early resulted in an increase in the number of berries per cluster and weight per berry. Thinning at both dates increased soluble solids, but the magnitude of increase did not vary with date of thinning (Table 16).

There was no significant effect of the 1963 cluster thinning on any of the factors studied in 1964. The interaction of cluster thinning at either date with nitrogen or sawdust application was not significant for any factor studied.

DISCUSSION

Effect of Shading and Foliage Density on Soluble Solids

Increasing the leaf to fruit ratio by thinning clusters resulted in an increase in soluble solids only if the vines were not shaded. Also, an increase in leaf area per pound of fruit was associated with an increase in soluble solids only if the foliage density remained relatively constant. This indicates that the effectiveness of the leaf to fruit ratio is dependent on exposure to sunlight, and that increasing the leaf to fruit ratio does not necessarily result in an increase in soluble solids. This occurred in the vine and shoot shading experiments and in a similar shoot shading study by Shaulis (52). Sites and Reitz (56) found that fruit soluble solids of Valencia oranges were highest when the fruit was borne on the top portion of the tree; lowest when borne inside the tree and intermediate when borne at other positions.

The depressing effect of increasing foliage density may be explained on the basis of a reduction in light intensity, due to mutual shading of the leaves, resulting in lower photosynthetic efficiency per unit leaf area. Such an effect of foliage density on fruit soluble solids of the Concord grape has also been suggested by Kimball and Shaulis (33).

As has been pointed out by Heinicke and Childers (28) and Kramer and Clark (34), maximum photosynthetic rates, under usual atmospheric carbon dioxide concentrations, are attained at a light intensity of one-fourth to one-third full sunlight. However, as has been pointed out by Meyer and Anderson (40), such results are obtained only when a single leaf or a small plant, in which there is little or no shading of one part by another, is used as the experimental material. When the effect of light on photosynthesis is considered in terms of an entire tree, a different relationship holds. Heinicke and Childers (28) have shown that the rate of photosynthesis for an entire apple tree increases in proportion to increased light intensity up to or nearly that of full sunlight. In Michigan vineyards, the case of the single leaf or small plant is approached in vineyards of low foliage density; and the case of the dense foliage plant, or apple tree, is characteristic of vineyards with high foliage density.

Further evidence that the effect of foliage density on soluble solids production is due to inadequate exposure of the foliage to sunlight was obtained by altering the conventional trellis. The alteration was made in a southwestern Michigan vineyard by the grower. The conventional four-arm Kniffin training system (37) was altered to a modified Munson system. The Munson training system (55) was modified in that the central wire was omitted, leaving two wires that passed over the ends of 2 x 4 wood cross-pieces about 21 inches long, set at right angles to the row on posts five feet high. This trellis provided better exposure of the foliage to sunlight. During the 1964 harvest season, fruit yields, berry size and fruit soluble solids were obtained from 17 three vine plots of the modified trellis and compared to a like number of observations from adjacent Kniffin trellised vines.

Vines trained on the modified Munson trellis produced fruit with higher soluble solids than vines trained on the four-arm Kniffin trellis (Table 17). Soluble solids were consistently higher in all 17 three vine plots. There were no differences in yield or weight per berry.

In this comparison of training systems, the foliage density of the check plots averaged 65.5 percent. Thus, considering the relationship of soluble solids and foliage density, the effect of such a change in

Table 17. Effect of trellising on soluble solids, yield per vine, and weight per berry, 1964.

Training	Soluble solids - %	Yield lbs./vine	Weight berry - gms
Kniffin	14.8	21.0	3.18
Modified Munson	15.7	21.0	3.25
	**	n.s.	n.s.

training on soluble solids would be expected to become greater with increasing foliage density.

In the shading studies, the effect of foliage density on soluble solids appeared to be expressed during the few weeks before harvest. This is in agreement with published information that the rate of soluble solids accumulation increases during the few weeks before harvest (18).

The depressing effect of increased density on soluble solids does not appear to be due to growth _per se_. This is evidenced by the lack of a correlation of soluble solids with growth per shoot or rate of growth. Also, soluble solids were positively correlated with days of growth. If the depressing effect of denser foliage on soluble solids was due to growth _per se_, a negative correlation would be expected with days of growth. In addition, removing the terminal portion of the shoot tips did not influence soluble solids, but terminal growth may have ceased when the treatment was applied (August 15). In 1963, the average date on which shoot extension ceased was August 15 $\pm$ 9.6 days.

The correlation of square feet per vine with soluble solids was an indirect relationship of foliage density and vine spacing. There was no

correlation of soluble solids with square feet per vine if the effect of foliage was held constant. Such an effect of spacing on soluble solids has been demonstrated by Kimball and Shaulis (34). They found that removing part of the vines in a vineyard of high foliage density and thus increasing spacing resulted in an increase in soluble solids. They attributed this increase in soluble solids to better exposure of the foliage to sunlight.

Variations in trellis height appeared to have no influence on soluble solids. However, the effect of trellis height and spacing on soluble solids cannot be adequately evaluated in a vineyard survey. This is due to the lack of a consistent relationship between vigor and spacing. For example, a vineyard with wide spacing may have high vigor vines while another vineyard with the same spacing may have low vigor vines. Thus, in this study, no definite conclusion could be made concerning the effect of trellis height or spacing on soluble solids.

Considering the effect of shading on soluble solids production, grapes grown on the top wire of the trellis would be expected to have a higher soluble solids content. Such was not the case (Table 8). This was probably due to the higher yields which are usually produced on the top wires (37). Also, a larger number of canes may have been left on the top wires, resulting in denser foliage on the top wire than on the bottom.

Effect of Variation of Leaf Area per Pound of Fruit on Soluble Solids

The increase in soluble solids, obtained by thinning clusters was probably due to increasing the leaf area per unit of fruit. The effect of the leaf to fruit ratio appeared to be expressed primarily during the

the ripening period as indicated by the cluster thinning experiment at Sodus. The increase in soluble solids, obtained by removing clusters following full bloom, was not different from the increase obtained by removing clusters immediately before the ripening period began.

Effect of Nitrogen on Fruit Soluble Solids

Applying one pound of ammonium nitrate per vine, at Sodus, did not affect soluble solids, but increased growth as measured by pruned weight. Since these vines were balance pruned (37), a larger number of buds were left in 1964 on vines receiving nitrogen. This increase in bud number was associated with an increase in foliage density and lower soluble solids in 1964. The effect of nitrogen indirectly resulted in an increase in foliage density.

In the survey plots, which were not balance pruned, applications of nitrogen had no effect on shoot length or soluble solids. Petiole nitrogen was positively correlated with shoot length and leaf area per shoot. This appears to be somewhat contradictory, but was probably due to the wide range in nitrogen content in the soil between vineyards as compared to the small increase obtained by nitrogen application. In 1963, 50 percent of the total variation was due to nitrogen content between vineyards while only 15 percent was due to the current season's nitrogen application. In 1964, these percentages were 56 and 18, respectively. The difference obtained in petiole nitrogen, due to application of nitrogen, may not have been of sufficient magnitude to affect shoot length, shoot weight and/or soluble solids. If there was an effect it may have been masked by differences in pruning severities.

Continuous applications of high levels of nitrogen, over a period of years, would be expected to affect soluble solids production as shown by the results at Sodus and by the positive correlation of growth and petiole nitrogen. Higher than normal applications of nitrogen would be expected to increase foliage density and yields and decrease soluble solids. But if the trellis could be modified to provide adequate foliage exposure, nitrogen application would be expected to increase yields and soluble solids until no further increase in the leaf area per unit of fruit was obtained.

Nitrogen per se would not be expected to decrease soluble solids production by inducing excessive growth (Figure 2). The quadratic equation of leaf area per shoot to length of shoot indicates that as length of shoot is increased there is a more rapid increase in leaf area; and thus potential net carbohydrate production per shoot increases at an increasing rate.

It may be suggested that net carbohydrate production does not increase on high vigor shoots since a large portion of the leaves may be immature and thus dependent on the older leaves on the same shoot for carbohydrates. This does not appear to be the case. Data of Hale and Weaver (25) indicate the number of immature (non-expanding) leaves of vinifera grapes averaged about 7.4 and remained relatively constant with time. In 1964, a similar situation was found to exist with the Concord variety. The number of immature leaves remained relatively constant and averaged 8.9. Also, Hale and Weaver (25) found that the grape leaf started transporting assimilates when half its final size.

Since the number of immature leaves remains relatively constant, the ratio of mature to immature leaves per shoot would be expected to increase with time. This is confirmed by calculations from the data of Hale and Weaver (25).

Thus, carbohydrates production per shoot would be expected to increase with increasing shoot length and leaf area per shoot. This is suggested by the positive correlation of soluble solids with leaf area per pound of fruit and days of growth. The relationship of soluble solids to days of growth (Table 11) was probably due, in part, to the positive correlation (.744**) of days of growth and leaf area per shoot.

