THE CONCORD GRAPE -- Pruning and Chemical Studies in Relation to the Fruiting Habits of the Vine.

by

A. Albert Lee Schrader.

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By A. Lee Schrader

INTRODUCTION

Grapes have been the subject of much observation and study from many angles but especially in regard to the pruning and training of the vine. Some of the pruning systems have resulted in large decreases in the production of fruit largely due to ignorance of the fruiting habits of the vine. In all methods of pruning which are used successfully, a knowledge of the fruiting habits of the vine has been found essential. Observations have been relied upon to furnish reliable indices in the selection of the wood at pruning time. In the same way, experience and observations have been used to formulate general rules in regard to the pruning of young vines in establishing a vineyard.

The present experiments were designed first to see if some definite relation existed between the growth and fruiting habit of the cane and, if so, it was hoped that a better measure would be furnished for selection of the most fruitful type of cane. Second, a chemical study of the various nodes of the shoot and cane during the year was conceived in an attempt to correlate the chemical constitution of the nodes with any observed differences in the fruitfulness of the various nodes of the cane. Third, a study of the fruitfulness of the buds on the various nodes on the cane was planned in conjunction with the chemical study of the nodes. Fourth, a chemical study of the roots and tops of the vine during the dormant season was made in order to study any possible translocation of reserves as reported in French investigations. Their results were applied in France in regulating the time of pruning and the time of taking cuttings. Fifth, the severe pruning practice as recommended for young vines was modified to determine if this severe pruning was necessary to develop a full bearing vine. Sixth, root studies were made to measure the effects of pruning on the root development of young vines.

HISTORICAL REVIEW

Pruning of the vine is an established practice which is undoubtedly the most important means of regulating the growth and fruiting of the grape. The fact that this pruning of the grape consists of the removal of the greater part of the new growth produced in the previous season will serve to emphasize how pruning becomes such an important factor in its regulatory influence. Bioletti (1911) has estimated that 90-98 percent of the new wood of the vine is removed at pruning time which is in great contrast to the amount of wood which is pruned from tree fruits. Since the practical vineyardist has used this apparently simple means of controlling the vine under culture, there have arisen various methods of pruning and training the vine which have, more or less, resulted in an apparent confusion of practices.

In regard to the pruning of young vines in establishing a vineyard, it has become a recommended practice to prune the vine at planting time to two or three buds although no experimental work has been reported to prove that such a practice is the most desirable. It is unnecessary to cite all the references on this point. At the end of the first season's growth, this severe pruning is again generally recommended, removing all cane growth except two or three buds on one cane. Cullinan (1922) states that such a practice provides a strong growing trunk, and Maney (1915) and Bioletti (1914) maintain that a strong root system is thus developed. Most of the recommendations are based upon the theory that root growth will be favored by cutting away the top. However, Partridge (1923) under Michigan conditions and the writer (1923) under Maryland conditions have recently suggested that a single cane may be brought to the top wire to form a trunk at the end of the first year provided that the vine has made sufficient growth. Maney (1915) in Iowa recommended the development of a single shoot during the first season and bringing the cane to the lower wire at the end of the first year.

Contrary to the theory that suppressing the top growth promotes root development, the writer (1923) reported that the root systems of two year old Concord vines were not increased by pruning to two buds in the two years after planting. The work of Richey and Bowers (1924) more recently reported shows that one year old Concord "vines with the largest tops had the largest root systems." A larger root system was produced on the vine with two shoots than on the vine with only one shoot.

Previous recommendations for pruning of the young vine after the second season generally are found to consist of tying a single cane to the trellis which is pruned to form a trunk to the top wire. However, some writers, as Lake (1901.), Knapp (1914), Crider (1923) and Gladwin (1911), recommend that a single cane should be pruned to reach the lower wire and in the next year the trunk should be extended to the top wire using a cane arising near the lower wire.

Pruning of the bearing vine, although widely varied in practice, follows certain established rules in respect to the fruiting habits of the vine. Thus, with either the American or European grapes, the vines produce more fruit buds than can be matured without greatly devitalizing the vine. Keffer (1906) found that unpruned canes of the American varieties, although yielding heavily, had a greatly reduced shoot growth with a consequent large decrease in yield the following season. Ravaz (1906) holds the opinion that overbearing is the cause of the death of many vines in France and other countries. Bioletti (1908) presents the theory that too large a crop reduces the storage of reserve materials in the canes and buds [illegible], which is followed by a weak growth in the spring. Later, Bioletti (1922) reports that Sultinana vines with 80 feet of bearing canes per vine produced poorly ripened shoots of 5 to 15 inches in length. All writers have recognized the fact that the vine will overbear with subsequent disastrous results and that only a limited number of fruit buds can be left at pruning time. Cooper (1922) recommends that 30 buds per vine is the proper number to leave. Knapp (1914) suggests 30 to 80 buds per vine. Gladwin (1919) under New York conditions gives 32 to 40 buds as the ideal number of buds. Hedrick (1919) mathematically calculated that 15 to 30 buds would give a yield of 15 pounds of fruit on American varieties. With the Concord grape in Michigan, Partridge recommends 40 buds per vine as the average which should be decreased for weak vines and increased for strong vines. Colby and Vogele (1924) found that the yield of Concord grape vines increased with the number of buds left but beyond 55 buds the bunches and berries were smaller.

