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GIRDLING: ITS RELATION TO CARBOHYDRATE NUTRITION AND DEVELOPMENT OF THOMPSON SEEDLESS, RED MALAGA, AND RIBIER GRAPES

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Girdling experiments with three varieties of grapes over an eight-year period verified earlier findings or hypotheses that:

1. Carbohydrates are increased above the girdles and decreased in the roots.

2. There is a sensitive time relation between girdling and maximum berry size in Thompson Seedless and between girdling and most rapid increase in maturation in Red Malaga and Ribier grapes.

3. Girdling does not permanently weaken the vines.

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GIRDLING: ITS RELATION TO CARBOHYDRATE NUTRITION AND DEVELOPMENT OF THOMPSON SEEDLESS, RED MALAGA, AND RIBIER GRAPES[1]

ROBERT J. WEAVER[2] and STANLEY B. McCUNE[3]

IT HAS long been a standard practice among growers of table grapes to apply a girdle to Thompson Seedless grapes soon after the impotent flowers fall following bloom, since this procedure results in a considerable increase in the size of the berries (Jacob, 1931; Winkler, 1953). It is known that if girdling is delayed after the berry shatter stage, the berries increase far less in size (Winkler, 1953). Evidence that the carbohydrate level is increased above the girdles in some plants (Kraybill, 1923; Murneek, 1941) has led to this factor's being considered as associated with or the cause of the increase in the size of the berries.

Herein are reported several experiments performed in certain years from 1949 to 1956 inclusive designed to investigate the effects of girdling Thompson Seedless grapes at different stages of development and to point up changes in available carbohydrates in the shoots and roots. Other experiments were centered on a comparison of responses of Thompson Seedless to various techniques of girdling.

Commercially, it has been a rewarding practice for years to apply girdles to Red Malaga and Ribier vines when the berries are first tinged with color, for the rate of coloration and ripening is increased (Jacob, 1931; Weaver 1952, 1955). Experiments prior to the present work demonstrated that girdling when the total soluble solids content of fruit was only 5 or 6 per cent usually resulted in the most rapid maturation of fruit (Weaver, 1955). It was desirable, however, to gather more data on the response of the vines girdled at various times, especially when girdling took place early, an undertaking which this paper describes. One experiment in particular was designed to study the changes in available carbohydrate levels in shoots and roots after girdling.

These studies of changes in carbohydrate levels in the vine resulting from various times of girdling were intended to shed light on why girdling stimulates responses. In addition, an attempt was made to determine whether any permanent weakening of the vine occurs as a result of girdling.

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PREVIOUS INVESTIGATIONS OF GIRDLING AND CARBOHYDRATE CHANGES

Important findings on the question of the effect of ringing on carbohydrate changes in woody plants extend back to Wiggans, whose large bibliography in a publication of 1918 included known effects of girdling up to that time.

Fisher (1905) observed that girdling hastened and increased flowering. Several investigators have shown that girdling increases accumulation of food substances above the girdle in tree fruits (Leclerc du Sablon, 1905; Murneek, 1941) and that it has been associated with greater bud formation. Leclerc du Sablon (1905) showed that in the autumn the reserves in the roots of girdled pear trees were lower than in ungirdled trees, and that the reverse was true with the leaves. Wiggans (1918) used the freezing-point method for his determinations, noting that girdling nursery apple trees increased the concentration of sap in the parts above the girdle.

Kraybill (1923) demonstrated that ringing McIntosh apple trees increased the number of spurs forming fruit buds and that this was associated with an increase in available carbohydrates above the rings. He stated that ringing was effective largely by preventing translocation of carbohydrates to the roots rather than by inhibiting the intake of nitrogen.

Jacob (1931) recommended either trunk or cane girdling for Thompson Seedless to increase berry size. He suggested that the proper time for girdling in order to obtain the maximum increase of about one third was when the berries were approximately one-fourth grown. Narrow wounds made at this time heal rapidly. Jacob stated that ripening can be slightly hastened by girdles which are open and effective during the ripening period, but he did not recommend this practice because the wounds heal very slowly and imperfectly with a consequent serious weakening of the vine. He emphasized that girdling is a weakening operation, but that if they are not overcropped and are irrigated somewhat more frequently than is necessary for similar ungirdled vines, vines on fertile soil may be girdled each year for several years without serious weakening.

A comprehensive experiment on the effect of time of girdling of Thompson Seedless grapes on increase in berry size was performed by Winkler (1953). He found that to obtain maximum increases in berry size, girdling the vine must be done immediately after the normal drop of impotent flowers following bloom, probably because this coincides with the time of most rapid berry development. Considerable increase in berry size (as compared with ungirdled vines) resulted when the girdling was delayed six days, but berry weight was increased only slightly when girdling was delayed three weeks. Winkler recommends that to achieve an advance in coloring and maturation, Ribier and Red Malaga girdling should coincide with the earliest trace of color development. Maturation, he states, may be advanced three to six days as determined by hastening of coloration and increased percentage of total soluble solids. He found that girdling to advance maturation of seedless varieties is ineffective.

According to Weaver (1955), early girdling resulted in most rapid maturation of Ribier and Red Malaga grapes. In an earlier paper (Weaver, 1952) he reported that girdling when the total soluble solids content of fruit was

only 5 or 6 per cent usually resulted in the most rapid maturation. However, in 1954 the first three girdlings, applied when the percentages of total soluble solids of fruit were 5.7, 8.3, and 13.8, respectively, produced about an equal advance in maturity as judged by the harvests (Weaver, 1955).

In Arizona, in 1953 and 1954, Sharples, Hilgeman, and Milne (1955) found that the optimum time for girdling Cardinal grapes to hasten maturation coincided with the first appearance of color, when the average total soluble solids content was about 5 per cent. These investigators reported that girdling within a period of five days beginning with the first appearance of color results in increased maturation.

Winkler and Williams (1945) made a comprehensive study of the changes in carbohydrates in normally pruned Carignane vines for an entire year. Eighteen samplings were taken and carbohydrate analyses tabulated of the various vine parts.

It was demonstrated by Murneek (1939) that ringing increased the size of several types of fruits (apples, peaches, pears, cherries, grapes). Concord grapes from ringed vines appeared to be sweeter. Murneek (1941) also demonstrated that ringing of apple spurs resulted in higher carbohydrates of fruit and spurs and a slight decrease in nitrogen.

Many investigators have shown a positive correlation between fruitfulness of spurs in tree fruits and the level of available carbohydrates (Davis, 1931; Kraybill, 1923; Greene, 1937).

Greene (1937) demonstrated that ringed branches of Grimes Golden apples were higher in sugars and starch than were spurs on nonringed branches, and that early ringing was also associated with an increased percentage of blossoming spurs.

THE PRESENT INVESTIGATIONS

Davis vineyards were used as test plots for the current studies, involving mature vines in an irrigated vineyard. Thompson Seedless was normally pruned to four canes in the experiments at the University of California campus. In some experiments Thompson Seedless clusters were berry-thinned by removing the apical half after the shatter of berries in the manner described by Winkler (1931). Red Malaga and Ribier were cordon-trained and spur-pruned. Cane girdling was performed in Thompson Seedless by removing a strip of bark $\frac{3}{16}$ inch wide at the base of the cane with girdling pliers. Trunk-girdling was performed on all varieties by making a girdle $\frac{3}{16}$ inch in width with a double-bladed girdling knife on the trunk. Double-girdling the trunk was accomplished by making two girdles about 2 inches apart.

Samples of shoots and roots for carbohydrate analyses were usually obtained between 7 and 9 a.m. The basal 5 or 6 inches or a similar section from the middle of the shoots or both were used. Five or ten canes were utilized per sample. Clusters were sometimes collected, five per sample. Berries were snipped off and the frameworks were thoroughly washed with running water to remove any sugar adhering to the outside of tissues. Analyses were made of the frameworks. A hole about 2 feet deep and 3 feet in diameter was dug by one side of the vine, and roots were removed from the soil mass. Roots were divided into small (less than 2 mm thick), medium (2 to 6 mm thick), and large (6 to 14 mm thick); and roots over 14 mm thick were discarded. Roots

from two vines comprised a sample. After the soil was washed from the roots with running water, the roots were chopped into small pieces with pruning shears, dried in a dehydrator at about 65° C, and finally ground in an intermediate Wiley mill; they were then stored in tightly closed screw-cap bottles until the chemical analysis was run. Duplicate samples were used for analysis. Extraction procedures adopted by Winkler and Williams (1945) were followed except that an 0.5 per cent solution of Clarase was used for starch digestion. Sugar determinations were made according to the method of Phillips (1941). Analytical data are expressed as percentage values on a dry-weight basis.

The percentage of total soluble solids in the juice was obtained with a Balling hydrometer, and the total acidity was determined by diluting 10 ml of the juice to 50 ml with distilled water and titrating with 0.133 *N* NaOH, using phenolphthalein as an indicator. The degree of coloring was estimated visually. Berry size was arrived at by removing berries from clusters, thoroughly mixing them, and weighing lots of 100 or 200 in duplicate.

Conditions for growth: The usual viticultural practices were followed in caring for the vines. Water was not a limiting factor for growth, and nearly all days during the growing season were clear and sunny. Mean monthly temperatures and cumulative degree-days heat for 1955 and 1956 are presented (table 1) with reference to the experiments with Red Malaga and Ribier. There was a greater number of degree-days of heat in 1956, although the mean temperatures in August and September were lower than in 1955.

RECORDS OF RESULTS

Relation of Time of Girdling to Carbohydrate Nutrition in Thompson Seedless

The purpose of these experiments was to determine whether an increased level of carbohydrates resulting from girdling is associated with an increase in berry size. Such studies may explain why girdling within about one week after berry shatter produces a maximum increase in berry size.

In the first experiment the vines were not thinned, and each vine bore about 60 clusters. On May 19, 1949, two canes on opposite sides of the head of the vine were cane-girdled at a point about one third the distance from the apical end of the cane. The other two canes served as ungirdled controls.

At the time of girdling, samples were taken for carbohydrate analyses. The apical 20 to 30 inches (about two thirds of the total length of the cane, with the girdle on girdled canes in approximately the center of the segment) of the canes were removed, leaving on the vine a basal portion bearing two or three shoots. The detached section was cut into apical and basal sections corresponding to the parts above and below the girdle. A ½ inch section with the girdle was discarded. The apical section was usually 12 to 16 inches long with four or five shoots, and the basal about 8 to 13 inches long with two or three shoots. Bark was peeled from the wood of the cane, and the basal 4 inches of the shoots were also collected. Similar samples of control and girdled canes were taken on May 24, May 29, July 6, July 11, and July 16. Four canes were used for each treatment, and canes from two vines were used at each collection.

By July 6 most of the girdling wounds had healed over. The cane above the girdle had become much thickened, mainly by bark growth. The bases of some shoots above the girdle were more yellowish than the controls. On July 16, date of last sampling, the clusters apical to the girdles were large and compact, and had larger berries than had the corresponding controls. The average weight of girdled clusters was 0.95 lb., while that of the controls was only 0.54 lb.