Effect of Soil Texture and/or Cation Exchange Capacity on Fruit Soluble Solids

The positive correlation of soluble solids with soil texture and negative correlation with cation exchange capacity was low but consistent between years. The effect of these soil factors on soluble solids is probably due to an indirect effect on foliage density and possibly leaf area per unit of fruit. The low degree of correlation of soluble solids with soil texture and cation exchange capacity may be due, in part, to the method of soil sampling. The soil samples were taken to a depth of about six to eight inches. Such a sampling procedure does not provide conclusive information concerning the nature of the soil in the root zone.

Variation of Fruit Soluble Solids Between Years

The leaf area per pound of fruit was less in 1964 than in 1963. This was reflected by a slightly greater effect of leaf area per pound of fruit on soluble solids in 1964 than in 1963. The higher leaf area per pound of fruit in 1963 was due, in part, to the lower yield and

greater leaf area per shoot in 1963 than 1964.

The effect of foliage density was less in 1964 than in 1963. This difference in foliage density may have been due to the difference in climatic conditions. In 1964, the total number of heat units accumulated was greater than in 1963. Most of the difference in heat units occurred during the first 60 days after full bloom. This early heat unit accumulation probably resulted in an earlier development of the maximum leaf area per shoot in 1964 than in 1963. Clore and Bryant (16) have also suggested that high heat accumulation early in the season results in earlier development of shoot growth of the Concord grape and high soluble solids. Winkler (68) has shown that the time of maturity of grapes is positively correlated with time to development of maximum leaf area. Thus, an increase in the time of maximum leaf area in 1964 compared to 1963 would be expected to result in higher soluble solids in 1964 than 1963, as was the case.

The correlation of foliage density in 1963 with that in 1964 was .916**. Thus, foliage density remained fairly constant between years. Leaf area per shoot was positively correlated with foliage density in both years. Thus, the effect of an early development of maximum leaf area on soluble solids would be expected to increase with increasing foliage density. Vineyards which produced relatively low soluble solids in 1963, due to denser foliage, produced relatively higher soluble solids in 1964 at the same level of foliage density. This would help to explain part of the reduction of soluble solids variation in 1964 as compared to 1963 (Table 18).

The reduced effect of foliage density on soluble solids in 1964 was perhaps also due to higher light intensity. The effect of foliage

Table 18. - Seasonal variation of soluble solids according to foliage density.

Foliage density - %	Soluble solids - %[1] 1963	1964	Difference
75 - 100	14.1	15.8	1.7
50 - 74	15.0	16.4	1.4
below 50	16.9	16.8	- .1

1/ Data were adjusted for yield by equation in Figure 8.

density would be less with an increase in light intensity. The soluble solids change between years would be expected to increase with an increase in foliage density. An increase in light intensity would result in a reduced variation of soluble solids in 1964 as compared to 1963.

The distribution and amount of rainfall may have affected the variation of soluble solids between years. Rainfall during the first 30 days after full bloom was greater in 1964 than in 1963. This may have resulted in an earlier development of maximum leaf area in 1964. The rainfall following the first 30 days after full bloom and to harvest was greater in 1963 than in 1964. This may have been associated with more cloudy days and lower light intensity in 1963 than 1964.

Therefore, it appears that soluble solids may be positively correlated with days of growth within any particular year provided the foliage exposure is adequate. This would be expected since leaf area per unit of fruit is limiting soluble solids production. However, between years, soluble solids would be expected to be negatively correlated with days of growth provided the leaf area per unit of fruit does not vary drastically between years. The early development of the maximal leaf area would result in a longer period of photosynthetic activity.

The fact that some vineyards are consistently low or high with respect to soluble solids can probably be explained on the basis of the constancy of the foliage density. The variation of average soluble solids from year to year is probably a response to difference in temperature and/or light intensity between years. Also, the amount and time of rainfall and associated cloudy weather may be important.

In each year of this study (1962 - 1964), average soluble solids was relatively high. During years of more unfavorable conditions for soluble solids production, the effects of spacing, soil type, leaf area per unit of fruit and foliage density would be expected to be accentuated.

Obviously, the growers have little control over climatic variation between years. But they should be able to change growing conditions or cultural practices to increase soluble solids within any particular year as well as reduce variation between years. In these studies, the major vineyard and cultural factors influencing soluble solids were those associated with foliage shading and to a lesser extent with leaf area per unit of fruit. As shown in Table 19, fruit soluble solids were lowest with the highest levels of foliage density, fruit yields, soil cation exchange capacity and/or soil texture and close spacing.

In order to achieve maximum fruit soluble solids, the grower should (1) modify the trellis to insure maximum leaf exposure to sunlight, and (2) initiate practices to increase the leaf to fruit ratio.

Also, planting vineyards on soils of medium or low cation exchange capacity with adequate spacing would be expected to result in slightly higher soluble solids, but would probably reduce yields. However, since both the effect of soil and spacing on soluble solids appear to be indirect, these effects might be eliminated if the trellis was modified to provide exposure to sunlight.

Table 19. - Relationship of soluble solids to foliage density, clusters per vine, cation exchange capacity, soil texture and square feet of spacing per vine. Survey vineyards, 1962 and 63.

Soluble solids - %		Vigor rating	Clusters/ vine	CEC - m.e./ 100 gms	Soil texture	Spacing ft.^{2}/vine
			1962			
15.0 or less	(15)[1/]	3.7	110	7.8	2.8	77
15.1 - 16.0	(27)	3.9	102	5.7	3.2	82
16.1 - 17.0	(33)	3.2	83	3.9	4.3	82
17.1 or above	(16)	2.5	83	3.1	4.3	88

Soluble solids - %		Foliage density - %	CEC - m.e./ 100 gms	Soil texture	Spacing ft^2./vine
			1963		
15.0 or less	(15)	83	6.6	3.7	94
15.1 - 16.0	(16)	50	6.8	3.7	92
16.1 - 17.0	(15)	42	4.6	4.3	88
17.1 or above	(2)	33	3.0	5.0	97

1/ Number of vineyards in soluble solids class.

SUMMARY

An investigation was initiated to determine factors associated with variation of fruit soluble solids of Concord grapes in Michigan. The investigation involved (1) shading, shoot tipping and cluster thinning experiments, (2) a vineyard survey and (3) nitrogen studies.

Soluble solids were increased by cluster thinning (increasing the leaf to fruit ratio) only when the vines were exposed to full sunlight. Shoot tipping had no effect on soluble solids, regardless of degree of shade (sunlight).

The survey revealed that shading, due to high foliage density, and a low leaf to fruit ratio was a problem in many vineyards.

A more detailed study indicated that foliage density and leaf area per unit of fruit accounted for a high percentage of the total variation of fruit soluble solids. The effect of foliage density was greater than the effect of leaf area per pound of fruit. Growth per shoot, rate of shoot growth, or days of growth were not inversely related to soluble solids. Modifying the trellis to provide better exposure of the leaf surface to sunlight resulted in greater production of soluble solids.

Applications of nitrogen had no effect on soluble solids, yield per vine or growth in the growers'vineyards. However, at Sodus, application of nitrogen increased growth when measured as pruned weight. This resulted in more buds per vine in 1964 with greater foliage density and lower soluble solids. The difference in growth response to nitrogen between the growers' vineyards and the Sodus vineyard was probably due to balance-pruned vines and less soil variation at Sodus.

To increase production of soluble solids, the grower should initiate practices to provide better leaf exposure and increase the leaf area per unit of fruit.

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APPENDIX

APPENDIX TABLE I. Nutrient content of grape petioles. Survey vineyards, 1962.