Various observations and records agree on the fact that the various buds on the cane differ in fruitfulness, especially that the basal buds of the cane are poorly fruitful. Keffer (1906) has reported that the fourth to sixth buds from the base are the most fruitful buds on a cane pruned to twelve buds and a decrease in yield occurs as the tip and base are approached. Kovessi (1901) states that well ripened canes of Vinifera grapes commence fruiting at the third bud, whereas poorly ripened canes do not have fruit buds until the fifth bud. Cooper (1922) has noted an increase in yield from the first to the third buds, an equal yield for buds three, four and five, and then a marked decrease in yield to the seventh bud. Bioletti (1911) observed with the Vinifera grapes that buds one and two are usually poorly fruitful, buds four and five show the greatest fruitfulness and buds beyond five are equally fruitful, but less than buds four and five. Partridge (1921) found that the yield increased up to the fourth bud and then decreased to the end of pruned canes of the Concord vine. Later, however, Partridge (1922) reported that vines growing on a sandy loam showed a maximum yield at the eighth bud, vines on a medium loam had a maximum at the ninth bud and vines on a heavy loam increased in productiveness from the base to the tip of the cane. The investigation of Chauzit and Barba (1904) on systems of pruning of the Vinifera varieties shows the effect of the low yielding basal buds on the yield; thus, vines pruned to one bud spurs produced 3.131 kilograms per vine, vines pruned to two bud spurs yielded 4.451 kilograms per vine, vines pruned to three bud spurs yielded 4.841 kilograms and longer canes produced correspondingly greater yields. In comparing the spur and long cane systems of pruning of the Concord grape, Maney (1915) found that the long cane system yielded 41 percent more fruit than the spur system which is due to the low yielding basal buds that were utilized exclusively in the spur system, whereas the long cane system also makes use of the higher yielding portion in the middle of the cane. Gladwin (1919) found that the horizontal arm spur system gave low yields and inferior fruit.

It has also been frequently observed by various investigators that fruit buds are not formed uniformly on all canes of the vine but that some canes may be so-called sterile canes and others, fruitful canes. In general, it has been reported that very vegetative canes of large diameter, called "bull" canes, arising from wood older than two years, as suckers and water sprouts, are usually not provided with fruit buds and are hence a non-fruiting or sterile canes. The most fruitful canes are those of medium diameter which arise from the two year old wood. A study of the relation of diameter of cane to the fruitfulness of the cane was made by Partridge (1922) in which he finds that the "pencil-size" canes or canes of about a quarter of an inch in diameter gave the greatest yields. The writer (1923) has shown that this "pencil-size " cane may vary in productiveness depending on the length of the cane growth. A medium length of cane growth of this pencil-size diameter gave the greatest yield.

Chemical analyses of the grape, especially of the fruit itself, have been reported by numerous workers. Kovessi (1901) and (1911) in an investigation on the ripening of grape canes found amuch greater amount of starch in the well ripened cane than in the poorly ripened cane of Vitis rupestris, expressed in the percentage of volume, and shows that ripening of the cane is accompanied by an increased number and size of starch grains and a thickening of the walls of wood-cells and bast fibers. He found starch in the xylem, medullary rays and the phloem. Zeissig (1901) and (1902) reported essentially the same findings as Kovessi, following micro-chemically the starch and anatomical changes in the shoots of Vitis Taylor from August 1 to October 15. Zeissig noticed that the starch accumulated at first in the medullary rays and by September 21 the wood cells were filled with starch and some starch was found in the phloem which increased in amount by October 15. In a study of summer topping and pinching of two varieties of Vitis vinifera, Bioletti and Flossfeder (1918) analyzed some canes in December at pruning time and noted little difference in carbohydrate content between the summer pruned canes and the canes not pruned in the previous summer, although the ash and moisture content was lower in the latter canes. Kling (1913) cites various feed analyses in regard to the food value of green shoots for animals but these analyses are not applicable to any pruning questions. Chippaz (1908) made analysis of vines of Vitis riparia during the growing season and reported that three-fourths of the nitrogen was taken up by the vine before the flowering season. Griffon (1905) in respiration studies on young shoots of the grape, concludes that young leaves are not parasitic upon the cane but actually assimilate materials.