TABLE 1

MEAN MONTHLY TEMPERATURES AND DEGREE-DAYS HEAT SUMMATION FOR 1955 AND 1956

Month	Mean monthly temperature, °F		Cumulative degree-days heat*	
	1955	1956	1955	1956
April	54.0	58.4	120.0	252 0
May	65.9	65.2	612.9	723 2
June	70.0	71.8	1,212.9	1,377.2
July	72.6	74.5	1,913.5	2,136.7
August	74.2	72.4	2,663.7	2,831.1
September	74.2	71.2	3,389.7	3,467.1

* Degree-days heat calculated by subtracting 50 degrees F from mean temperature for each day and adding these quantities together.

Wood, bark, and shoot bases located apical to the girdle are referred to as apical, and those basipetal to the girdle as basal. Girdling had little effect on sugars of apical wood, except on July 6, when the wood contained 5 per cent sugars (fig. 1). Starch was consistently higher in the girdled wood, as were the total available carbohydrates (sugars plus starch). The apical girdled bark had a consistently higher percentage of sugars, but starch content showed little change (fig. 2). Starch and sugar contents of bases of apical shoots were consistently higher in girdled treatments although the increase in sugar content as a result of girdling was slight at some samplings (fig. 3).

Although the percentages of sugars and starch were irregular in basal wood, the total available carbohydrates (sugars plus starch) were lower in girdled treatments until about the time the girdles had healed (July 6), after which they were higher (fig. 4). The results with basal bark were very irregular (fig. 5). The total available carbohydrates in basal shoots were higher in the girdled treatment, although there was little difference at the last two samplings (fig. 6).

A second experiment, four years later, was designed to study the time of girdling in relation to increasing berry size as well as carbohydrate nutrition. When Thompson Seedless is girdled at the time of bloom or berry shatter, the berry increases considerably in size. As the time of girdling is delayed, the increase is smaller, so that a girdle applied three or four weeks after shatter brings about little or no increase (Winkler, 1953). The reason for these results is unknown. This experiment was run to determine if there is a differential increase in carbohydrates which is related to different times of girdling. If the greatest increase in percentage of carbohydrates occurs as a result of girdling at berry shatter, this may be responsible for the great increase in berry size.

In early June of 1953 all clusters were removed except five per cane. The remaining clusters were berry-thinned by removing the apical two thirds. In the first treatment vines were girdled at time of berry shatter (June 11), and in a second treatment they were trunk-girdled about three weeks after shatter when the berries were about 7 mm in diameter (July 1). A third set of vines served as ungirdled controls. A randomized complete block design was used. There were eight vines per plot, and each plot was replicated five times. Samples of shoots were taken and chemical analyses made on the dates of girdling. At each time of sampling one shoot was removed from each vine in each plot. Other samples from vines girdled on June 11 were taken on June 16, June 22, June 26, and July 1. Samples from vines girdled on July 1 were obtained on July 6, July 10, July 16, and July 21. Samples from control plots were taken at the same times.

At harvest in late August the average weights per berry of ungirdled vines, vines girdled on June 11, and vines girdled on July 1 were 1.45, 2.46, and 2.06 grams, respectively. The degree Balling readings in the same order were 23.0, 23.6, and 23.0, and total acids were 0.61, 0.62, and 0.60 per cent. In 1953 the second girdling should have been delayed until after July 1 to avoid any increase in berry size.

The general trend of sugars in basal-shoot segments of ungirdled canes was downward during the experimental period, but both the first and second girdling increased the percentage (fig. 7). Each girdling also increased the starch percentage in the basal shoots. Data for the middle-shoot segments are not presented because they contained about the same amount of available carbohydrates as the basal segments, and the trends were similar. Sugar content of the medium-sized (2–6 mm thick) root segments was constant in all samples, but girdling markedly decreased starch content (fig. 8). Data are presented for only the medium-sized roots. Small roots (less than 2 mm thick) had about the same percentages, while large roots (6–14 mm thick) had lower percentages of sugars and starch than did the medium-sized roots. However, in all cases the relative changes were about the same.

The preceding experiment performed in 1953 was repeated in 1954. One series of vines was girdled at the time of berry shatter, and a second series three and one-half weeks later. At both early and later girdlings sugar and starch increased in the shoot segments, and starch content of roots fell rapidly as a result of the girdling. At harvest it was determined that the first girdling greatly increased size of berry, but that the second girdling failed to increase size.

Recovery of Girdled Vines

There is an apprehension current that girdling has a permanent weakening effect on the vine. Experiments were performed on Thompson Seedless and Ribier grapes to determine whether there is any foundation for this belief by following the changes in the available carbohydrates after girdling on into the dormant season. Before the girdle is healed, root growth is probably restricted for lack of food materials elaborated in the foliage. The previous experiments in this paper had shown that starch content in roots of girdled vines rapidly decreases. After the girdle heals, the depleted reserves in the roots are probably replenished. If the results approach the levels of those of the controls, the indication is that no weakening has occurred.

Thompson Seedless. Five-year-old vines pruned to four canes were used. On June 6 all clusters were removed except five per cane, and the remaining clusters were berry-thinned.

Vines were trunk-girdled on June 11, 1954. Each plot consisted of 12 vines and was replicated four times. A randomized block design was used. At time of girdling the middle segments of shoots and root samples were taken. Similar samples from girdled and control vines were taken on June 29, August 4, September 7, October 22, 1954, and February 7, 1955.

At harvest on September 23 average berry weights were 2.54 grams for girdled vines and 1.86 for the controls. The percentages of total soluble solids were 21.8 and 23.1, respectively.

In the middle-shoot sections girdling increased the percentage of sugars until August 4, after which it was lower than the control until the dormant season, when it was about equal (fig. 9). Although results with starch were rather irregular, the percentage of total available carbohydrates was at first increased by girdling. In September the percentages were reversed, but by final collection (February 7), they were equal.

In the small roots (less than 2 mm thick) the percentage of sugars remained low and constant throughout the experimental period (fig. 10). Starch percentage decreased rapidly, but by the sampling in the dormant season (February 7, 1955) it was as high in roots of girdled vines as in that of the controls. Since the analytical data for medium roots were about the same as for the small, they are not presented. The results for large roots (fig. 11) are also similar to those of the small. However, the percentage of starch in the large roots is less than that in the small roots, except at the final sampling in the dormant season (February 7, 1955) when the percentages were about equal.

Although statistical analyses showed that there were no significant F values, these data lend evidence that girdles, when they are properly made, result in no permanent injury to Thompson Seedless vines. After the grapes were picked on September 23, total available carbohydrates continued to increase for at least one month in both shoots and roots (figs. 9, 10, 11). This indicates that the foliage of the vine was actively producing photosynthate in late fall long after the grapes were harvested.

Ribier. In this experiment the effect of girdling on changes in available carbohydrate contents of shoots and roots was followed to shed light on why ripening is accelerated by girdling and to determine whether the girdling operation, when done properly, is weakening.

Eighty vines were cluster-thinned early in June to 12 to 16 clusters. Forty vines were trunk-girdled on July 21, 1955, when the green berries had a degree Balling of about 5.6 (fig. 12). On this date samples of fruit weighing about 15 lbs. were taken for analyses, and shoots and roots were also sampled for carbohydrate analyses. Five shoots were taken from each vine, sampled, and combined for analyses on basal and middle 6 inches of shoot and cluster frameworks. A randomized split-plot design was used, and there were four replicate vines per treatment. Each vine was sampled only once during the experiment. Similar collections for fruit or carbohydrate analyses or both were made on July 21, August 3, August 17, August 29, 1955, and on February 10, 1956. On February 10, 1956, berries were completely raisined; and

much mildew grew on the clusters. The dry berries were removed and cluster frameworks thoroughly washed before analyses were made.

The data of figure 12 show the degree Balling readings, percentages of acid, and color estimations on the dates of sampling. After August 3 girdling hastened coloration, although by August 29 the percentage of the surface of control fruit that was colored was almost as high as the girdled. Girdling increased degree Balling readings, and resulted in a slight decrease in the percentage of total acid.

The percentage of sugars and starch in middle shoot segments rapidly increased as a result of girdling (fig. 13). By the dormant season, however, there was little difference between controls and girdled vines. Since results for the studies of basal shoot segments are very similar to those of the middle, the outcomes are not included here. Results were generally similar to those with the cluster frameworks, although at the sampling on August 29, sugars were higher in the controls (fig. 14). In the large roots girdling decreased the percentage of starch until the dormant season, and the percentage of sugars fell for about a month, after which the sugars became greater than in the controls until the last sampling (fig. 15). Since similar results were obtained with the small- and medium-sized roots, the data are not presented.

When statistical analyses were applied to total available carbohydrates for cluster frameworks or roots, it was found that at the 5 per cent level the controls were not significantly different from the girdled.

Effect of Various Girdling Techniques on Carbohydrate Nutrition and Quality of Fruit

The purpose of the first experiment was to note the effect of different types of girdling on the fruit, as well as changes in percentage of available carbohydrates. Thompson Seedless vines were thinned to five clusters per cane and the remaining clusters were berry-thinned. One set of vines was trunk-girdled on June 4, 1956. A second lot was double-girdled on the same date, the girdles being about 2 inches apart on the trunk. A third lot was girdled on June 4, and the girdles in this treatment were reopened every seven to ten days until harvest. At no time did these girdles heal over. A fourth lot was girdled on August 6 when the degree Balling reading was about 12, and a fifth lot served as the controls. There were four vines per treatment, each replicated three times. A complete randomized block was used.

The single girdles were completely healed over in about a month, but it took six weeks for both girdles of the double girdles to heal over. The latter wounds apparently healed over at approximately the same time. In girdles that were reopened, much healing and sap exudation occurred for about one month, but later the girdle hardened and appeared scarred.

On July 27 and August 13, refractometer readings of ten berries were taken separately from each plot. The average of each treatment is shown in figure 16 along with degree Balling reading at harvest. The degree Balling was highest on those vines where the girdle was kept continuously open. On July 27 the percentage of total soluble solids of single- and double-girdled grapes was higher than that of controls, but in August their percentage rapidly fell behind, probably owing to the greater weight of fruit on girdled vines. Girdling at 12 degrees Balling had little or no effect on rate of ripening.

Fruit was harvested on August 21, 1956. Foliage was green in all but one treatment; on vines where the girdles were kept open it was brown and yellow. Shoots on the latter vines were stunted by as much as 3½ feet.

All vines girdled at the time of berry shatter produced larger berries than controls (table 2). On vines where the incision remained open, ripening was hastened somewhat (fig. 16, table 2). On these vines many berries developed a soft texture and a light color, and waterberry, sunburn, and raisining occurred more frequently than among berries produced under the other treatments.