Vineyard number	Percent					Parts per million					
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
1	0.84	3.06	.235	0.94	0.21	894	62	12.9	24.8	28	4.2
2	0.86	1.04	.202	0.83	0.42	842	62	20.3	24.8	26	4.2
3	0.78	1.54	.193	0.98	0.46	236	62	12.9	26.0	30	4.6
4	0.82	1.96	.218	0.87	0.46	140	47	7.6	19.0	15	4.0
5	0.92	2.22	.254	0.83	0.40	337	53	83.4	23.6	24	4.0
6	1.00	2.74	.264	0.73	0.31	188	57	42.4	19.0	19	3.2
7	0.82	2.44	.159	0.91	0.37	384	56	10.2	20.2	28	4.0
9	0.88	1.14	.245	0.87	0.38	1193	102	92.0	21.3	34	3.8
10	0.92	1.96	.401	0.98	0.52	1193	85	88.2	27.2	34	4.6
11	0.90	2.44	.344	0.77	0.22	1193	56	12.9	23.6	34	3.0
12	0.98	2.44	.235	0.80	0.35	1102	69	12.0	23.6	36	3.6
13	0.88	1.64	.210	0.83	0.33	286	50	12.0	21.3	28	4.0
14	0.92	1.64	.442	0.98	0.53	151	53	12.9	24.8	28	4.6
15	0.80	1.21	.193	0.94	0.48	366	37	55.5	21.3	22	4.6
16	0.92	1.54	.227	1.02	0.48	204	50	56.6	22.5	28	4.8
17	0.62	0.98	.235	0.83	0.42	568	56	63.4	20.2	28	3.8
18	0.94	1.50	.392	0.91	0.59	80	91	15.6	21.3	24	4.4
19	0.84	1.76	.264	0.94	0.38	67	56	13.7	21.3	22	4.6
20	0.86	1.54	.254	0.73	0.42	231	34	27.1	20.2	24	3.6
21	0.76	1.44	.227	0.91	1.00	177	31	19.5	21.3	28	4.2
22	1.00	0.80	.317	1.02	0.40	119	44	10.2	22.5	24	5.0
23	0.88	1.04	.159	1.06	0.38	263	53	13.7	21.3	30	4.8
24	0.84	1.70	.354	1.10	0.29	274	66	12.0	24.8	28	5.2
26	0.70	1.54	.282	0.77	0.21	1167	50	111.4	24.8	34	3.6
28	0.78	1.96	.392	0.98	0.43	297	47	104.8	29.5	36	4.4
29	0.78	1.36	.210	0.91	0.29	314	88	42.4	23.6	34	4.4
30	0.72	1.86	.264	0.83	0.20	390	104	57.8	23.6	34	4.8
31	0.68	0.76	.227	1.10	0.66	516	72	68.2	28.3	34	5.6
32	0.68	1.14	.184	1.10	0.52	193	111	103.5	23.6	28	5.4
33	1.04	0.72	.184	1.18	0.60	408	44	15.6	29.5	38	5.6
34	0.72	2.08	.193	0.91	0.22	595	66	50.0	27.2	34	4.6
35	0.68	1.50	.336	1.10	0.35	291	75	78.0	24.8	34	5.8
36	0.64	1.44	.184	0.98	0.15	1193	72	186.8	23.6	41	4.8
37	0.78	1.70	.290	1.18	0.57	633	47	139.8	23.6	38	5.2
38	0.70	0.98	.210	1.10	0.40	881	85	12.9	23.6	41	4.8
39	0.58	0.38	.142	1.06	0.68	384	111	12.9	26.0	34	5.0
40	0.72	2.22	.245	1.22	0.21	627	98	12.9	28.3	36	6.0
41	0.70	1.86	.235	1.18	0.31	242	56	11.0	34.3	34	6.0
42	0.64	0.72	.120	1.18	0.60	215	78	11.0	27.2	44	5.2
43	0.60	1.10	.235	1.44	0.45	71	50	12.9	34.3	47	6.2
44	0.64	1.14	.112	1.06	0.43	360	85	15.6	28.3	41	4.8
45	0.74	1.14	.168	0.94	0.43	528	72	17.6	21.3	36	4.2
46	0.66	2.08	.218	1.10	0.38	595	34	17.6	23.6	34	4.8
47	0.60	1.10	.193	0.94	0.53	777	50	111.4	20.2	34	4.8
48	0.60	0.92	.392	0.98	0.46	343	75	139.8	24.8	41	5.4

APPENDIX TABLE I. Continued.

Vineyard number	Percent					Parts per million					
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
49	0.60	1.10	.136	0.98	0.29	209	56	18.5	23.6	34	4.8
50	0.62	0.76	.235	0.94	0.42	633	56	24.2	24.8	34	4.4
51	0.68	1.50	.159	1.06	0.30	946	78	24.2	27.2	44	4.6
52	0.68	2.22	.227	1.14	0.23	104	69	23.2	30.7	54	5.0
53	0.56	1.10	.202	1.06	0.50	204	56	11.0	21.3	30	5.0
54	0.66	1.76	.159	0.94	0.25	252	44	7.6	24.8	28	4.0
55	0.96	1.44	.151	1.44	0.72	378	53	92.0	24.8	36	6.7
56	0.80	1.21	.142	1.18	0.66	252	37	45.6	26.0	34	5.6
57	0.80	1.96	.136	1.06	0.52	124	50	51.0	27.2	30	5.0
58	0.63	1.90	.159	0.88	0.25	205	29	2.5	24.6	19	4.0
59	0.64	2.22	.136	1.10	0.30	269	41	11.0	23.6	34	5.2
60	0.64	2.15	.384	1.21	0.24	173	69	8.3	32.3	19	5.2
61	0.86	2.48	.694	0.95	0.18	365	39	5.6	27.8	12	4.1
62	0.66	1.70	.422	0.98	0.37	302	69	12.0	27.2	34	5.0
63	0.56	1.04	.411	0.94	0.30	390	75	12.0	24.8	36	5.4
64	0.50	0.92	.136	0.91	0.21	242	53	8.4	22.5	36	4.6
65	0.58	0.64	.151	1.22	0.53	236	37	10.2	26.0	36	5.8
66	0.64	0.60	.168	1.06	0.53	320	44	9.3	24.8	28	5.0
67	0.76	1.50	.136	0.83	0.37	291	98	12.0	24.8	41	4.2
68	0.68	1.96	.168	0.80	0.22	354	56	10.2	24.8	28	3.8
69	0.74	0.76	.264	1.31	0.52	42	56	90.7	34.3	50	6.4
70	0.74	1.36	.202	1.22	0.45	63	44	122.0	30.7	47	6.5
71	0.66	1.36	.159	1.18	0.34	390	47	10.2	29.5	44	5.6
72	0.66	1.76	.202	1.14	0.20	225	34	25.1	29.5	30	5.0
73	0.80	0.72	.120	1.14	0.50	85	47	238.8	30.7	36	5.2
74	1.02	3.26	.128	1.10	0.12	136	47	122.0	26.0	36	5.4
75	0.60	0.80	.282	0.98	0.33	1154	72	36.0	27.2	41	4.4
76	0.72	0.88	.168	0.94	0.22	408	50	33.0	23.6	36	5.0
78	0.76	1.96	.112	1.22	0.28	177	44	94.6	29.5	54	5.2
79	0.62	1.21	.184	0.98	0.34	595	34	88.2	26.0	44	5.0
80	0.58	1.21	.308	0.94	0.34	225	34	126.8	24.8	41	4.4
81	0.92	1.70	.142	0.91	0.29	378	25	16.6	22.5	34	4.2
82	1.02	1.64	.136	1.06	0.35	337	34	10.2	26.0	36	4.6
83	0.80	0.92	.136	1.14	0.59	348	34	11.0	27.2	38	5.2
84	0.74	0.98	.168	1.10	0.46	258	37	15.6	23.6	36	4.8
85	0.74	1.36	.120	1.06	0.37	198	18	42.4	27.2	38	4.2
86	0.72	1.30	.105	1.22	0.52	477	34	53.0	26.0	47	6.0
87	0.76	0.48	.151	0.98	0.72	332	31	28.0	26.0	36	5.0
88	0.78	0.30	.136	1.22	0.43	1128	66	37.0	24.8	41	6.2
89	0.72	1.50	.128	1.14	0.40	162	28	139.8	29.5	47	6.0
90	0.82	0.80	.112	1.40	0.57	50	47	173.8	29.5	64	6.9
91	0.80	1.04	.142	0.94	0.37	384	31	18.7	28.3	38	4.6
92	0.90	2.52	.136	0.98	0.13	933	25	13.7	26.0	50	4.0
93	0.54	1.21	.392	1.26	0.74	34	50	33.0	31.9	41	6.0
94	0.68	2.22	.136	1.26	0.28	54	34	38.0	35.6	41	5.2
95	0.70	1.76	.099	1.02	0.22	58	34	181.8	30.7	38	5.4

APPENDIX TABLE I. Continued.

Vineyard number	Percent N	K	P	Ca	Mg	Parts per million Mn	Fe	Cu	B	Zn	Mo
96	0.56	1.36	.336	1.02	0.38	204	34	189.8	30.7	38	5.0
97	0.60	2.08	.520	1.06	0.20	528	25	12.0	29.5	36	4.8
98	0.58	0.98	.411	1.06	0.45	390	28	11.0	27.2	38	5.2
99	0.52	0.50	.151	0.94	0.70	348	91	10.2	23.6	36	5.0
100	0.62	1.21	.299	1.02	0.35	145	44	14.7	24.6	30	5.0

APPENDIX TABLE II. Nutrient content of grape shoot tips. Survey vineyards, 1962.