The work of Vidal (1911) on chemical changes and translocation in the vine is perhaps most interesting in this connection. Vidal analyzed 5 year old Vinifera vines during the dormant season, early spring and early fall for total carbohydrates content obtained by hydrolyzing dried and ground tissue in boiling 10 percent hydrochloric acid (0.117). He noted some decrease of carbohydrates in the canes immediately before or after leaf fall (November 23 was the date of leaf fall). Thus on November 9 the canes contained 29.8 percent of carbohydrates and on December 8, a content of 25.8 percent. This decrease in carbohydrates in the canes is considered as a movement of reserves to the root, probably an adaptive response on the part of the vine to store materials in the part of the vine that is least liable to cold injury. After this so-called "inversion" Vidal suggests that the reserves slowly pass from the roots to the canes since he found a decreased carbohydrate content of the roots and a slight increase in the canes. On the basis of these analyses, Vidal recommends that pruning be done after mid-winter after the carbohydrates have moved to the roots. On the other hand, he believes that cuttings should be taken at leaf fall before the reserves go to the roots. The roots are regarded as the reserve storage organ of the vine. A content of 9.14 percent of carbohydrates was found in young shoots on May 23.

Fruit bud formation in the grape has received little attention as to the exact time at which the flower primordia are laid down. Goff (1899) and (1901) and Bioletti (1911) have made observations that fruit bud formation occurs in the summer previous to blossoming. Goff (1899) and Behrens (1898) state that a single bud contains in embryo a shoot with blossom primordia. Behrens (1898) reports that shoot primordia appear when the buds first develop in the axils of the leaves and subsequently the blossom primordia appear. Studies in October by Goff showed flower primordia in the buds.

GENERAL METHODS AND MATERIALS USED IN THE MARYLAND EXPERIMENTS.

A. VINEYARD USED.

Ninety-six one year old Concord vines, propagated from three bud cuttings, were planted in the spring of 1921, in a gravelly loam soil having a slight slope. The vines were spaced ten feet apart in the row with eight feet distance between the rows. A two wire trellis was put up, designed for the four cane single stem Kniffin system of training with the lower wire three feet from the ground and the upper wire two and one-half feet above the lower wire. This system of training has proved to be most productive under Maryland conditions as shown by Auchter and Ballard (1922).

This vineyard furnished material for the pruning studies on young vines and the subsequent studies on a mature bearing vineyard.

B. VINES GROWN IN GALVANIZED IRON CANS.

In order to facilitate chemical and growth studies of roots of young vines, large cylindrical galvanized cans measuring two and one-half feet in depth and twenty inches in diameter were filled with a gravelly loam suitable for the growth of vines. A small hole one-half inch in diameter was drilled in the side of the can close to the bottom to insure drainage. A uniform lot of one year old Concord vines propagated from cuttings were planted in these cans in the same way that the vines are planted in the field. The cans were then lowered with a chain-block into large sewage tile which had been set vertically in the ground with the top of the tile about 3 inches above the level of the surrounding soil. This arrangement protected the cans from the heat of the sun and approached natural conditions. Water was supplied to the cans during dry periods of the season but usually the rain sufficed to maintain the soil moisture. The developing shoots were allowed to lay on the ground and staked down to prevent the wind from injuring the shoots.

Records were taken of the growth made by the shoots and the total leaf area of each vine at several times during the season.

During the dormant season, the vines were removed from the cans for the purpose of studying the root development and to obtain chemical samples of roots and tops. A chain-block was used to remove the cans from the tiles. After removing the tops of the vines the cans were then taken to a nearby slope where a can could be placed on its side to aid in washing out the soil. A stream of water from the nozzle of a garden hose sufficed to wash the soil from the cans with the minimum loss of roots in the washings. The roots were then washed free of all soil and organic matter and allowed to dry for approximately a half hour after which the green weight was obtained. Both roots and tops were cut into small pieces and dried in an oven at 85^{o}-90^{o} C. for 72 hours for dry weight and chemical determinations.

C. METHODS OF CHEMICAL ANALYSIS.

Sampling and preservation of material. All samples of growing shoots were taken on a clear day about 10 o'clock in the morning. Ten to twelve shoots were taken at each sampling, selecting shoots of approximately the same length and diameter, each shoot bearing blossoms or fruit on nodes two, three, and four, counting from the basal end of the shoot. The shoots were removed by cutting close to the one year wood, and all leaves were cut off close to the axillary bud. Nodes one to nine inclusive (counting from the basal end) were taken from each shoot retaining about one inch of the adjacent internodes with each node. Analagous nodes of the various shoots were placed together in a weighed and stoppered Erlenmeyer flask so that a sample of each node up to and including the ninth node was obtained. The early samplings of the young shoots which were quite short, did not, of course include nine nodes. Each sample was weighed for green weight and immediately dropped in hot alcohol which was then refluxed for 30 minutes at 70° C. The samples were prepared for analysis by decanting off the preserving extract and drying the solid material in an oven at 80°C for twenty-four hours. After weighing, the dry material was ground to pass a 40 mesh sieve, and the extract was made up to 200 cc. volume.