At harvest time the basal 6 inches of shoots, a 6-inch segment from the center of the shoot, and cluster frameworks (five for each sample) were taken for carbohydrate analyses. The data (fig. 17) show that percentages of total available carbohydrates (sugars plus starch) were greater in the shoots and cluster frameworks in the treatment where the girdle was kept open, and that the single and double girdles increased the percentage in the basal-shoot segment and cluster framework. The differences were due largely to an increase in the percentage of sugars.

In a second experiment performed to compare the effects of single and double girdling, more detailed studies on the carbohydrate nutrition were made. Early in June of 1956 all clusters were removed except five per cane, and the remaining clusters were berry-thinned. On June 11 one set of vines was trunk-girdled and another set double-girdled. A third set served as untreated controls. There were five vines per treatment, and each treatment was replicated three times in a randomized block.

At the time of girdling samples of the basal 6 inches of the shoots, a 6-inch section from the middle of the shoot, and cluster frameworks (five per sample) were taken for carbohydrate analysis. Samples were taken again on June 26, July 17, July 30, and at harvest on August 28, when root samples were also obtained. Single girdles healed in about four weeks, double girdles in about six.

The data (table 3) show that single and double girdling had about the same effect on berry size, degree Balling, and acid. Since the two types of girdling had practically the same effect on total available carbohydrates in shoots and roots, the data are not presented. The results confirm the data of the previous experiment, described in this section, which also included single and double girdle treatments applied early in June.

Effect of Time of Girdling on Rate of Maturation in Red Malaga and Ribier

Each treatment consisted of a block of eight vines replicated three times. At each girdling one cluster was picked from each vine to be girdled, and the percentages of total soluble solids and total acid were determined on the combined fruit from each block. Several pickings were made of each variety except during the Ribier experiment in 1955. Harvested grapes met the minimum standards of U. S. Fancy table grapes as defined by the U. S. Department of Agriculture Standards for Table Grapes (1952).

Red Malaga vines were cluster-thinned in early June of 1955, leaving about 16 clusters. Table 4 shows the stage of development of the grapes at the times of girdlings.

TABLE 2

DATA AT HARVEST (AUGUST 21, 1955) FOR THOMPSON SEEDLESS GRAPES GIRDLED AT DIFFERENT TIMES AND IN DIFFERENT MANNERS

Treatment	Wt. fruit per vine, lbs.	Av. wt. per cluster, lbs.	Wt. per berry, grams	Degree Balling reading	Percentage of acid
Control	21.2	1.06	2.00	19.2	0.92
Single girdle at berry shatter	28.3	1.46	2.65	17.7	.87
Double girdle at berry shatter	29.3	1.57	2.78	17.6	.85
Girdle kept open	25.4	1.51	2.70	20.9	.78
Girdle at 12° Balling	21.3	1.19	2.01	18.8	0.88
L.S.D. at 5 per cent level	5.9	0.22	0.18	N.S.	N.S.

TABLE 3

DATA AT HARVEST (AUGUST 28, 1956) FOR THOMPSON SEEDLESS VINES SINGLE- AND DOUBLE-GIRDLED ON JUNE 11

Treatment	Total wt. crop per vine, lbs.	Wt. per berry, grams	Degree Balling reading	Percentage of acid
Control	19.4	1.85	20.0	0.70
Single girdle	23.5	2.78	18.9	.74
Double girdle	26.0	2.67	18.9	0.72
L.S.D. at 5 per cent level	N.S.	0.65	N.S.	N.S.

The first picking was made on August 29, 1955, when the degree Balling of colored grapes ranged from 16 to 20. The degree Balling of well-colored clusters was only slightly higher than that of clusters with less color. This is in contrast to work of previous years when degree Balling usually was more directly correlated to depth of color (Weaver, 1955). The second picking was made on September 8 and the third on October 4.

The data (table 5, fig. 18) show that fruit on vines girdled on August 8, when about 8 per cent of the total surface of fruit was colored, ripened the most rapidly. Fruit girdled on July 19, when berries were still green, matured next most rapidly.

Ribier vines were also cluster-thinned early in June of 1955, to 16 to 20 clusters per vine. Vines were girdled on July 7, July 19, August 8, and August 17 (table 4). The grapes colored rapidly, but the degree Balling lagged. Although most berries were well colored, their degree Balling often measured less than the legal minimum permitted for harvesting. This made the harvesting of individual clusters impractical at the usual time of the first picking. Refractometer readings were therefore taken of berries on various clusters. Twenty readings were made in each plot on each of the following dates: September 8, September 13, September 22, and October 4.

The data (fig. 19) show that the girdling on August 8 produced the most rapid maturation, closely followed by the girdling of August 17. The results show that later girdling in the Ribier was just as effective as girdling about ten days earlier in the Red Malaga in 1955.

In another experiment with Ribier the following year vines were thinned to 12 to 16 clusters early in June, and girdled on various dates (table 4). On September 4 refractometer readings showed that vines girdled on July 27

were the only ones with fruit over 17 degrees Balling. About 30 per cent of this fruit had a degree Balling of 17 or higher. Ribier colored rapidly in 1956, but the degree Balling was low.

The first picking was undertaken on September 4, and a second on September 11 when refractometer readings showed that all plots had some clusters at 17 degrees Balling or higher. A third picking took place on September 26, and the fourth on October 6 when the fall rains began.

The data (table 6, fig. 20) indicate that the fruit of vines girdled on July 27, when fruit color was just beginning, ripened most rapidly; girdling on July 16 or August 8 also hastened maturation. Girdling on June 27 gave little or no beneficial results.

TABLE 4

CONDITION OF UNGIRDLED RED MALAGA AND RIBIER FRUIT ON THE VARIOUS DATES

Dates of girdling	Degree Balling reading	Percentage of total acid	Percentage of surface of fruit colored
Red Malaga, 1955			
July 7	5.0	2.60	0
July 19	6.5	3.14	0
August 8	10.3	2.12	8
August 17	13.6	1.27	28
Ribier, 1955			
July 7	4.8	2.58	0
July 19	5.2	2.88	0
August 8	6.5	2.71	0.5
August 17	9.2	2.05	35.0
Ribier, 1956			
June 27	3.8	....	0
July 16	5.9	2.85	0
July 27	5.3	2.60	1
August 8	8.8	2.11	12

TABLE 5

AVERAGE WEIGHT OF RED MALAGA GRAPES PER VINE AT SUCCESSIVE PICKINGS FROM VINES GIRDLED AT ONE OF FOUR DATES OR LEFT UNGIRDLED IN 1955

Figures are averages of three plots

Date of girdling	Average weight of grapes harvested per vine at 3 dates, lbs.		
	August 29	September 8	October 4
July 7	1.0	7.7	15.1
July 19	4.6	8.0	11.0
August 8	9.7	6.8	2.2
August 17	0.9	11.0	8.7
Not girdled	0	6.0	17.4
L.S.D. at 5 per cent level	2.6	N.S.	9.9

TABLE 6
AVERAGE WEIGHT OF GRAPES PER VINE AT SUCCESSIVE PICKINGS FROM RIBIER VINES GIRDLED AT ONE OF FOUR DATES OR LEFT UNGIRDLED IN 1956
Figures are averages of three 8-vine plots

Date of girdling	Average weight of grapes harvested per vine at 4 dates, lbs.			
	September 4	September 11	September 26	October 6
June 27	0	1.3	3.7	5.4
July 16	0	2.5	7.7	1.0
July 27	4.7	2.2	0	1.5
August 8	0	3.5	3.6	0.2
Not girdled	0	0.8	2.9	3.9
L.S.D. at 5 per cent level		N.S.	5.4	4.0

DISCUSSION

Girdling Thompson Seedless raised the level of total available carbohydrates in the vine apical to the girdle. When girdling took place immediately after berry shatter it resulted in an increased berry size. However, the increased level of available carbohydrates cannot be considered to be the sole cause of increased berry size. If it were, thinning should also increase berry size, since there would be more available carbohydrates per cluster. Winkler (1932) has shown that available carbohydrates produced in one portion of a vine are readily translocated to clusters located in other parts of the vine. However, thinning alone usually results in little increase in size of seedless berries.

Girdling probably alters the levels of naturally occurring hormones and related compounds in the vine, by increasing the level above the girdle. Thinning may also result in more hormones per cluster, an assumption that also applies to carbohydrates. Synthetic growth-regulators, however, are generally believed to be much more restricted in their movement in the vine than are the soluble carbohydrates. For example, it is possible to kill one cordon of a vine with 2,4-dichlorophenoxyacetic acid without any injury to the other cordon. Perhaps movement of natural hormones is also restricted so that a shoot bearing no clusters furnishes no hormone to clusters on adjacent shoots.

In Thompson Seedless, girdling increased the available carbohydrates in shoot bases above the girdle and decreased them in the roots, whether the girdle was applied after berry shatter or was delayed for three weeks. In shoots, starch usually remained at a low level, while in roots the percentage of sugars was low. The girdle prevents the stream of elaborated food materials from moving to the roots from the shoots, and results in utilization of the stored starch in the roots.

Question of Weakening. Jacob (1931) believed that proper girdling of irrigated healthy Thompson Seedless vines resulted in no weakening. This statement is supported by the fact that many Thompson Seedless vineyards have been girdled for ten years or more with no apparent weakening of the

vines. The data in this paper also indicate that proper girdling is not weakening. Although girdling increased the levels of carbohydrates in the shoots and decreased it in the roots, by the dormant season the levels in ungirdled and girdled vines were about equal.

Time of Maximum Effect. The stimulus resulting from girdling has its maximum effect during flowering or after berry shatter when the berries are actively growing. It is during this period that a rise in level of natural hormone or carbohydrates, or both, would perhaps have the greatest effect. That the naturally occurring fruit-enlarging hormone may be at a suboptimal level at this period is indicated by the striking enlargement of berries that is obtained by applying the synthetic regulator 4-chlorophenoxyacetic acid at this time (Weaver, 1956).

Regulatory Agents. Murneek (1941) in his work on apples has suggested that growth substances may be the real regulatory agents, while nitrogen, carbohydrates, and other food materials may merely serve as substrates for these catalysts. Branch-ringing may cause the retention of growth substances above the ring, and thereby increase the general concentration from this point up.

Corrorboration by Previous Experiments. Previous experiments had indicated that early girdling when total soluble solids content of fruit was 5 or 6 per cent resulted in most rapid maturation of Red Malaga and Ribier grapes (Weaver, 1955). These experiments indicate that girdling in the first week in July failed to advance ripening. The results with Ribier in 1955 and 1956 were much the same as those obtained previously. Rapid advances in ripening were obtained when the degree Balling was 5.2 or 5.3, just at the onset of coloring. However, in 1955, girdling on August 17 when degree Balling was 9.2 also resulted in rapid maturation. Weaver (1955) showed that the earliest girdling in 1952 and possibly in 1953 resulted in the most rapid maturation, and that each of the first three girdlings in 1954 produced about an equal advance in maturity. However, with Red Malaga in 1955 the most rapid maturation resulted from girdling when degree Balling was 10.3. This is the only instance when girdling at 10.3 degrees Balling produced more rapid ripening than that performed at 5 or 6 degrees Balling. These results cannot be explained on the basis of degree-days heat (table 1) or by comparison with previous work (Weaver, 1952, 1955).