Vineyard number	Percent					Parts per million					
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
1	2.56	2.08	.392	0.87	0.23	172	134	27.1	23.6	47	4.2
2	2.68	2.08	.422	0.70	0.29	145	200	26.1	27.2	41	3.2
3	2.72	2.08	.392	0.77	0.26	71	75	19.5	24.8	44	3.6
4	2.64	1.96	.401	0.77	0.29	63	85	21.3	26.0	41	3.6
5	2.84	2.12	.452	0.58	0.26	85	82	31.0	24.8	44	3.0
6	2.54	2.08	.401	0.67	0.28	90	98	45.6	19.0	47	3.2
7	2.78	1.76	.363	0.64	0.28	80	69	19.5	21.3	38	3.0
8	2.66	1.70	.354	0.73	0.25	114	111	28.0	20.2	44	3.8
9	2.94	1.95	.432	0.70	0.25	167	82	27.1	22.5	44	3.8
10	3.20	1.96	.422	0.70	0.23	302	78	24.2	19.0	38	4.0
11	2.76	2.08	.422	0.55	0.25	354	262	32.0	24.8	60	2.8
12	2.92	1.86	.344	0.64	0.29	151	238	29.0	22.5	44	3.6
13	3.22	1.86	.401	0.70	0.26	90	102	29.0	22.5	44	4.0
14	3.24	2.12	.452	0.64	0.25	58	88	24.2	21.3	41	3.2
15	2.82	1.86	.422	0.67	0.26	90	88	106.2	21.3	36	3.6
16	2.86	2.08	.432	0.64	0.25	67	78	94.6	21.3	38	3.4
17	2.64	1.86	.363	0.70	0.29	85	102	*222.8	20.2	38	4.0
18	3.24	2.12	.460	0.64	0.29	54	259	27.1	23.6	44	3.4
19	3.06	2.12	.401	0.70	0.22	50	114	27.1	19.0	44	4.2
20	3.12	1.96	.401	0.64	0.29	67	56	29.0	19.0	38	3.2
21	2.78	1.96	.422	0.67	0.25	67	72	25.1	21.3	38	3.0
22	3.10	1.96	.432	0.64	0.26	50	59	22.2	21.3	41	3.8
23	2.70	2.12	.401	0.67	0.22	63	146	23.2	23.6	41	3.4
24	2.48	2.12	.432	0.61	0.23	67	66	19.5	22.5	44	3.0
25	2.38	2.34	.501	0.77	0.26	85	72	25.1	27.2	54	4.0
26	2.68	1.96	.401	0.58	0.23	220	66	59.0	21.3	41	2.8
27	2.60	2.08	.422	0.61	0.22	94	75	65.8	24.8	30	2.8
28	2.70	1.96	.460	0.49	0.25	58	56	62.2	31.9	30	2.6
29	2.78	1.96	.422	0.64	0.22	80	186	29.0	24.8	44	3.4
30	2.48	1.86	.422	0.64	0.22	99	277	35.0	24.8	34	3.2
31	3.20	2.08	.510	0.67	0.22	76	111	25.1	26.0	28	3.6
32	3.20	1.86	.530	0.67	0.23	58	82	22.2	21.3	30	3.4
33	2.60	1.96	.401	0.70	0.18	76	91	22.2	27.2	24	3.8
34	2.66	2.08	.422	0.58	0.22	85	128	28.0	23.6	28	2.4
35	2.80	1.96	.422	0.61	0.22	67	102	29.0	19.0	30	3.2
36	2.70	1.70	.382	0.77	0.21	252	137	119.5	22.5	25	4.0
37	2.94	2.12	.452	0.55	0.21	67	62	29.0	20.2	24	3.0
38	2.84	1.96	.460	0.61	0.20	99	114	24.2	22.5	24	2.6
39	2.78	1.76	.481	0.70	0.26	80	146	24.2	24.8	26	3.4
40	2.74	1.76	.481	0.61	0.21	119	82	22.2	17.9	24	2.6
41	2.78	2.08	.460	0.64	0.21	63	69	17.6	23.6	24	3.4
42	2.86	2.08	.491	0.55	0.21	42	95	22.2	22.5	28	3.0
43	2.96	2.22	.491	0.55	0.20	26	75	21.3	23.6	24	2.6
44	3.12	1.86	.481	0.61	0.22	63	75	21.3	22.5	28	3.2
45	2.66	2.12	.401	0.61	0.23	90	95	22.2	23.6	30	3.4

APPENDIX TABLE II. Continued

Vineyard number	Percent					Parts per million					
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
46	2.76	2.22	.442	0.52	0.22	63	62	18.5	21.3	24	3.2
47	2.66	2.12	.442	0.55	0.23	85	104	56.6	20.2	41	2.6
48	2.62	1.96	.471	0.64	0.26	63	75	50.0	23.6	28	1.9
49	2.70	2.12	.471	0.58	0.22	54	75	17.6	24.8	28	3.2
50	2.66	2.22	.452	0.58	0.22	76	66	17.6	22.5	28	2.6
51	2.68	2.22	.452	0.49	0.22	104	153	20.3	24.8	30	2.2
52	2.96	2.22	.452	0.52	0.21	42	153	21.3	24.8	30	2.8
53	2.42	1.96	.422	0.61	0.22	76	91	20.3	23.6	34	3.2
54	2.60	2.12	.363	0.64	0.25	46	95	15.6	21.3	26	3.4
55	3.14	2.08	.411	0.55	0.20	63	47	76.8	24.8	24	3.4
56	2.72	2.34	.432	0.52	0.23	50	44	82.0	28.3	28	3.0
57	2.92	2.22	.452	0.55	0.23	38	47	22.2	24.8	28	3.0
58	2.80	2.12	.460	0.61	0.23	58	59	15.6	22.5	28	3.0
59	3.00	2.12	.460	0.55	0.22	63	50	19.5	20.2	26	3.0
60	3.00	2.12	.471	0.67	0.22	50	75	16.6	26.0	28	3.4
61	2.76	2.22	.501	0.49	0.25	67	143	19.5	22.5	24	2.8
62	2.92	2.34	.530	0.52	0.22	71	166	17.6	22.5	24	2.4
63	2.58	1.96	.432	0.55	0.22	71	146	17.6	20.2	47	3.0
64	2.10	1.54	.336	0.80	0.28	104	186	14.7	26.0	30	4.2
65	2.72	1.96	.442	0.61	0.22	58	72	17.6	23.6	28	3.4
66	2.78	1.96	.481	0.61	0.25	76	88	14.7	27.2	28	3.0
67	3.00	2.22	.432	0.46	0.22	58	183	28.0	22.5	30	2.6
68	2.52	2.12	.471	0.55	0.25	99	114	23.2	24.8	34	3.0
69	2.32	1.30	.317	0.94	0.26	38	137	238.8+	33.0	28	5.6
70	2.72	1.70	.344	0.73	0.22	38	121	238.8+	26.0	24	4.2
71	2.42	1.76	.411	0.64	0.22	90	53	17.6	24.8	28	3.4
72	2.78	1.96	.452	0.61	0.20	54	75	18.5	22.5	24	3.0
73	2.40	1.86	.372	0.67	0.29	34	78	238.8+	28.3	28	3.8
74	2.26	1.76	.392	0.64	0.20	58	75	50.0	22.5	28	3.6
75	2.74	2.08	.411	0.61	0.20	129	118	35.0	27.2	28	3.8
76	2.56	2.08	.411	0.67	0.21	85	102	29.0	26.0	28	3.8
77	2.54	2.08	.392	0.52	0.22	63	69	29.0	22.5	26	3.0
78	2.60	1.54	.336	0.67	0.20	54	88	97.2	26.0	22	3.6
79	2.48	1.64	.372	0.64	0.25	104	102	*152.8	28.3	24	3.2
80	2.38	1.70	.422	0.61	0.26	71	66	*162.8	27.2	24	3.2
81	2.84	2.12	.442	0.61	0.23	99	82	20.3	22.5	30	3.4
82	2.58	1.76	.452	0.55	0.22	76	114	20.3	23.6	30	2.8
83	3.06	2.08	.471	0.58	0.25	54	56	19.5	23.6	26	3.0
84	2.44	1.86	.422	0.52	0.23	54	121	23.2	22.5	28	2.8
85	2.54	1.86	.401	0.55	0.21	50	59	21.3	23.6	24	3.0
86	2.48	1.64	.336	0.61	0.22	63	91	30.0	26.0	26	3.4
87	2.36	1.76	.442	0.52	0.23	54	59	19.5	23.6	24	2.6
88	2.28	1.44	.354	0.61	0.20	104	137	33.0	21.3	26	3.0
89	2.42	1.96	.392	0.58	0.22	42	56	103.5	26.0	28	3.0

APPENDIX TABLE II. Continued

Vineyard number	Percent					Parts per million					
	N	K	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Mo
90	2.60	1.64	.392	0.67	0.22	26	85	*142.8	23.6	26	3.4
91	2.46	1.70	.372	0.52	0.21	85	66	14.7	23.6	22	2.6
92	2.52	1.96	.432	0.55	0.20	162	78	15.6	23.6	30	3.2
93	2.26	1.64	.363	0.64	0.28	22	114	29.0	28.3	26	3.6
94	2.16	1.76	.326	0.67	0.23	38	72	22.2	28.3	26	4.2
95	2.40	1.86	.363	0.67	0.28	42	128	238.8+	29.5	30	4.2
96	1.86	1.54	.282	0.80	0.34	67	180	238.8+	30.7	26	4.4
97	2.46	2.22	.411	0.64	0.21	129	85	22.2	24.8	28	3.4
98	2.62	1.96	.372	0.61	0.25	94	72	22.2	24.8	24	3.4
99	2.04	1.50	.290	0.70	0.28	71	153	20.3	23.6	17	3.8
100	2.44	2.08	.336	0.67	0.23	63	211	21.3	24.8	26	3.8

APPENDIX TABLE III. Soil analysis. Survey vineyards, 1962.