Samples taken during the dormant season were simply cut up in small pieces and dried in an oven at 85-90°C for 72 hours.

Reducing Substances. About a three gram portion of the ground sample, well dried, was placed in a Sohxlet siphon extraction apparatus and extracted for three hours with 150 cc. of 50 percent alcohol. Aliquots of preserving extract and dried material were used in case of samples preserved in alcohol. The alcohol was removed from the extract on a water bath and water was added to about 150 cc volume. The extract was then cleared with a few drops of saturated solution of neutral lead acetate. The extract was made to 250 cc volume, filtered and the excess lead removed with anhydrous sodium carbonate. The reducing power of the extract was then determined by the Bertrand modification of the Munson-Walker method as given by Matthews' Physiological Chemistry, 1921. The result was expressed in terms of dextrose.

Total Sugars. A 50 cc. portion of the sugar extract was hydrolyzed by hydrochloric acid (5cc of concentrated acid) at room temperature for 24 hours, neutralized with anhydrous sodium carbonate and made up to 100 cc. volume. The reducing power of this solution was determined as in the method for reducing substances and reported as dextrose.

Sucrose. The difference between the reducing substances and total sugars is reported as sucrose in terms of dextrose.

Starch. About a 1 gram portion of the dry residue from the sugar extract was ground to a fine powder (to pass 100 mesh sieve) in a mortar using small quantity of white quartz sand to facilitate grinding. The powder was transferred quantitatively to a 250 cc beaker to which was added 100 cc of distilled water. After standing 15-20 minutes, 50 cc of boiling water was added and the beaker (covered with a watch glass) was suspended in a water bath 100°C for one hour. After removing the beaker from the bath and cooling to approximately 40° C., 5 cc. of filtered saliva was added and mixed thoroughly. The material was then digested one hour in an oven starting at 40°C. The oven reached 50°C in about 30 minutes. After digestion the beakers were again immersed in a water bath at 100°C for 15 minutes after which a second digestion with 5cc. of saliva for one hour was sufficient to change all starch to sugar. Microchemical test with I K I showed no starch present in the digested material. After complete digestion, the beakers were placed again in a water bath above 80°C for 10 minutes. The material and extract was then cooled and transferred to a 200°cc. Kohlrausch flask made to volume* and filtered. A 100 cc. portion of the filtrate was hydrolyzed by adding 10 cc of concentrated hydrochloric acid and boiling for two and one half hours. The extract was neutralized with anhydrous sodium carbonate, and the reducing power determined as in the procedure cited. The result is expressed in terms of dextrose.

* At this point, the alcoholic clearing of Walton and Coe's Method (1923) was found to be unnecessary since 65 percent alcohol caused no precipitate.

<u>Total Hydrolyzable Polysaccharides</u>. About a half gram portion of the dried residue from the sugar extraction was hydrolyzed by refluxing with hydrochloric acid (10 cc. of concentrated acid to 100 cc. of water) for two and one-half hours. This extract was neutralized with anhydrous sodium carbonate and made up to 250 cc volume, and the reducing power was determined as in the above procedure. The result is expressed in terms of dextrose.

<u>Total Nitrogen</u>. The Kjeldahl method with a modification by Gunning, Jodlbauer and Forster, to include nitrates was used in this work.

<u>Soluble Materials</u>. The difference in weight between the total dry material before extraction with alcohol and the dried residue after extraction represents the soluble material.

<u>Moisture and Dry Weight</u>. With sample preserved in alcohol 10 cc. of the preserving extract was placed in a 50 cc. beaker and dried to constant weight in an oven at 75°C. The total dry weight of the extract was calculated and added to the dry weight of the solid material to obtain the total dry weight of the sample. The dry weight of other samples not preserved in alcohol was obtained directly after drying. The mositure was determined by difference.

EXPERIMENTS AND RESULTS

A. Pruning Studies.

PRUNING YOUNG VINES

Yield and Early Bearing Studies.

Ninety-six one year old Concord vines were planted in the spring of 1921 in a well drained gravelly loam and all vines were pruned to two buds. An application of manure resulted in a strong growth of shoots during the first season. In the winter after the first season's growth (March 1922), the following systems of pruning were used:

Method I.

All top growth was removed from 45 vines except a short portion of the largest cane leaving two buds per vine, according to the usual commercial practice. After growth started only one shoot was allowed to develop which was tied to an upright stake.

Method II.

All canes were removed from 24 vines except the longest cane of each vine which was tied to the trellis and pruned to form a trunk to the top wire (See Plate I) The buds below the lower wire were removed and any shoots which developed on this lower portion of the vine were removed as they appeared during the season. (See Plate II)

Method III.