Girdling Ribier grapes in the latter part of July usually increased the percentage of sugars and starch in the shoots and cluster frameworks, and decreased it in the roots. By the dormant season, however, these percentages in girdled and ungirdled vines were about equal. This is evidence that girdling toward the latter part of the growing season does no permanent injury to the vine.

SUMMARY

The effect of girdling on development of Thompson Seedless, Red Malaga, and Ribier grapes was studied in various years from 1949 to 1956, inclusive, with special reference to carbohydrate nutrition of the vine.

Several experiments were performed in which one series of Thompson Seedless canes or trunks was girdled around the time of full bloom or berry shatter, and another series about three weeks later. The first girdling re-

sulted in an increased size of berry, but the late girdling usually resulted in less or none. The percentage of total available carbohydrates (sugars plus starch) in the shoots was increased by each girdling. Each girdling also markedly decreased the starch content of roots.

Thompson Seedless vines were trunk-girdled on June 11, 1954, and Ribier vines were similarly girdled on July 21, 1955. Samples of shoots and roots were taken for analyses at times of treatment and at later intervals, including one in the dormant season. The results showed that by the dormant season the percentages of sugars and starch in shoots and roots were about the same in girdled and ungirdled vines, indicating that proper girdling is not a weakening operation.

A comparison of single-girdling and double-girdling at berry shatter stage, girdling at shatter stage with girdle kept open throughout the growing season, and single-girdling on August 6, 1956, when degree Balling was 12, was made on Thompson Seedless. Vines girdled at time of berry shatter produced larger berries than controls. On vines where girdle was kept open ripening was hastened. At harvest, August 21, 1956, percentages of total available carbohydrates were greater in the shoots and cluster frameworks in the treatment where the girdle was kept open. The single and double girdle increased the percentage of available carbohydrates in basal shoot segments and cluster frameworks. In 1956 another experiment comparing effect of single and double girdling at berry shatter confirmed results of previous experiment.

In 1955 Red Malaga grapes were girdled on one of four different dates. Girdling on August 8 when about 8 per cent of the total surface of fruit was colored resulted in the most rapid maturation. A similar experiment with Ribier in 1955 also showed that girdling on August 8 at the beginning of coloration produced most rapid maturation, but in 1956 the most rapid ripening of fruit resulted from girdling on July 27 when coloring was just beginning.

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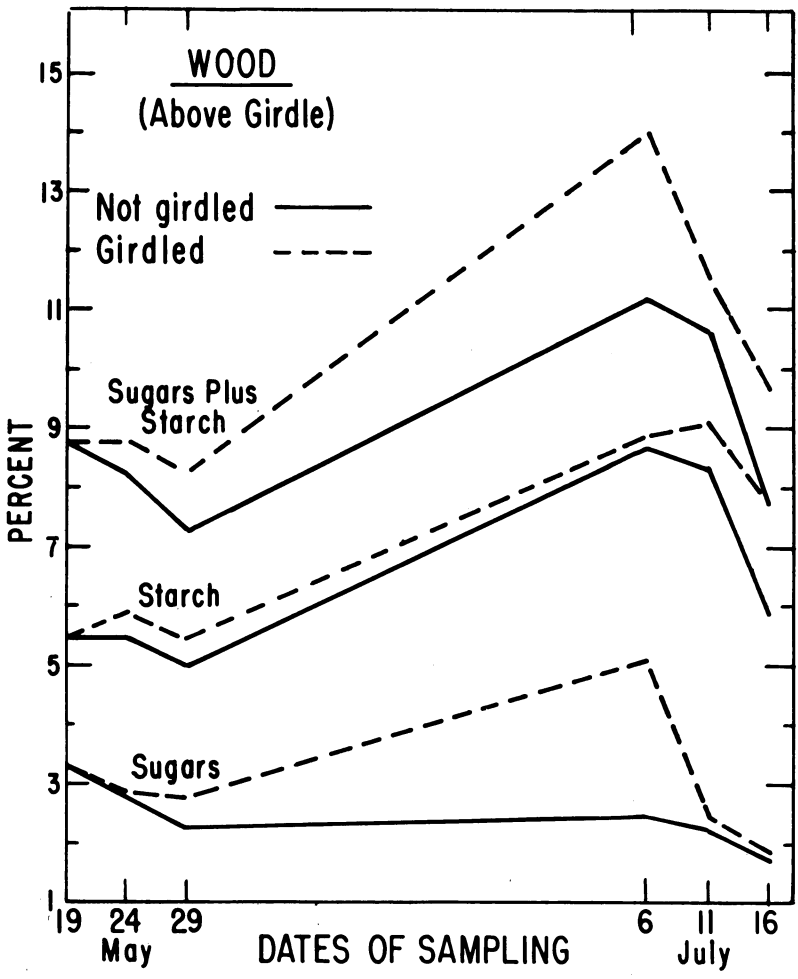

Fig. 1. Effect of cane girdling of Thompson Seedless on sugars and starch in cane wood apical to the girdle.

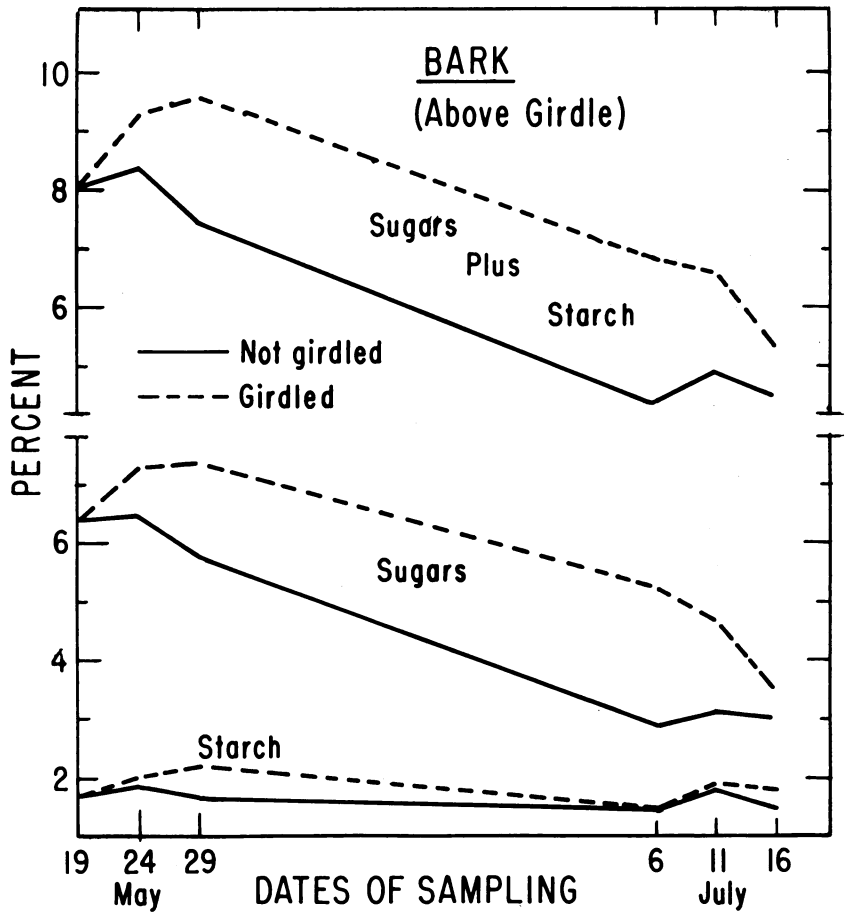

Fig. 2. Effect of cane girdling of Thompson Seedless on sugars and starch in cane bark apical to the girdle.

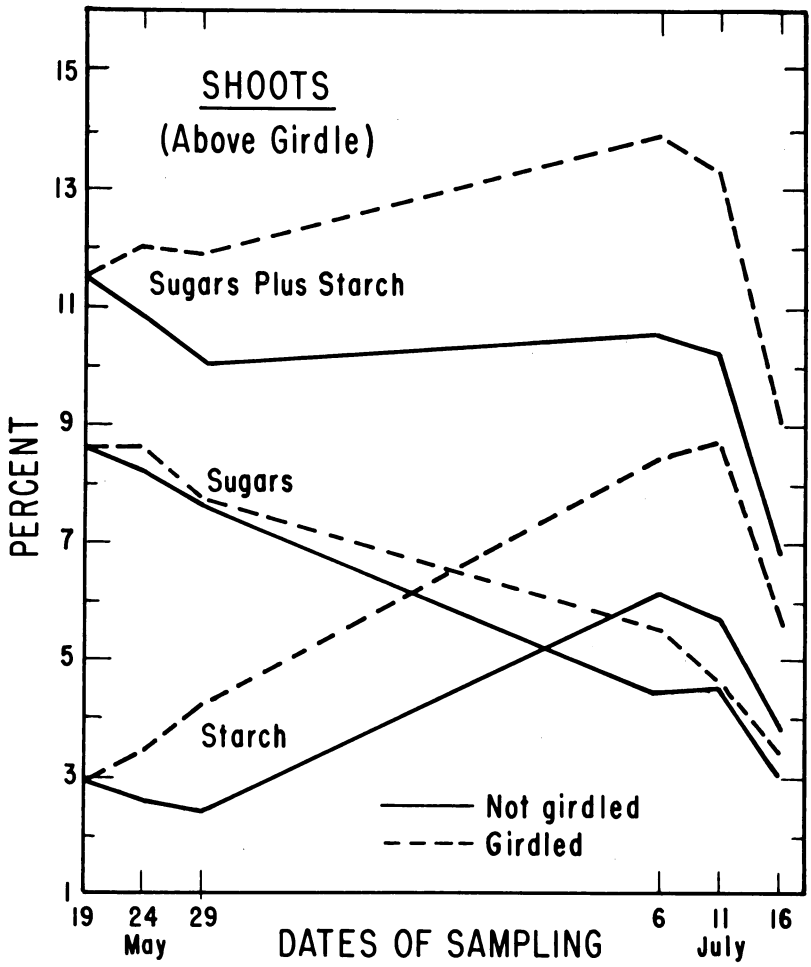

Fig. 3. Effect of cane girdling of Thompson Seedless on sugars and starch in shoot bases apical to the girdle.