Vine-yard number	Soil texture	pH	lbs./acre - avail. P	K	Ca	Mg	CEC	% saturation K	Ca	Mg	% base satur-ation
1	4	5.9	154	160	911	32	4.5	4.4	48.8	2.2	55.5
2	5	6.0	154	96	575	80	2.8	4.2	50.0	10.7	64.2
3	4	5.9	154	104	671	80	4.0	3.2	40.0	7.5	50.0
4	4	6.4	160	136	958	210	3.6	4.7	63.8	22.2	88.8
5	5	6.6	142	72	911	182	3.3	2.7	66.6	21.2	87.8
6	5	6.3	154	80	575	128	2.4	4.1	58.3	20.8	83.3
7	5	6.4	147	48	624	176	2.6	23.5	57.6	26.9	84.6
9	5	5.4	123	104	328	61	4.1	3.1	19.5	4.8	26.8
10	5	5.4	154	100	312	40	3.9	3.0	17.9	2.5	23.0
11	4	5.2	119	208	368	40	5.2	5.0	17.3	1.9	23.0
12	4	5.4	96	88	296	61	4.0	2.7	17.5	5.0	25.0
13	4	6.0	154	136	1056	160	5.3	3.2	49.0	11.3	62.2
14	5	6.5	142	192	768	192	3.3	7.2	57.5	24.2	87.8
15	4	6.6	96	112	648	64	2.3	6.0	69.5	8.6	82.6
16	3	6.3	98	196	1248	96	4.7	5.3	65.9	8.5	78.7
17	4	6.0	99	232	958	96	3.9	7.4	58.9	10.2	74.3
18	4	6.6	81	184	1392	288	5.1	4.5	66.6	23.5	94.1
19	5	6.4	136	100	766	166	3.0	4.0	63.3	20.0	86.6
20	5	6.2	154	160	720	150	3.0	6.6	60.0	20.0	86.6
21	3	6.3	46	288	1103	96	3.9	9.2	69.2	10.2	87.1
22	3	6.4	93	80	1103	166	3.8	2.6	71.0	15.7	89.4
23	3	5.5	160	112	1248	80	9.5	1.4	32.6	3.1	36.8
24	2	5.9	96	244	1008	160	8.4	3.6	29.7	7.1	40.4
26	4	4.6	44	152	160	46	5.6	3.3	7.1	1.7	10.7
28	2	5.3	74	248	1630	150	10.9	2.8	36.6	5.5	44.9
29	2	5.3	81	328	1200	160	11.0	3.8	27.2	5.4	36.3
30	2	5.2	28	336	911	96	10.0	4.3	22.0	4.0	30.0
31	5	6.4	132	128	624	160	2.6	6.1	57.6	23.0	84.6
32	5	6.7	9	176	720	176	3.0	7.3	60.0	23.3	90.0
33	5	5.6	136	184	575	80	3.9	5.8	35.8	7.6	48.7
34	4	5.3	105	168	280	93	4.2	5.0	16.6	7.1	28.5
35	5	6.2	132	160	575	118	2.3	8.6	60.8	17.3	86.9
36	4	4.5	160	328	184	32	6.9	6.0	5.7	1.4	13.0
37	4	5.6	74	128	376	112	2.4	6.6	37.5	16.6	58.3
38	5	5.6	84	136	720	80	4.2	4.0	42.8	7.1	52.3
39	5	5.7	66	72	400	61	2.2	4.0	45.4	9.0	54.5
40	5	4.6	170	136	144	32	2.5	6.8	12.0	4.0	20.0
41	5	5.0	128	88	152	27	1.5	7.3	20.0	6.6	33.3
42	5	5.3	154	120	352	27	1.5	10.0	53.3	6.6	66.6
43	2	5.8	25	120	1440	51	6.9	2.1	52.1	2.8	56.5
44	2	4.6	123	100	256	40	10.8	1.1	5.5	.9	7.4
45	3	5.5	115	216	624	118	4.1	6.5	36.6	9.7	51.2
46	5	6.3	119	280	616	118	2.6	13.4	57.6	15.3	84.6
47	5	6.5	115	72	376	83	1.4	6.4	64.2	21.4	85.7

APPENDIX TABLE III. Continued

Vineyard number	Soil texture	pH	lbs./acre - avail. P	K	Ca	Mg	CEC	% saturation K	Ca	Mg	% base saturation
48	4	6.2	154	80	624	118	3.0	3.3	50.0	13.3	66.6
49	2	5.8	128	240	863	150	7.0	4.2	30.0	8.5	42.8
50	2	5.4	79	168	575	96	7.0	3.0	20.0	5.7	28.5
51	2	4.5	160	376	1056	96	12.4	3.8	20.9	3.2	27.4
52	2	4.9	160	568	1680	128	12.4	5.8	33.8	4.0	43.5
53	5	7.0	154	208	1151	160	3.6	7.2	77.7	16.6	99.9
54	3	5.8	160	232	815	61	5.4	5.3	37.0	3.7	44.4
55	4	6.5	105	136	1200	96	3.9	4.3	76.9	10.2	89.7
56	5	6.4	132	104	958	118	3.3	3.9	69.6	12.1	84.8
57	5	6.6	90	80	766	83	2.7	3.7	70.3	11.1	85.1
58	5	5.5	102	152	527	61	4.6	4.1	28.2	4.3	34.7
59	5	5.6	136	136	1056	51	3.4	5.0	76.4	5.8	85.2
60	3	6.3	115	200	1728	138	5.4	4.6	79.6	9.2	92.5
61	5	6.4	136	200	1151	128	3.9	6.4	71.7	12.8	89.7
62	5	6.0	98	104	671	93	3.0	4.3	53.3	10.0	66.6
63	5	6.0	66	112	376	80	1.7	8.2	52.9	17.6	76.4
64	5	6.5	160	120	336	40	1.4	10.7	57.1	7.1	71.4
65	3	6.5	55	88	815	32	2.5	4.4	80.0	4.0	88.0
66	4	6.8	48	88	958	51	2.9	3.7	79.3	6.8	89.6
67	3	5.6	31	144	344	61	4.1	4.3	19.5	4.8	26.8
68	3	5.5	160	200	248	46	1.9	13.1	31.5	5.2	47.3
69	2	6.2	160	312	3120	237	13.1	3.0	59.5	6.8	69.4
70	3	6.8	98	248	1920	118	5.9	5.2	81.3	6.7	93.2
71	2	5.7	54	272	1248	83	5.7	5.9	54.3	5.2	64.9
72	3	5.7	160	240	863	51	6.6	4.5	31.8	3.0	39.3
73	2	5.9	26	216	2592	262	9.6	2.8	66.6	10.4	79.1
74	2	6.1	50	320	1344	176	5.4	7.5	61.1	12.9	81.4
75	2	5.4	62	352	1296	93	8.9	5.0	35.9	3.3	43.8
76	2	5.9	81	248	1200	80	4.6	6.7	65.2	6.5	78.2
77	4	5.8	136	592	1440	274	7.4	10.1	48.6	14.8	72.9
79	2	5.5	44	264	1248	138	6.9	4.7	44.9	7.2	56.5
80	2	5.8	42	436	1728	210	7.6	7.2	56.5	10.5	73.6
81	2	5.3	54	312	1248	96	7.9	5.0	39.2	5.0	49.3
82	2	6.4	64	272	1824	118	5.6	6.0	80.3	7.1	92.8
83	4	6.0	123	168	863	118	3.7	5.6	56.7	10.8	72.9
84	4	6.0	132	168	863	138	3.3	6.3	63.6	15.1	84.8
85	2	6.5	39	200	1872	61	5.2	4.8	88.4	3.8	96.1
86	2	6.2	37	200	1728	80	5.8	4.3	74.1	5.1	82.7
87	5	5.4	128	32	232	51	1.1	3.6	45.4	18.1	63.6
88	5	4.8	147	35	184	46	2.5	1.6	16.0	4.0	20.0
89	2	5.6	36	352	1872	262	8.0	6.5	57.5	12.5	75.0
90	2	6.5	27	280	2208	166	6.7	5.2	82.0	8.9	95.5
91	3	4.7	160	256	766	96	7.6	4.2	25.0	5.2	34.2
92	3	4.1	160	224	304	80	12.2	2.2	5.7	2.4	9.8