Sixteen vines were pruned to leave a single cane to form a trunk to the lower wire. Canes of these vines were not long enough to reach the top wire. Only four or five upper buds were retained. All sucker growth on the lower part of the cane was kept removed during the season.

In the winter after the second season (March 1923) the vines under the methods outlined were pruned with varying numbers of fruiting canes. The treatments of each group were as follows:

Method I.

The single shoot which was allowed to develop on the vines after pruning to 2 buds in March 1922 had grown so vigorously in 1922 that many long laterals had also been produced. By using the main cane for a trunk and the laterals for fruiting canes, a complete framework for the 4 cane single stem Kniffin system was available. Four laterals were left on twenty-one of the vines and three laterals each on thirteen vines. The latter vines did not possess four laterals of sufficient length for tying. Each lateral was pruned to twelve buds.

Method II.

These vines in which a trunk had been left to the top wire in March 1922 had developed several long canes. Thirteen of these vines were pruned to four canes of twelve buds each, that is, a complete full bearing vine, (See Plate III) and the remaining eleven vines were pruned as follows: Two canes were left on the lower wire, and the canes above the lower wire were removed except two canes which were cut back to renewal spurs of one bud near the top wire.

Method III.

These vines were pruned to three canes one of which was used to extend the trunk to the upper wire from the original short cane left in March 1922. The other two canes were pruned to twelve buds each and tied to the lower wire.

In the winter after the third season (March 1924) every vine in all three methods had a complete framework of a full bearing vine. (See Plate IV) Hence, four canes of twelve buds each were left for fruiting wood according to the 4 cane Kniffin system.

TABLE I. RESULTS OF PRUNING YOUNG VINES FOR EARLY BEARING

(Vines planted spring 1921).

Method	1922 Pruning	1923 Pruning	1924 Pruning	1923 Av. Yield per vine ozs.	1924 Av. Yield per vine ozs.	Total Yield per vine ozs.
I	2 buds (21)	4 canes laterals	4 canes	296.8	201.2	498.0
	2 buds (13)	3 canes laterals	4 canes	270.1	235.1	505.2
II	1 cane to top wire (13)	4 canes	4 canes	274.2	241.0	515.2
	1 cane to top wire (11)	2 canes on lower wire	4 canes	192.0	254.9	446.9
III	1 cane to lower wire (14)	2 canes plus upright cane	4 canes	249.7	227.1	476.8

Note:- Numbers in parentheses represent the number of vines.

Table I presents this experiment in tabular form with the average yields in ounces per vine. Method I and II gave full bearing vines in the third season after planting. The yield from method I (using 4 canes in 1923) show a considerable drop from 296.8 oz. to 201.2 oz. in 1924 which indicates too heavy bearing in 1923. This is borne out by the smaller decrease when only three canes were used in 1923. Method II which uses a single cane to the top wire in the second season, gave consistently high yields in the third and fourth seasons using four canes per vine. When two canes were used in the third season instead of four canes the yield for that season was correspondingly reduced, but the yield in the following season with four canes was brought up to full bearing. In Method III where the cane was only long enough to reach the lower wire at the beginning of the second season and had to be extended to the top wire in the third season, the yield of the third season was in keeping with the number of buds left, but the yield of the fourth season was decreased, apparently due to a dwarfing of the extension cane used to extend the trunk to the top wire. (See Plate V) This dwarfing will be discussed later. The best results were obtained then by Method II which yielded on an acre basis 9323 pounds of fruit in the third season after planting and 8194 pounds in the fourth season with a promise of a large crop in the fifth season.

Root development studies.

Owing to a general conception among practical men that heavy pruning of young vines during two or three years following planting is needed to promote root development and retard top development until the root system is large enough to furnish materials for a crop and vine growth, the following studies were made in connection with the pruning work described in the previous pages.

In this work twenty one-year-old Concord vines were planted on April 18, 1923 in galvanized cans as described under the general methods. A uniform lot of one year old vines were used and weights of the pruned vines were recorded. All vines were pruned to two buds at planting time. On May 3rd when the shoots were one to two inches long, all shoots were removed except one. At the beginning of the second season 1924 these vines were pruned in various ways as follows:

1. No pruning (4 vines) with average of 40 buds each.
2. Sixteen buds left on single cane, all laterals removed. (6 vines)
3. Two buds left. (5 vines).
4. One bud left. (5 vines) Shoot removed when 12 to 18 inches long.

Two of the vines under number three were discarded because of injury to the shoots.

At the end of the season's growth the vines were removed from the cans according to the method given under general methods, page 11. The new roots which had developed in the two seasons were separated from the original vine, dried at 80° C for 48 hours and weighed. The 1923 top growth, the 1924 top growth and the original vine were also separated, dried and weighed. By assuming a moisture content of 50 percent for the vines when planted, the dry weights of these vines when pruned for planting was calculated.