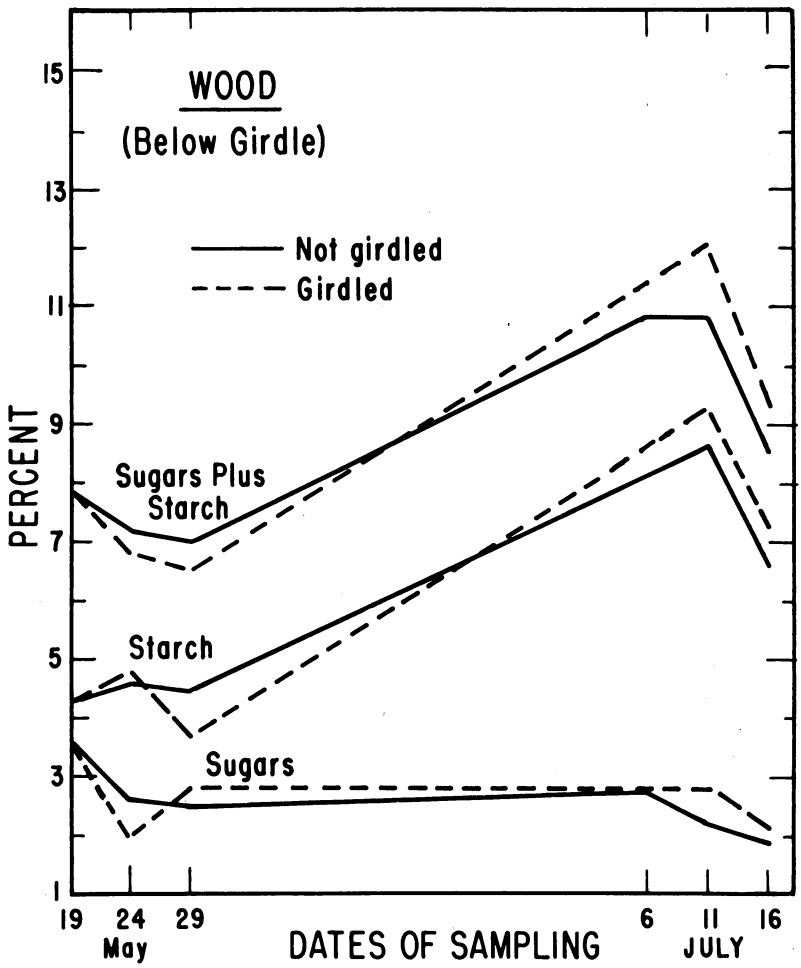

Fig. 4. Effect of cane girdling of Thompson Seedless on sugars and starch in cane wood basal to the girdle.

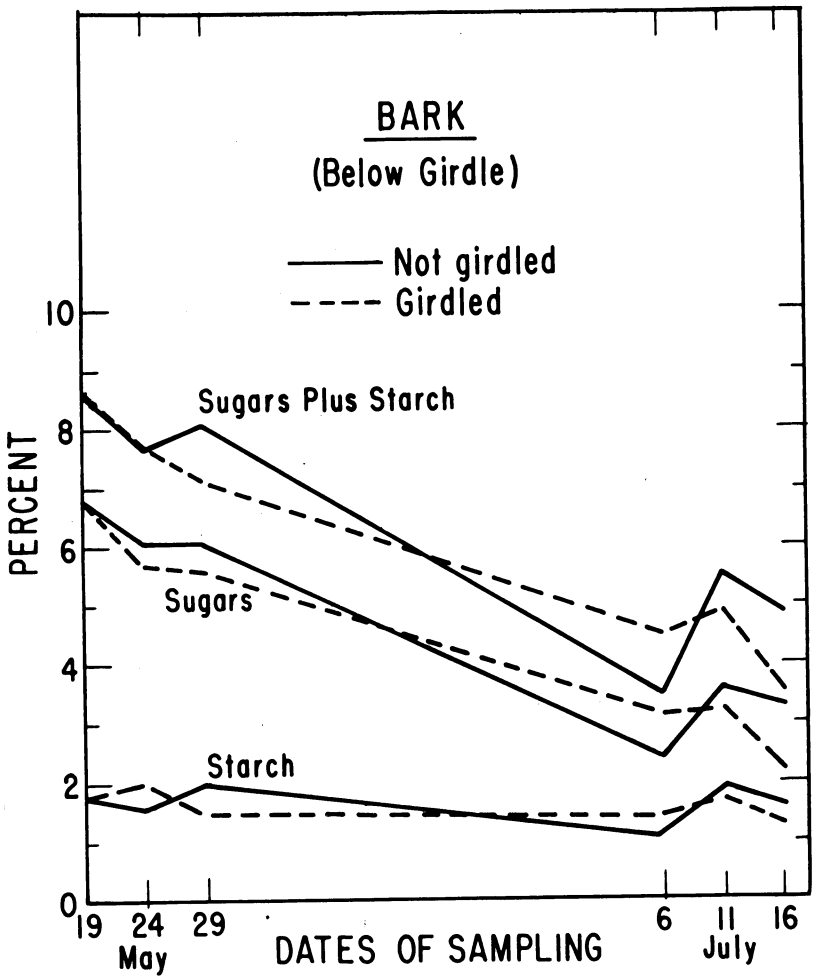

Fig. 5. Effect of cane girdling of Thompson Seedless on sugars and starch in cane bark basal to the girdle.

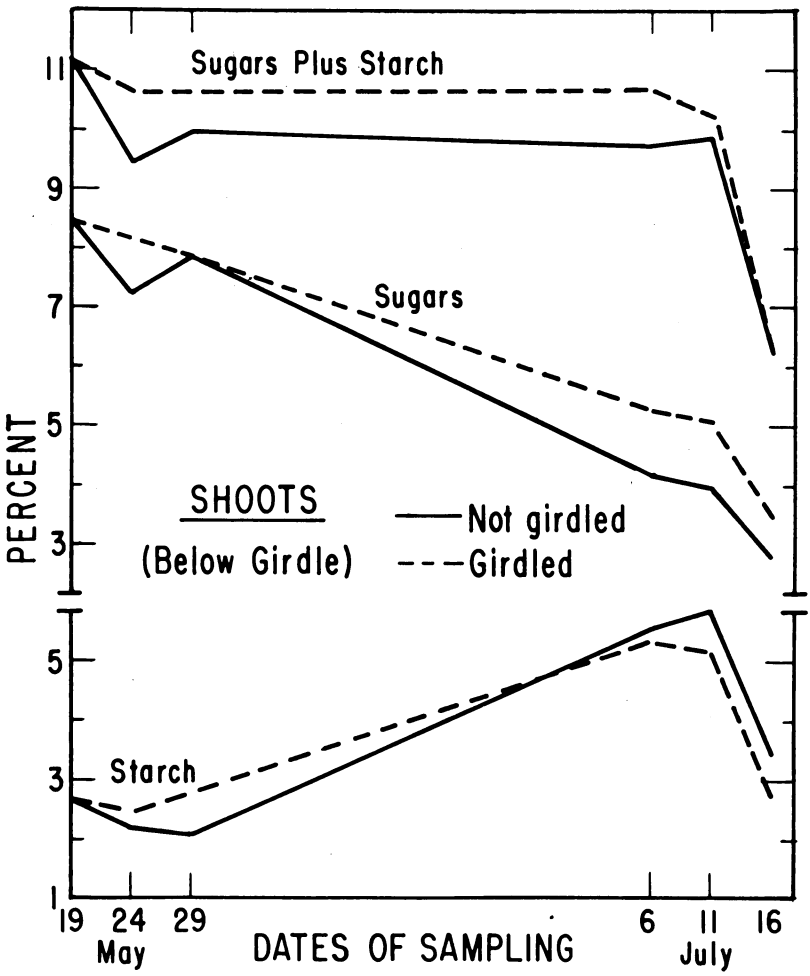

Fig. 6. Effect of cane girdling of Thompson Seedless on sugars and starch in shoot bases basal to the girdle.

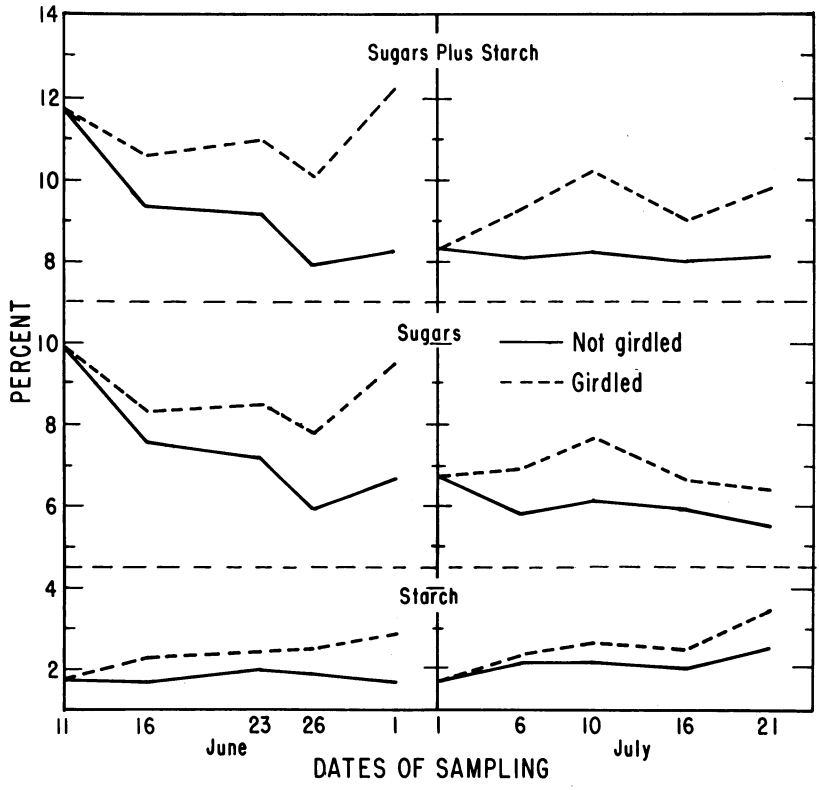

Fig. 7. Effect of trunk girdling Thompson Seedless on June 11 (left) or July 1, 1953 (right) on sugar and starch content of basal portions of shoots. Solid line, ungirdled, and broken line, girdled. The L.S.D. between girdled and ungirdled treatments for sugars plus starch on any given date at the 5 per cent level is 1.27.