APPENDIX TABLE III. Continued

Vine-yard number	Soil texture	pH	lbs./acre - avail. P	K	Ca	Mg	CEC	% saturation K	Ca	Mg	% base satur-ation
93	4	7.2	37	688	3120	400	10.2	8.6	76.4	15.6	99.9
94	4	6.3	9	288	1488	112	4.9	7.3	75.5	8.1	89.7
95	4	5.8	123	128	624	62	3.8	4.2	39.4	5.2	47.3
96	2	5.9	77	200	1248	224	8.2	3.0	37.8	10.9	51.2
97	4	5.4	75	136	671	40	4.8	3.5	33.3	2.0	37.5
98	4	5.9	55	160	1200	61	3.9	5.1	76.9	5.1	87.1
99	5	6.7	142	72	863	182	2.9	3.1	72.4	24.1	96.5
100	5	7.0	123	80	1248	128	3.7	2.7	83.7	13.5	99.9

APPENDIX TABLE IV. Row spacing, trellis height, vigor rating, clusters per vine and soluble solids. Survey vineyards, 1962.

Vineyard number	Row spacing - ft. within	Row spacing - ft. between	Trellis height	Vigor rating	Clusters/ vine	Soluble solids - %
1	10.0	8.0	4.83	4	88	16.0
2	10.0	11.0	4.17	4	92	16.5
3	8.0	10.0	4.14	3	102	17.5
4	7.5	8.0	5.00	4	86	16.5
5	8.0	9.0	5.50	4	65	17.5
6	8.0	10.0	4.50	4	55	17.0
7	8.0	9.5	4.17	3	71	17.0
9	8.5	8.0	4.83	3	78	16.5
10	7.5	7.5	4.17	3	63	16.5
11	8.0	8.0	4.50	4	82	16.0
12	8.5	10.0	4.33	3	98	16.5
13	8.0	10.0	5.67	3	142	15.0
14	8.0	9.5	5.33	4	120	15.5
15	8.0	8.0	4.50	4	82	16.0
16	8.0	10.0	4.67	4	67	15.5
17	10.0	10.0	4.67	2	74	17.5
18	10.0	9.5	4.83	4	88	15.0
19	10.0	10.0	5.33	4	88	16.5
20	9.0	10.0	4.83	3	116	17.0
21	8.5	9.5	4.33	4	90	17.0
22	7.5	9.5	4.67	3	48	17.0
23	7.5	9.0	4.50	3	58	17.0
24	9.0	9.2	4.71	4	70	15.0
26	10.0	9.0	4.50	3	82	15.5
28	10.0	8.0	4.33	4	72	15.0
29	8.0	9.0	5.33	5	63	16.0
30	9.0	9.5	5.00	4	68	15.5
31	8.0	9.0	5.17	3	47	18.0
32	9.0	10.0	5.00	4	123	16.0
33	10.0	8.5	4.50	4	64	17.0
34	9.0	9.5	5.00	4	87	15.0
35	10.0	9.5	4.83	2	67	17.0
36	9.0	10.0	5.00	4	123	16.0
37	10.0	9.5	4.67	3	84	16.5
38	8.0	10.0	4.50	3	83	17.0
39	8.0	10.0	4.50	2	92	17.5
40	10.0	10.0	4.50	3	88	17.0
41	8.0	10.0	4.67	3	70	18.5
42	12.0	10.0	4.00	2	112	17.5
43	8.0	8.0	4.50	4	90	15.5
44	9.0	9.0	5.00	3	123	15.0
45	9.0	9.0	4.83	4	75	16.5

APPENDIX TABLE IV. Continued

Vineyard number	Row spacing - ft. within	between	Trellis height	Vigor rating	Clusters/ vine	Soluble solids - %
46	8.5	8.5	4.67	3	58	17.0
47	10.0	10.0	4.83	3	84	17.5
48	9.5	10.0	4.50	2	103	17.5
49	10.0	9.5	5.00	5	109	15.5
50	10.0	9.5	5.17	5	111	15.5
51	9.0	9.4	4.63	3	86	17.0
52	8.0	10.0	4.33	3	121	15.5
53	7.5	8.0	5.00	2	71	17.5
54	8.0	10.0	4.67	5	76	15.5
56	8.0	9.5	4.67	3	123	15.5
57	8.0	10.0	4.67	3	119	16.0
58	7.0	10.0	5.17	4	123	16.0
59	8.0	10.0	5.00	4	101	15.5
60	8.0	10.0	4.17	4	117	15.0
61	8.0	8.0	5.00	3	64	17.0
62	9.0	10.0	4.50	3	95	16.5
63	9.1	9.4	4.63	3	86	17.0
64	9.0	9.5	4.94	2	92	19.0
65	10.0	9.0	5.00	3	90	17.5
66	9.5	9.5	4.17	3	97	17.5
67	10.0	10.0	5.17	4	129	15.5
68	8.0	10.0	5.00	5	95	15.5
69	12.0	7.5	4.50	2	110	15.0
70	10.0	8.0	4.50	2	146	16.0
71	12.0	8.5	4.67	3	100	17.0
72	11.0	9.5	4.50	3	84	15.5
73	8.0	9.0	5.33	5	130	14.0
74	10.0	8.0	5.00	4	110	14.0
75	9.5	9.5	5.17	2	71	18.5
76	9.5	9.5	4.33	4	108	15.5
78	8.0	8.0	4.17	2	160	13.5
79	8.7	9.2	4.67	2	128	16.0
80	8.7	9.2	4.67	3	102	16.5
81	6.0	10.0	5.00	5	43	14.0
82	6.0	10.0	4.80	5	69	15.0
83	8.0	9.5	4.67	3	82	16.5
84	6.5	9.5	4.33	3	69	16.5
85	10.0	8.0	4.83	5	138	15.5
86	11.0	9.0	5.33	3	149	14.5
87	9.0	9.0	4.00	3	121	16.5
88	10.0	9.0	4.33	3	108	16.5
89	10.0	8.0	4.50	4	134	16.0
90	9.0	8.0	5.00	2	92	15.5
91	7.0	9.0	4.17	4	109	14.0
92	8.0	8.0	4.33	4	135	14.0

APPENDIX TABLE IV. Continued

Vineyard number	Row spacing - ft within	Row spacing - ft between	Trellis height	Vigor rating	Clusters/ vine	Soluble solids - %
93	9.5	9.0	4.83	2	77	17.5
94	9.5	9.5	4.83	3	74	16.5
95	10.0	10.0	5.00	3	92	17.0
96	10.0	9.5	4.50	1	56	19.0
97	10.0	8.0	4.50	4	100	15.5
98	10.0	8.0	4.67	4	112	15.0
99	9.5	9.5	5.17	3	114	18.5
100	9.5	9.5	4.50	4	109	16.5

APPENDIX TABLE V. Nutrient content of grape petioles. Survey vineyards, 1963.