Plate I. Single cane of Concord vine tied to the top wire after the first season's growth instead of cutting back to 2 buds as has been the general practice in many grape regions. The above pruning results in commercial yields one year sooner

Plate II. Single cane of Concord vine developing shoots in the second season. All shoots are kept removed from the lower part of the cane. Picture was taken in May.

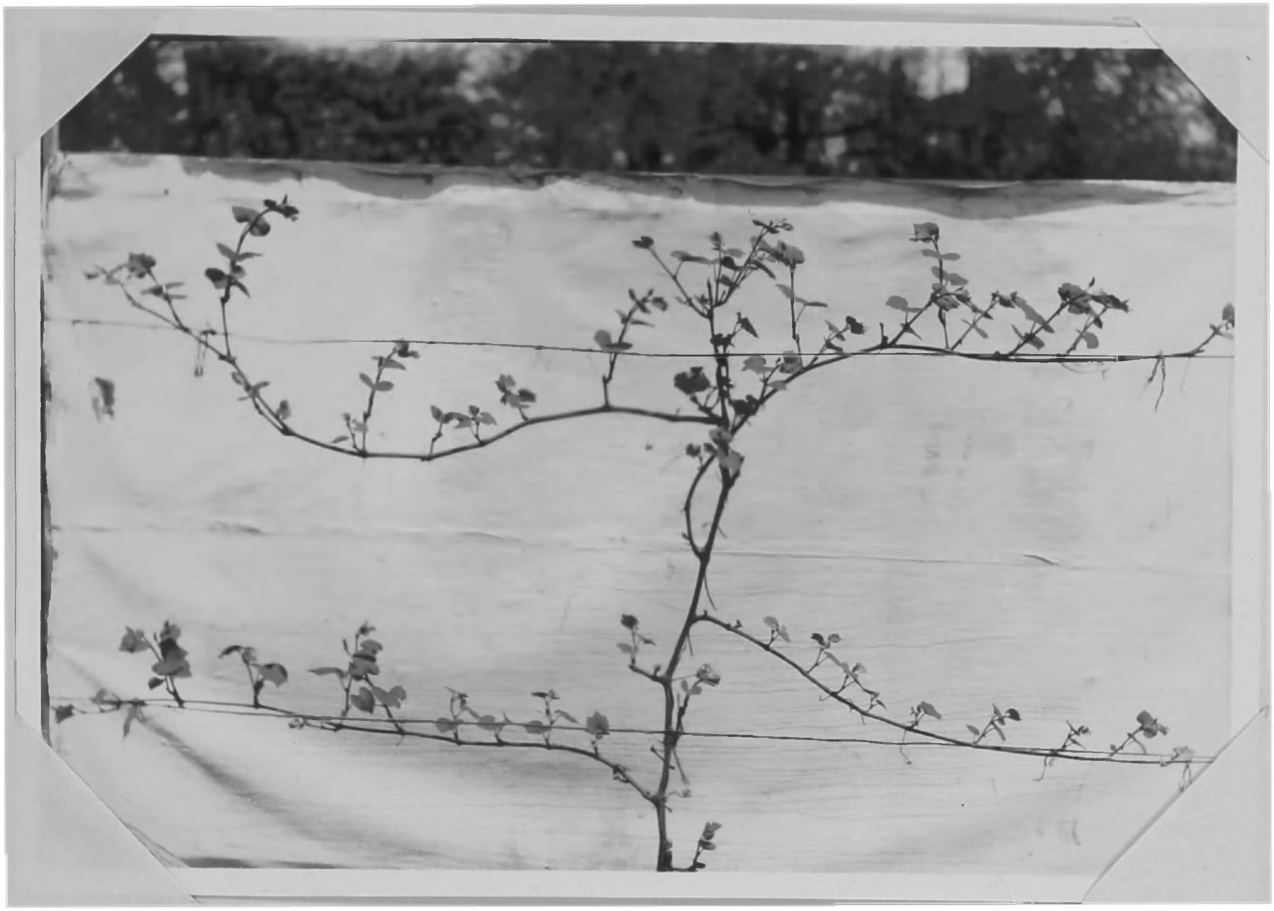


Plate III. Complete framework (four cane single stem Kniffin system) after second season's growth capable of bearin a full crop. A Concord vine--picture taken in May.