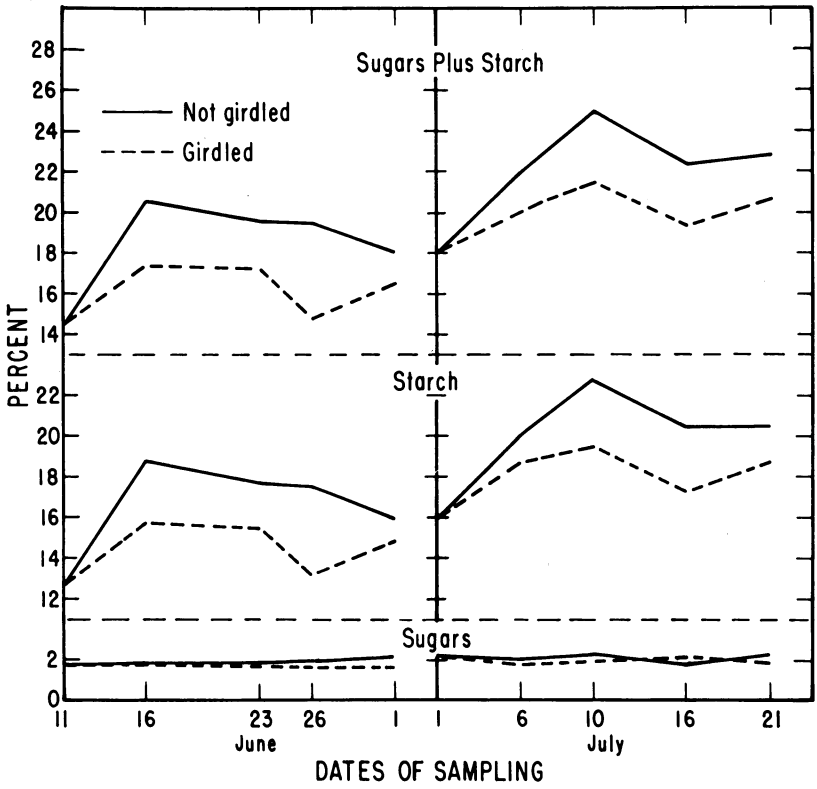

Fig. 8. Effect of trunk girdling on June 11 (left) or July 1, 1953 (right) on sugar and starch content of medium-sized roots. Solid line, ungirdled, and broken line, girdled. The L.S.D. between girdled and ungirdled treatments for sugar plus starch on any given date at the 5 per cent level is 2.80.

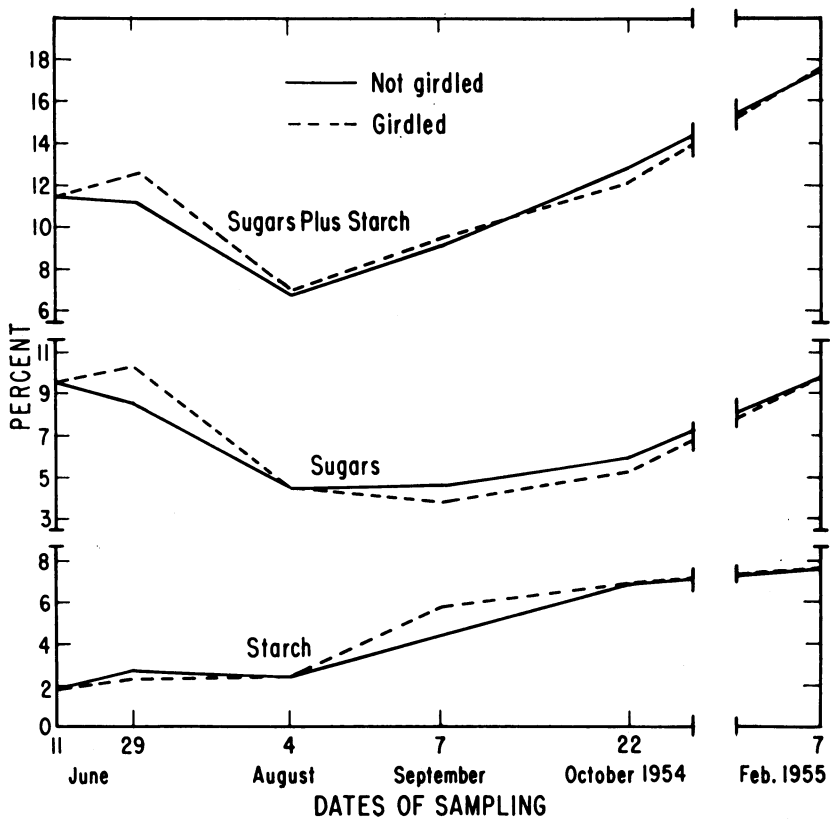

Fig. 9. Effect of trunk girdling Thompson Seedless grapes on June 11, 1954 on the available carbohydrates (sugars and starch) in middle shoot segments.

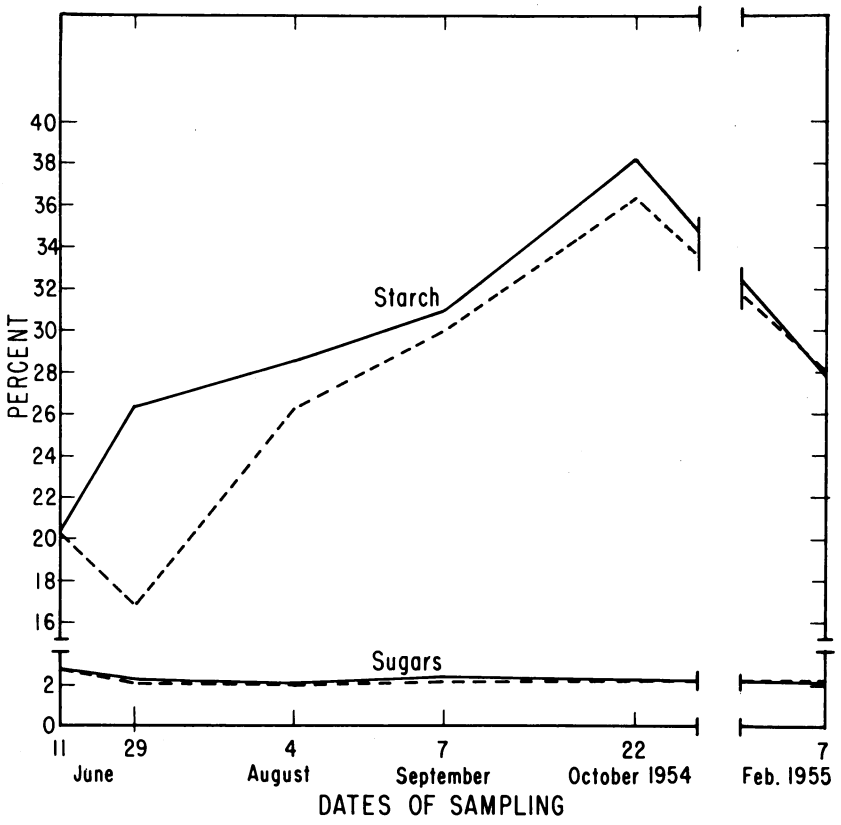

Fig. 10. Effect of trunk girdling Thompson Seedless grapes on June 11, 1954 on the available carbohydrates (sugars and starch) in small roots. Solid line, ungirdled, broken line, girdled.

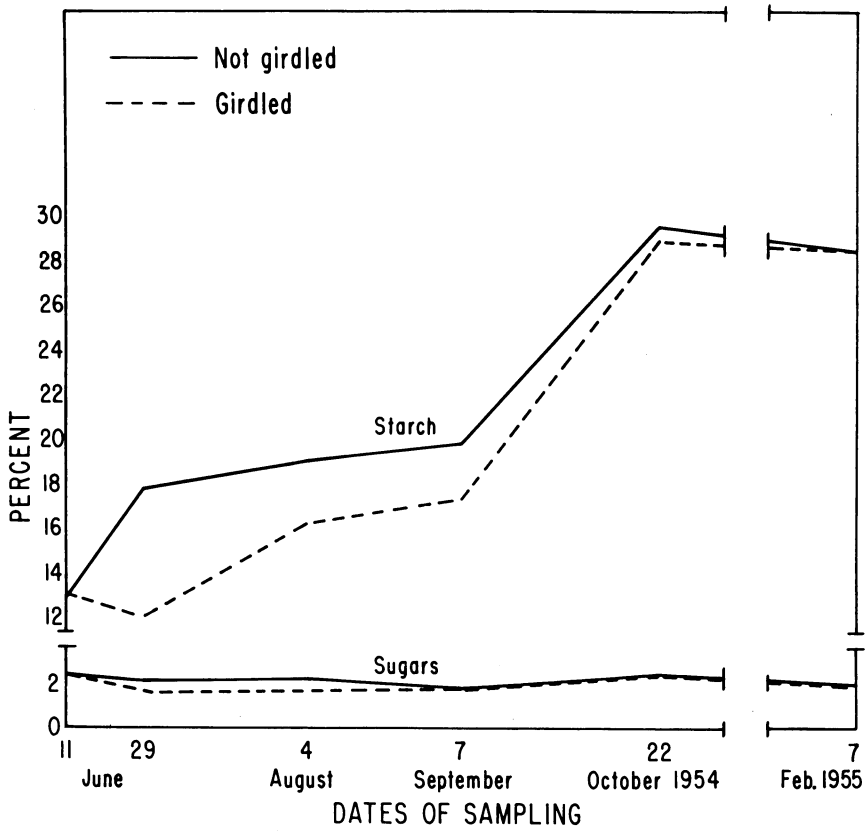

Fig. 11. Effect of trunk girdling Thompson Seedless grapes on June 11, 1954 on the available carbohydrates (sugars and starch) in large roots.

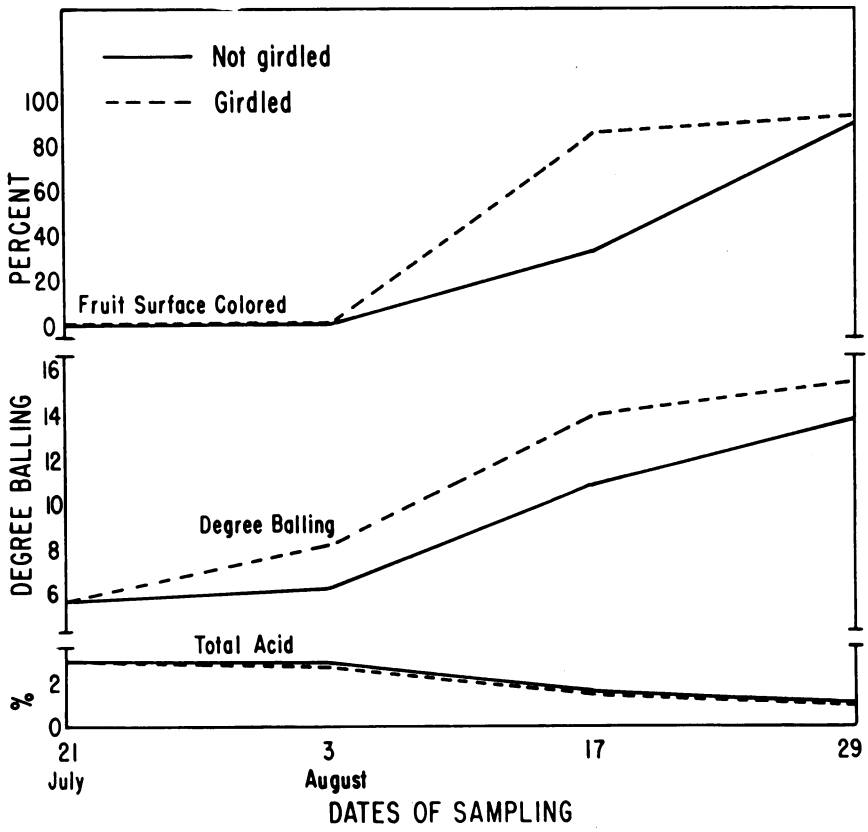

Fig. 12. Effect of girdling Ribier grapes on July 21, 1955 on the color, degree Balling reading, and total acid of fruit.