Vineyard number	Percent N	K	P	Ca	Mg	Parts per million Mn	Fe	Cu	B	Zn
6	1.34	3.20	.159	0.87	0.35	177	41	242.9	27.2	31
9	1.12	1.62	.210	1.14	0.92	7011	88	12.9	30.7	85
12	1.34	3.30	.264	0.80	0.34	753	95	46.7	29.5	60
15	0.96	1.80	.299	1.10	0.62	484	85	48.8	30.7	83
17	1.00	2.14	.290	0.94	0.37	484	62	13.7	26.0	67
24	1.04	2.22	.392	1.22	0.37	215	137	12.0	34.3	95
.25	0.98	2.14	.392	1.10	0.33	177	153	12.0	34.3	95
28	0.96	2.22	.382	1.06	0.43	396	62	29.0	34.3	95
29	0.94	1.74	.264	1.18	0.40	258	53	41.2	33.0	91
33	1.08	0.86	.235	1.14	1.17	177	59	15.6	27.2	71
38	1.00	1.52	.245	1.06	0.52	440	37	10.2	24.8	64
40	1.18	2.82	.471	1.44	0.29	634	75	15.6	29.5	79
41	1.20	3.10	.401	1.40	0.37	204	82	15.6	31.9	87
42	1.16	1.68	.151	1.31	0.60	151	111	15.6	31.9	87
43	1.16	2.08	.245	1.06	0.40	46	66	13.7	34.3	95
44	1.16	1.88	.193	0.87	0.57	151	66	20.3	34.3	95
47	1.42	2.22	.254	0.91	0.40	384	88	120.8	28.3	54
51	1.22	2.48	.218	1.06	0.40	528	37	21.3	27.2	71
52	1.18	3.10	.254	1.14	0.29	71	56	38.0	31.9	87
54	1.04	2.74	.218	0.91	0.28	129	37	16.6	29.5	79
59	1.32	4.00	.254	0.94	0.26	129	47	19.5	29.5	79
63	1.04	1.80	.326	0.98	0.43	280	75	10.2	29.5	79
64	0.96	1.80	.273	1.18	0.38	269	91	12.9	33.0	91
65	0.94	1.94	.168	1.35	0.59	269	53	10.2	31.9	87
66	1.04	1.88	.151	1.35	0.64	263	59	12.0	31.9	87
67	1.22	2.38	.151	0.98	0.53	263	88	47.6	28.3	67
70	0.94	1.88	.184	1.31	0.60	119	44	9.3	31.9	87
73	0.82	2.82	.290	1.10	0.60	85	98	11.0	29.5	79
75	0.88	1.62	.227	1.18	0.45	806	50	19.5	28.3	75
79	0.88	1.68	.273	1.18	0.48	378	53	199.3	41.6	123
80	1.14	2.00	.530	1.06	0.43	204	111	210.0	34.3	67
81	1.46	3.00	.210	0.87	0.30	151	44	12.9	29.5	79
82	1.38	2.92	.290	0.80	0.31	156	53	16.6	26.0	67
87	0.92	0.94	.175	1.10	0.82	193	91	130.1	29.5	67
88	0.84	0.38	.159	1.22	0.66	568	72	158.4	27.2	64
89	1.10	1.94	.227	1.02	0.52	80	41	100.8	31.9	87
90	1.50	0.90	.168	1.10	0.68	80	34	204.6	24.8	64
91	0.96	0.90	.175	1.06	0.66	496	37	12.9	31.9	87
92	0.96	2.82	.151	1.06	0.17	556	37	15.6	31.9	75
93	1.04	1.74	.344	1.10	0.72	30	59	84.6	34.3	75
94	1.20	2.92	.159	1.18	0.30	50	47	73.1	33.0	79
95	1.16	2.82	.175	1.06	0.28	50	34	137.1	29.5	79
96	1.06	2.08	.227	1.22	0.34	188	75	190.3	34.3	95
99	1.16	2.08	.184	0.98	0.50	247	88	15.6	39.2	113
100	1.04	2.22	.382	1.18	0.53	134	75	14.7	27.2	36

APPENDIX TABLE VI. Soil analysis. Survey vineyards, 1963.

Vine-yard number	Soil texture	pH	lbs./acre - avail. P	K	Ca	Mg	CEC	% saturation K	Ca	Mg	% base satur-ation
3	5	6.0	160	80	728	96	6.3	1.5	28.5	6.3	36.5
6	5	6.8	160	88	728	138	2.9	3.7	62.0	17.2	82.7
11	5	5.3	160	196	344	46	10.1	2.4	7.9	.9	10.8
12	5	5.7	128	120	360	83	4.3	3.4	20.9	6.9	30.2
15	5	6.5	123	152	632	83	2.8	6.7	71.2	10.7	85.7
17	5	6.1	61	104	416	61	3.3	3.9	30.3	6.0	39.3
19	5	6.7	132	88	728	138	2.8	3.9	64.2	17.8	85.7
21	4	6.8	34	196	1144	128	4.0	6.2	70.0	12.5	87.5
24	2	5.5	112	192	728	83	10.3	2.3	17.4	2.9	22.3
25	2	6.5	132	248	1450	166	7.5	4.1	48.0	8.0	60.0
28	2	5.2	64	264	1331	93	12.9	2.5	25.5	2.3	30.2
29	2	5.7	115	288	1560	150	10.8	3.3	36.1	5.5	44.4
31	4	7.0	70	80	728	150	2.5	4.0	72.0	24.0	99.9
33	5	6.5	84	80	1040	93	3.5	2.8	74.2	8.5	85.7
38	5	6.1	88	100	832	93	6.4	1.8	31.2	4.6	37.5
39	5	6.2	72	48	304	61	2.9	2.0	24.1	6.8	31.0
40	5	4.8	168	360	160	11	3.8	12.1	10.5	0.1	21.0
41	5	5.3	160	280	280	18	1.8	19.4	27.7	0.1	44.4
42	5	5.4	160	632	496	46	4.1	19.7	29.2	2.4	51.4
43	3	6.5	50	184	2184	138	7.1	3.2	76.0	7.0	85.9
44	3	5.6	147	128	728	150	9.5	1.6	18.9	6.3	26.3
47	5	6.8	98	72	392	118	1.6	5.6	56.2	25.0	81.3
48	5	6.8	147	152	1144	2.0	4.2	4.5	66.6	19.0	88.0
51	2	4.4	160	464	1040	128	15.6	3.7	16.6	3.2	23.0
52	2	4.9	168	648	1664	128	13.4	6.1	30.5	3.7	40.2
53	5	7.4	154	288	1331	182	4.3	8.3	76.7	16.2	99.9
54	4	6.0	154	192	1040	83	7.1	3.3	36.6	4.2	43.6
58	5	6.0	88	196	416	64	3.4	7.3	29.4	5.8	41.1
59	5	6.0	123	144	344	51	3.1	5.8	25.8	6.4	35.4
60	4	6.9	119	348	1331	166	4.7	9.3	70.2	12.7	91.4
63	5	6.3	160	120	392	112	1.7	8.8	52.9	23.5	82.3
64	5	6.8	174	112	432	93	1.7	8.2	58.8	17.6	82.3
65	5	6.8	50	80	1040	46	3.1	3.2	83.8	3.2	90.3
66	5	7.0	37	100	1144	83	3.2	3.7	87.5	9.3	99.9
70	4	6.1	115	624	1872	138	6.4	12.5	71.8	7.8	92.1
73	2	6.0	10	196	2704	262	11.9	2.1	56.3	8.4	66.3
75	2	5.0	61	616	1331	64	10.2	7.6	32.3	1.9	41.1
79	2	5.6	30	344	1331	166	9.3	4.7	35.4	6.4	46.2
80	2	6.3	42	640	1872	274	9.5	8.6	48.4	11.5	68.4
81	3	5.6	44	344	1331	118	10.1	4.3	32.6	3.9	40.5
82	3	6.7	54	288	2184	150	6.8	5.2	79.4	8.8	92.6
87	5	5.8	119	32	288	40	1.2	3.3	58.3	8.3	66.6
88	5	5.0	162	32	200	11	4.5	.8	11.1	.1	11.1
89	2	6.0	27	376	2080	304	8.8	5.4	59.0	13.6	77.2

APPENDIX TABLE VI. Continued

Vineyard number	Soil texture	pH	lbs./acre - avail. P	K	Ca	Mg	CEC	% saturation K	Ca	Mg	% base saturation
93	2	7.3	108	512	2080	224	6.7	9.7	77.6	13.4	99.9
94	4	6.4	9	344	1144	80	4.5	9.7	62.2	6.6	77.7
95	5	5.5	81	112	496	51	5.5	2.5	21.8	3.6	27.2
96	2	5.5	45	168	1456	224	7.7	2.7	46.7	11.6	61.0
99	5	7.0	142	72	728	160	2.4	3.7	75.0	25.0	99.9
100	5	7.2	136	88	1248	128	3.7	2.9	83.7	13.5	99.9

APPENDIX TABLE VII. **Foliage density, vigor rating and soluble solids. Survey vineyards, 1963.**

Vineyard number	Foliage density	Vigor rating	Soluble solids - %
3	48	3.0	16.57
6	80	4.0	15.60
11	70	4.0	15.35
12	60	3.5	16.19
15	65	4.0	14.74
17	43	3.5	15.89
19	85	4.5	14.98
21	78	4.0	13.78
24	35	2.5	15.36
25	38	3.0	15.14
28	100	4.5	13.14
29	98	4.0	13.14
31	38	3.0	15.57
33	35	3.0	16.19
38	40	3.0	16.72
39	30	2.0	16.98
40	40	2.5	16.01
41	45	3.0	16.65
42	40	2.0	15.79
43	35	3.0	15.69
44	40	3.0	15.61
47	58	3.0	16.64
48	28	2.0	17.96
51	68	3.0	15.34
52	60	3.0	15.70
53	33	2.0	16.74
54	90	5.0	14.60
58	65	3.5	15.08
59	83	4.0	13.75
60	98	5.0	13.82
63	38	3.0	17.24
64	20	1.0	16.74
65	60	3.5	15.12
66	75	4.0	14.45
70	35	2.5	16.35
73	75	4.0	13.94
75	65	3.0	14.95
79	25	1.5	15.50
80	43	3.0	15.11
81	100	5.0	12.96
82	100	5.0	14.06
87	70	3.0	15.51

APPENDIX TABLE VII. Continued

Vineyard number	Foliage density	Vigor rating	Soluble solids - %
88	38	2.5	15.62
89	83	4.0	16.01
93	28	2.0	16.30
94	63	3.5	14.52
95	43	3.0	15.56
96	25	2.0	16.71
99	53	3.5	16.17
100	70	4.0	14.60

APPENDIX TABLE VIII. Petiole nitrogen, yield per vine, foliage density and soluble solids. Nitrogen study - Growers' vineyards, 1963 and 64.