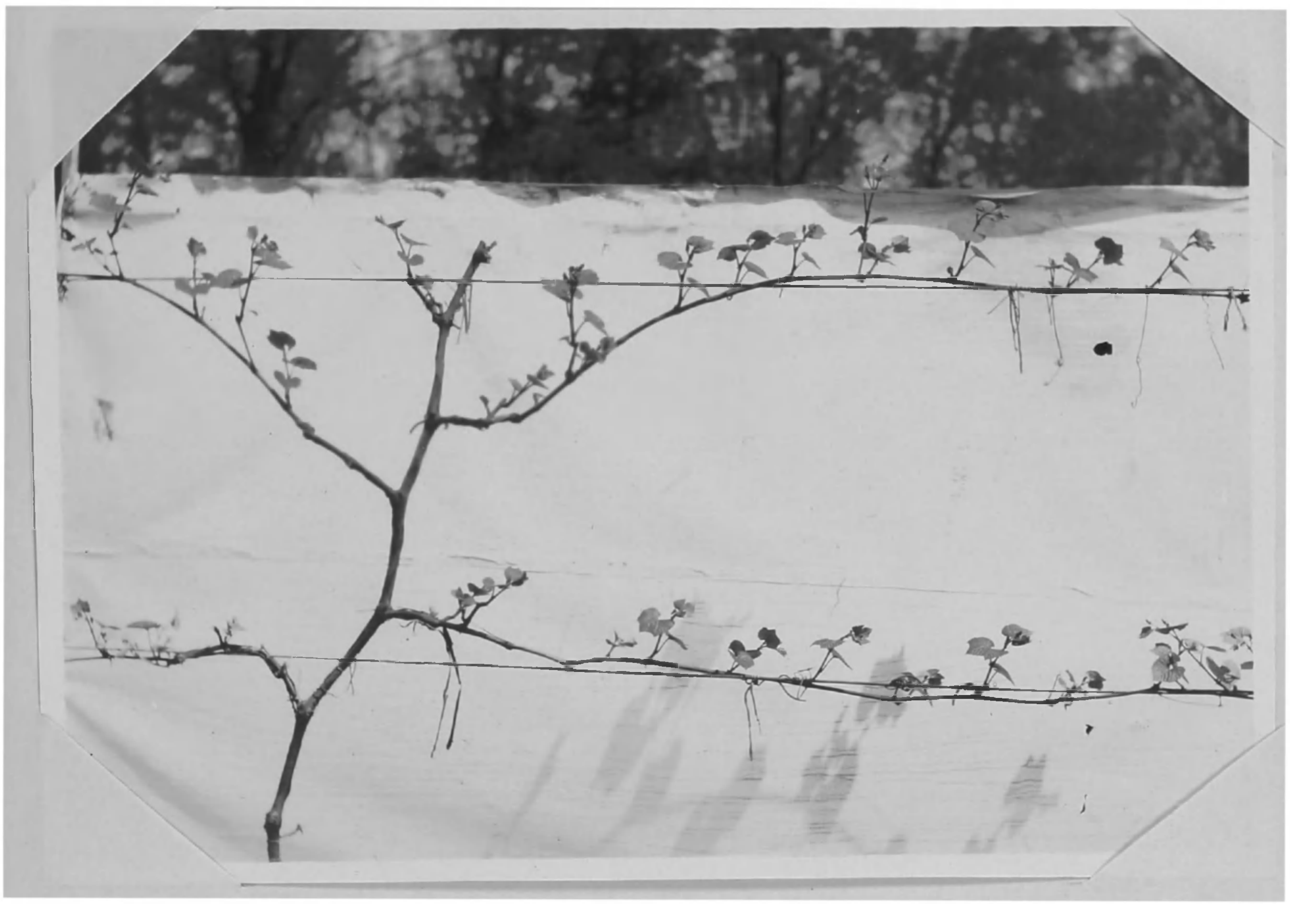


Plate IV. Concord vine in spring of fourth season after bearing a full crop in the third season. A full crop was produced on this vine in the fourth season.

Plate V. Concord vine in spring of fourth season, showing a poor development of the trunk above the lower wire. This section of the trunk was developed one year after the section of the trunk below the lower wire, as compared to a complete trunk in one year as in Plate IV. The above method often results in a poorer trunk and may decrease yield. Hence, this method is not advisable unless the cane growth at the end of the first season is insufficient to reach the top wire of the trellis.

TABLE II.

THE EFFECT OF PRUNING AFTER FIRST SEASON, ROOT GROWTH AND TOTAL GROWTH OF GRAPE VINES.

(Vines planted 1923).

Pruning at end of first season	Total Dry Wt. Average in grams	Dry wt. of 1923 and 1924 Roots Grams.	Differences in Dry Wt. of Roots.	Dry wt. of 1924 top growth	Av. Dry Wt. of Original Vine Before Planting.
No Pruning (4)	113.81±3.67	41.85±1.97		23.04±1.67	14.87
16 Bud Cane (6)	105.59±2.17	37.43±0.924	4.42±1.93	29.15±1.42	14.42
2 Bud Cane(3)	102.39±2.71	34.70±0.935	7.15±2.18	37.60±0.675	15.00
1 Bud Shoot Removed when 12-18 inches (5)	85.61±2.56	35.80±171	6.05±2.61	20.21±2.09	19.90

Differences in root growth compared to no pruning.
41.85-37.43 =4.42±1.93
41.85-34.70 =7.15±2.18
41.85-35.81 =6.05±2.61

Note: Modified Bessel's formula was usedin calculating the probable errors of the average. The ordinary formula involving the square root of the sum of the squares of the probable errors was used for calculating probable error of the differences.