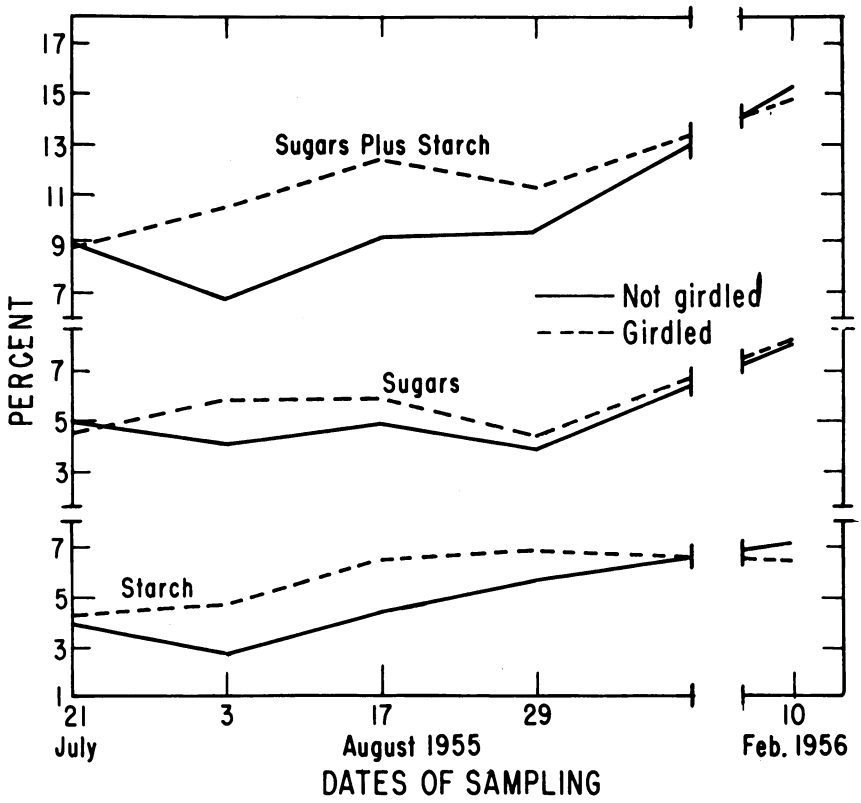

Fig. 13. Effect of trunk girdling Ribier grapes in 1955 on sugar and starch content of middle shoot segments. The L.S.D. between girdled and ungirdled treatments for sugars plus starch on any given date at the 5 per cent level is 1.92.

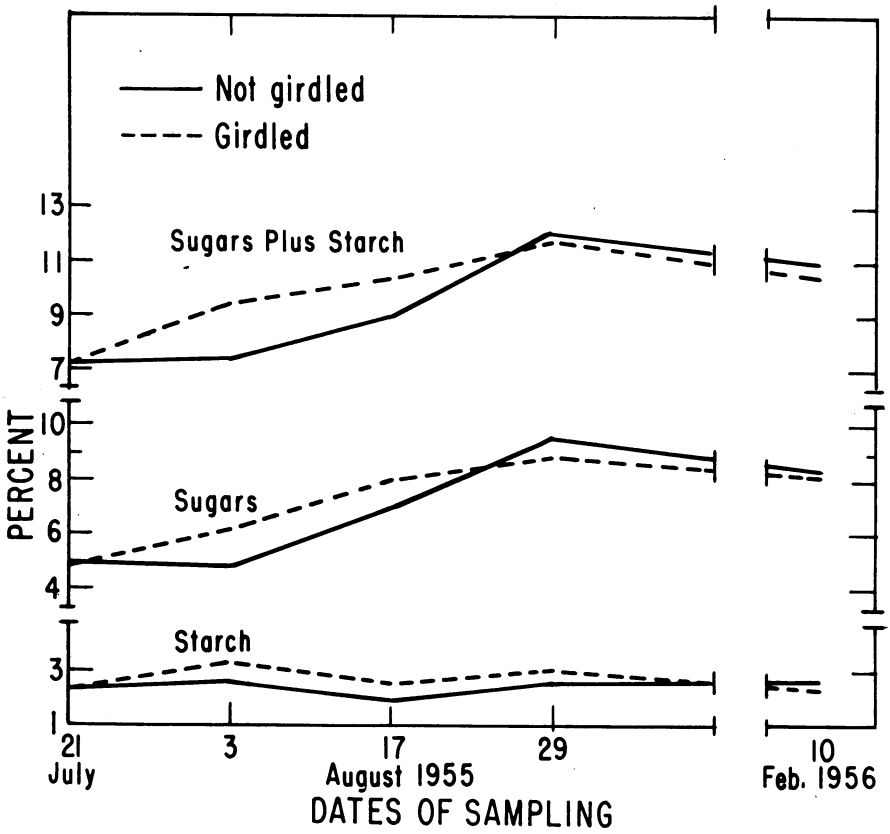

Fig. 14. Effect of trunk girdling Ribier grapes on July 21, 1955 on sugar and starch content of cluster frameworks.

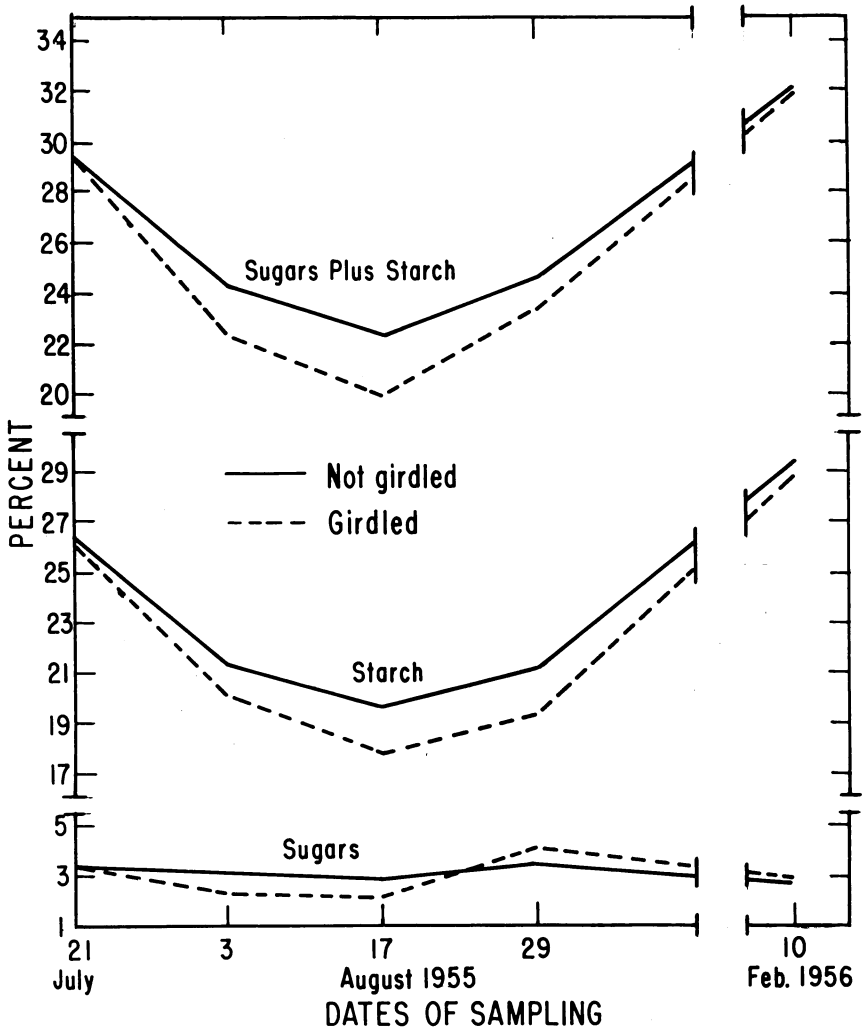

Fig. 15. Effect of girdling Ribier grapes on July 21, 1955 on sugar and starch content of large-sized roots.

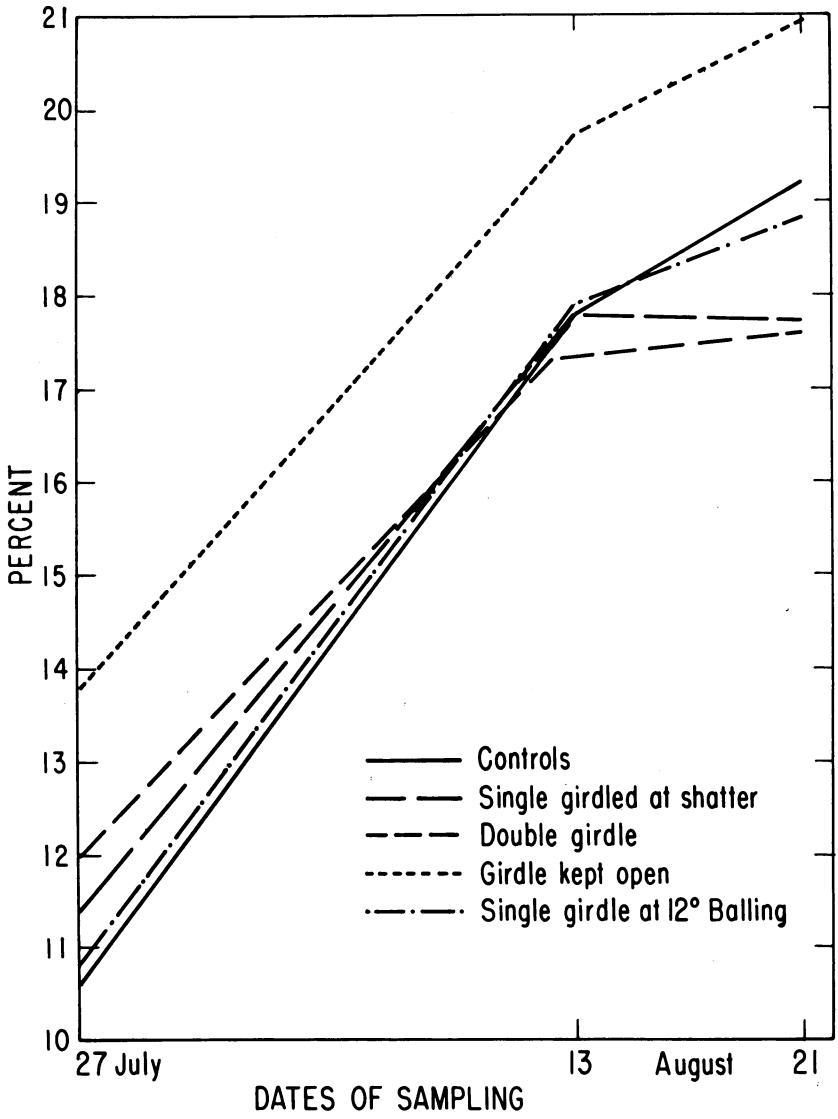

Fig. 16. Effect of various girdling techniques on percentage of total soluble solids in fruit of Thompson Seedless grapes. The highest degree Balling resulted when girdle was kept open.