Vine-yard number	Treat-ment nitrogen	Nitrogen - % June	Nitrogen - % July	Yield - lbs./vine	Foliage density - %	Soluble solids - %
			1963			
58	+	1.74	1.38	8.53	70	15.46
	o	1.70	1.10	9.38	65	15.08
31	+	1.85	1.16	19.08	43	15.28
	o	1.58	1.18	17.77	38	15.57
19	+	1.56	1.14	19.08	73	15.37
	o	1.62	1.24	20.35	85	14.98
21	+	1.48	1.28	25.50	93	13.43
	o	1.44	0.96	33.03	78	13.96
39	+	1.24	0.92	14.43	35	16.24
	o	1.22	0.90	10.55	30	16.98
60	+	1.84	1.46	23.18	100	14.03
	o	1.63	1.14	18.93	98	13.82
11	+	2.18	1.44	9.85	73	15.61
	o	2.00	1.12	11.08	70	15.35
53	+	1.46	0.94	14.20	43	16.96
	o	1.37	0.84	16.73	33	16.74
3	+	1.80	1.30	6.55	40	16.97
	o	1.63	1.14	14.29	48	16.57
48	+	1.70	1.40	9.07	40	17.88
	o	1.37	1.14	9.41	28	17.99
			1964			
58	+	1.59	1.40	22.58	77	15.69
	o	1.57	1.36	22.80	72	15.64
31	+	2.14	1.45	19.75	65	16.49
	o	1.34	1.27	10.88	42	16.74
19	+	1.49	1.40	26.93	69	15.60
	o	1.37	1.42	28.08	66	16.49
21	+	1.39	1.29	21.65	85	16.10
	o	1.20	1.06	23.30	73	16.07
39	+	1.28	1.21	19.45	51	16.62
	o	1.09	0.86	17.63	35	16.39
60	+	1.66	1.51	19.48	87	15.26
	o	1.19	1.33	19.98	83	14.89
11	+	1.67	1.52	12.13	68	16.76
	o	1.37	1.32	12.10	67	16.88
53	+	1.30	1.15	9.73	38	15.99
	o	1.11	0.91	10.28	25	17.10
3	+	1.71	1.32	18.98	45	15.74
	o	1.32	1.18	24.57	46	15.98
48	+	1.19	1.20	21.01	41	17.26
	0	1.03	1.00	23.73	28	17.09

APPENDIX TABLE IX. Petiole nitrogen, yield per vine, pruning weight and soluble solids. Nitrogen study - Sodus, 1963 and 1964.

NH_4NO_3	Sawdust - lbs./vine	Rep	Nitrogen - % June	July	Yield - lbs./vine	Soluble solids - %	Pruning - lbs./vine
				1963			
0	0	I	1.09	0.89	14.2	16.31	4.25
	10		1.02	0.79	15.1	16.66	2.25
	20		1.08	0.75	17.9	16.42	3.08
0	0	II	1.10	1.01	9.0	16.87	1.83
	10		1.02	0.81	18.7	16.75	2.33
	20		1.14	0.95	19.9	16.73	3.58
0	0	III	1.18	1.04	18.5	16.25	3.75
	10		0.99	0.88	22.7	15.95	3.00
	20		1.11	0.83	23.2	16.39	3.67
0	0	IV	1.07	0.95	19.8	17.01	3.08
	10		1.06	0.93	21.9	17.16	2.92
	20		1.21	0.92	18.4	16.34	4.42
1	0	I	1.48	1.15	14.5	16.61	5.08
	10		1.25	1.09	20.1	16.42	5.33
	20		1.33	1.09	17.4	16.57	4.17
1	0	II	1.80	1.03	13.8	16.37	3.67
	10		1.15	1.00	15.2	16.48	3.42
	20		1.76	0.93	18.5	16.78	3.00
1	0	III	1.26	1.05	16.4	16.12	4.83
	10		1.39	1.15	17.8	16.45	5.42
	20		1.19	1.08	12.9	16.40	5.67
1	0	IV	1.10	1.07	14.2	16.76	4.58
	10		1.20	1.08	14.9	16.35	2.67
	20		1.25	1.04	24.1	16.80	4.08
				1964			
0	0	I	1.41	1.37	15.7	16.73	•
	10		1.16	1.42	21.0	16.26	
	20		1.25	1.15	16.2	17.10	

APPENDIX TABLE IX. Continued

NH_4NO_3	Sawdust - lbs./vine	Rep	Nitrogen - % June	Nitrogen - % July	Yield - lbs./vine	Soluble solids - %
0	0	II	1.33	1.23	17.7	16.03
	10		1.12	1.03	15.2	16.90
	20		1.20	1.15	23.4	16.63
0	0	III	1.11	1.47	26.9	15.67
	10		1.17	1.39	24.9	16.43
	20		1.31	1.29	22.0	16.37
0	0	IV	1.35	1.35	22.6	16.00
	10		1.21	1.23	17.8	16.60
	20		1.22	1.20	21.1	16.47
1	0	I	2.14	1.42	21.3	16.47
	10		1.47	1.31	19.8	16.07
	20		1.47	1.23	23.9	16.07
1	0	II	1.75	1.27	21.7	15.93
	10		1.55	1.10	20.2	16.20
	20		1.87	1.20	20.3	15.80
1	0	III	1.47	1.41	19.9	15.47
	10		1.37	1.42	22.3	16.57
	20		1.43	1.42	23.0	15.87
1	0	IV	1.50	1.28	24.7	15.87
	10		1.66	1.39	18.9	15.23
	20		1.61	1.36	23.4	16.53

APPENDIX TABLE X. Yield per vine and soluble solids. Shading studies, 1962.

Shade	Sub-treatment	Rep	Yield - lbs./vine	Soluble solids - %
0	none	I	24.0	15.0
	shoots tipped		14.6	14.5
	clusters thinned		7.7	17.0
0	none	II	9.9	15.0
	shoots tipped		20.5	15.5
	clusters thinned		6.5	16.5
0	none	III	25.8	15.0
	shoots tipped		17.7	15.0
	clusters thinned		13.4	16.5
0	none	IV	12.0	16.0
	shoots tipped		14.6	16.0
	clusters thinned		6.1	16.5
30	none	I	5.0	15.5
	shoots tipped		14.3	15.0
	clusters thinned		8.9	15.5
30	none	II	8.4	16.5
	shoots tipped		8.4	15.0
	clusters thinned		8.1	16.5
30	none	III	13.8	14.0
	shoots tipped		13.5	15.5
	clusters thinned		6.8	16.0
30	none	IV	25.6	14.5
	shoots tipped		15.7	14.0
	clusters thinned		12.8	15.0
50	none	I	6.7	15.0
	shoots tipped		7.8	15.5
	clusters thinned		5.5	15.0
50	none	II	21.3	14.0
	shoots tipped		13.0	14.5
	clusters thinned		7.7	14.5
50	none	III	14.6	14.5
	shoots tipped		13.5	15.0
	clusters thinned		8.1	16.0
50	none	IV	5.4	15.5
	shoots tipped		14.3	13.5
	clusters thinned		7.9	15.5

APPENDIX TABLE XI. Yield per vine and soluble solids. Shading studies, 1963 and 64.

Date	Shade	Rep	Yield lbs./vine	Soluble solids - %
		1963		
6/17 to 8/7	0	I	7.5	15.16
	30		9.9	14.58
	50		4.3	16.21
	0	II	9.0	14.62
	30		9.3	14.33
	50		7.3	14.89
8/7 to 9/26	0	I	6.3	16.06
	30		7.8	14.68
	50		6.5	13.61
	0	I	4.3	15.17
	30		3.2	13.57
	50		4.3	13.43
		1964		
6/19 to 8/7	0	I	3.8	16.04
	30		12.6	15.65
	50		5.2	16.39
	0	II	14.3	16.37
	30		10.8	15.30
	50		7.8	14.44
8/7 to 9/24	0	I	13.8	17.14
	30		8.3	13.36
	50		8.7	12.95
	0	II	8.7	16.50
	30		9.0	13.59
	50		6.6	14.60