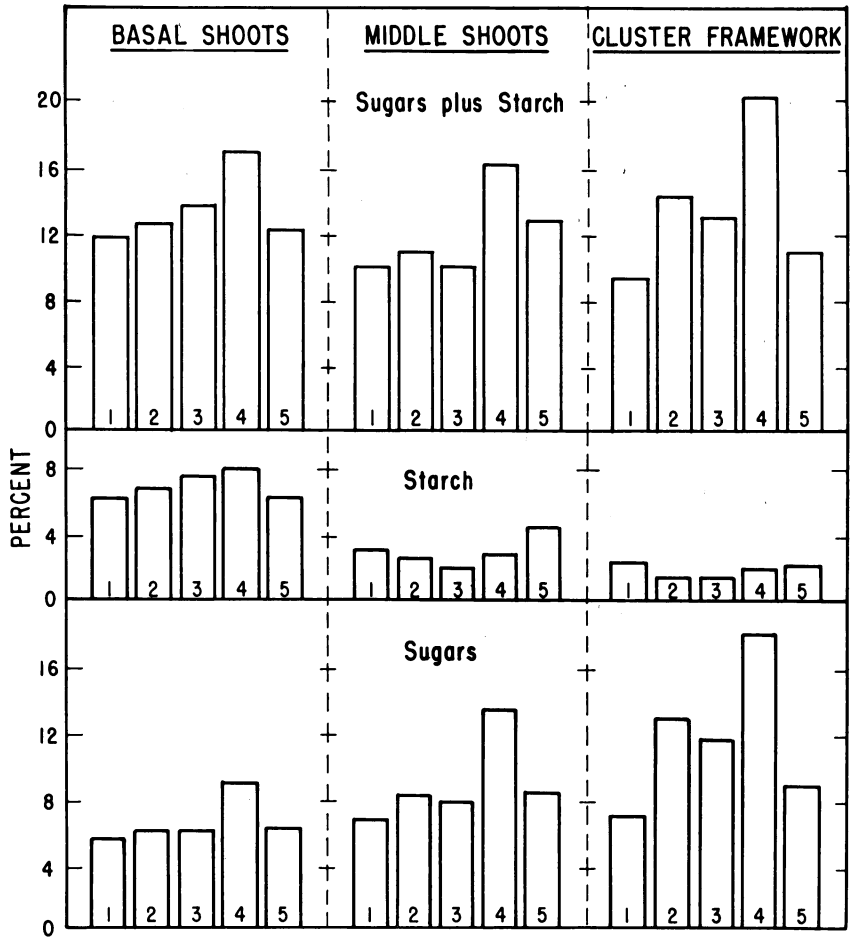

Fig. 17. Effect of various types of girdling on the total available carbohydrates (sugars plus starch) in the basal and middle shoot segments and cluster frameworks at harvest (August 21, 1956). 1, Ungirdled control; 2, single girdle at berry shatter; 3, a double girdle at berry shatter; 4, girdle kept open; and 5, single girdle at 12 degree Balling. The L.S.D. between different types of girdling treatments at the 5 per cent level for total available carbohydrates (sugars plus starch) are: basal shoot segments, 1.3; middle shoot segments, 2.4; and cluster frameworks, 2.5.

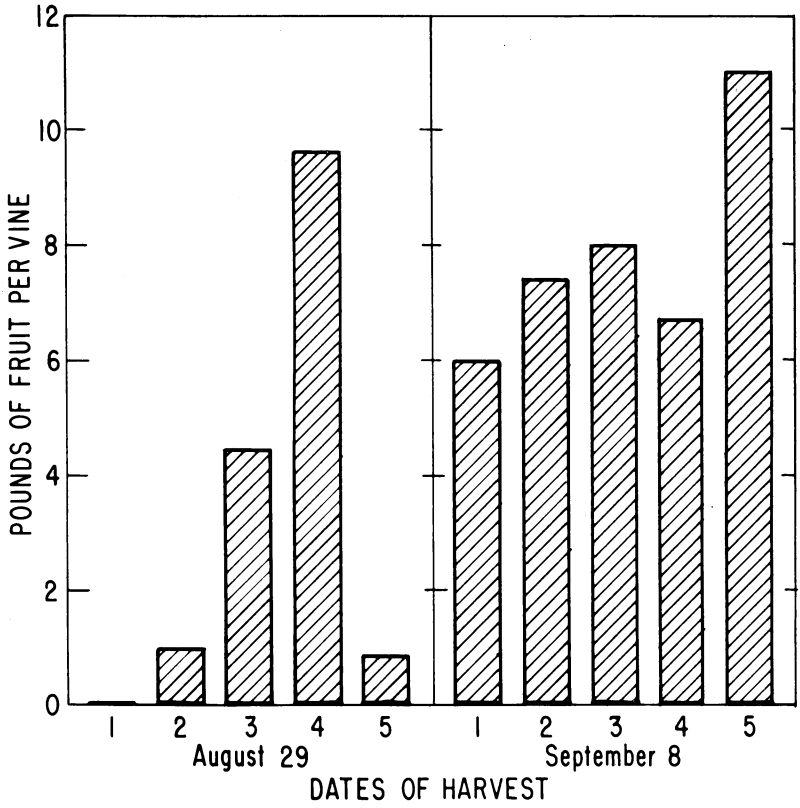

Fig. 18. Average weight (lbs.) of fruit per vine removed at first and second pickings from girdled and ungirdled Red Malaga vines in 1955. 2, 3, 4, and 5 represent girdlings on July 7, July 19, August 8, or August 17, respectively. Not girdled, 1. Note that vines girdled on August 8 ripened most rapidly.

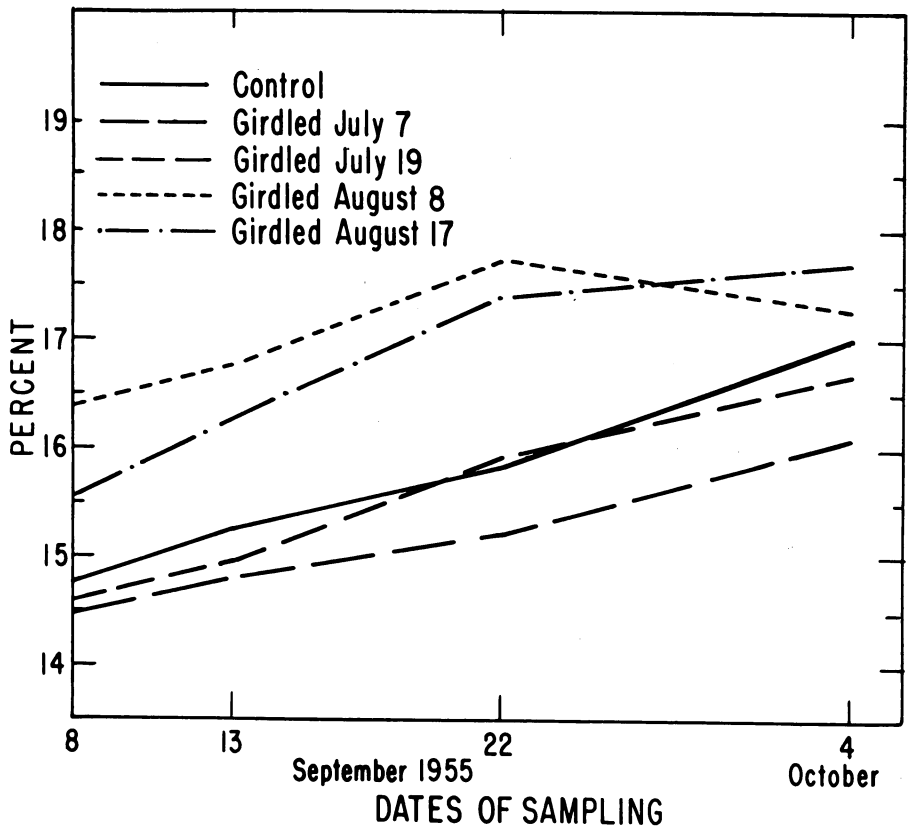

Fig. 19. Effect of girdling Ribier grapes at different times in 1955 on the percentage of total soluble solids. Note that girdling on August 8 or August 17 resulted in the most rapid maturation.

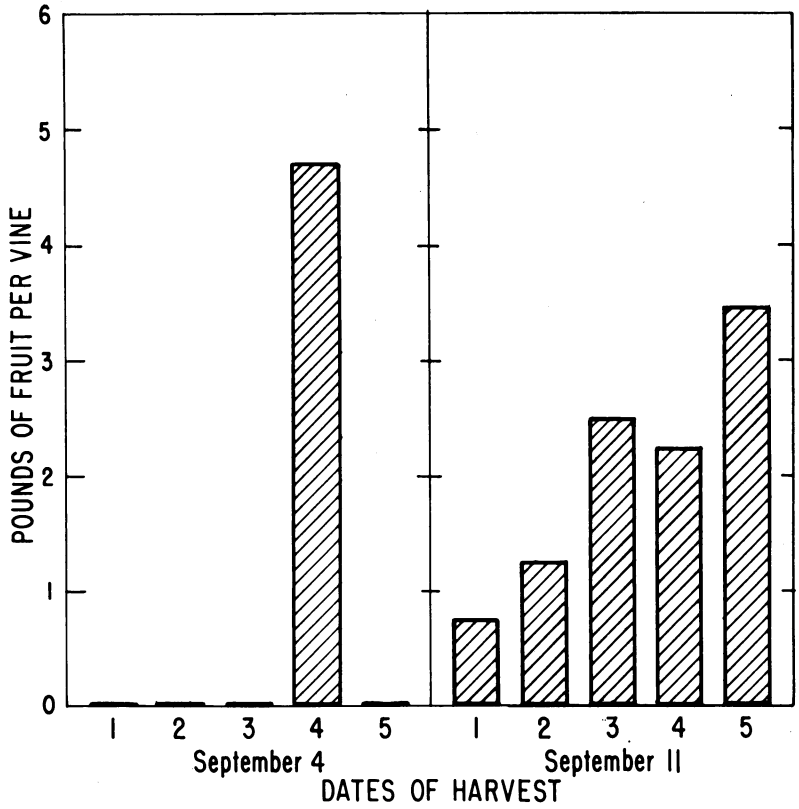

Fig. 20. Average weight (lbs.) of fruit per vine removed at first and second pickings from girdled and ungirdled Ribier vines in 1956. 2, 3, 4, and 5 represent girdlings on June 27, July 16, July 27, and August 8, respectively. Not girdled, 1. Fruit girdled on July 27 resulted in most rapid ripening of fruit.

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