The data in Table II indicate that pruning does not increase root growth but tends to decrease it. The vines left unpruned in the second season showed a significantly greater increment of roots than the vines pruned to two buds. The vines which had the shoot removed had a surprising increment of roots which is due probably to the large amount of reserves that are present in the roots. It will be remembered that the root increment of the first season (1923) when all vines were pruned alike is included in the figures for Table II and variations in this first season's root growth may serve to modify differences due to pruning in the second season. Richey and Bowers (1924) found that pruning to two buds at planting gave greater root growth in the first season than pruning to one bud, which shows that differences in pruning at planting time will modify the root systems of the first year.

The new growth of the top in the second season (1924) was related inversely to the root growth. Apparently, the pruning of young grape vines stimulates top growth.

PRUNING BEARING VINES

Relation Between Original Length of a "Pencil Size" Cane and Its Fruiting Capacity.

Diameter of the cane has been noted as a measure of fruitfulness by many observers, and the investigtions of Partridge (1923) especially point out that the "pencil size" cane or a cane having a diameter of about one quarter inch is the most fruitful. However, the writer observed that this type of cane varies in its growth in length from three feet to eighteen feet so that it seemed highly probable that the fruiting of these "pencil size" canes might vary with the length of the cane. Accordingly, some studies were made in 1923 and 1924 in a bearing vineyard of moderate vegetative vigor.

The preliminary work in 1923 included fifty canes of approximately "pencil size" diameter but ranged in length from three to twelve feet before pruning. Each cane was pruned to twelve buds and all canes were upper canes on the trellis. Total yields for each bud and number of bunches per bud were obtained for each cane. By calculation, the yield of each cane was obtained, and by grouping the canes according to original length of cane the average yield of canes of a given length were determined.

TABLE III. INFLUENCE OF ORIGINAL LENGTH OF CANE GROWTH ON THE FRUITING OF CANES PRUNED TO 12 BUDS (1923 Results).

Original length of Cane in feet	3-4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 12
Numbers of Canes Averaged	8	10	8	7	4	9
Average Yield Per Cane in ½ Ounces	124±7.2	160±7.4	159±4.7	153±12.2	138±4.6	128±5.1
Average Yield Per Shoot in ½ Ounces	12.1	15.2	15.6	15.8	13.7	14.1
Percent of Buds not Starting.	14.5	12.5	16.6	19.0	16.6	24.1
Average Weight of Bunch in ½ Ounces	4.5	5.2	6.0	5.8	5.0	5.4
Average Number of Bunches per Cane	25.6	30.3	25.9	25.7	25.0	23.2

Differences in yield per cane

$$159 - 124 = 35 \pm 8.8$$
$$159 - 138 = 21 \pm 6.8$$
$$159 - 128 = 31 \pm 6.9$$

Table III presents the data of this work. Although the number of canes used was small, some significant differences were found which indicate that short canes (3 to 4 feet) and long canes (8 to 12 feet) gave small er yields than medium length canes (4 to 8 feet) when all canes had been pruned to twelve buds. The data also show that the average yield per shoot and the average weight of bunch was greatest on the 5 to 7 foot canes which were responsible for the high yields of these canes. The converse is true for the short and long canes. The comparatively large number of bunches on the 4 to 5 foot canes accounts for the large yields for this group. To sum up the data, it may be suggested that the fruiting capacity of canes of a "pencil" diameter is modified by the original length of the cane. More extensive experiments in 1924 confirmed this conclusion.

The 1924 experiments were conducted in the same vineyard and "pencil-size" canes were used from 2 to 17 feet in length. The canes were pruned to twelve buds as in the previous experiment with the exception of some of the shorter canes which did not possess twelve buds and were left unpruned. The data collected from this experiment is tabulated in Table IV. As in 1923, the short and long canes bore less fruit than the canes of medium length, both on the basis of whole cane and single shoot. Canes of 7 to 8 feet in length showed the highest yield per cane and highest yield per fruiting bud. The high yield of this group can be ascribed largely to the greater number of bunches per shoot than any other group. It will be noted that the yields per shoot and per cane increased as the length of cane increased up to the 7 to 8 feet beyond which a decrease of yield occurred though the longest canes yielded more than the shortest canes. The number of bunches per shoot is the important factor in the yields of short canes whereas the weight of the bunch also influences the yields of long canes according to the data in Table III.

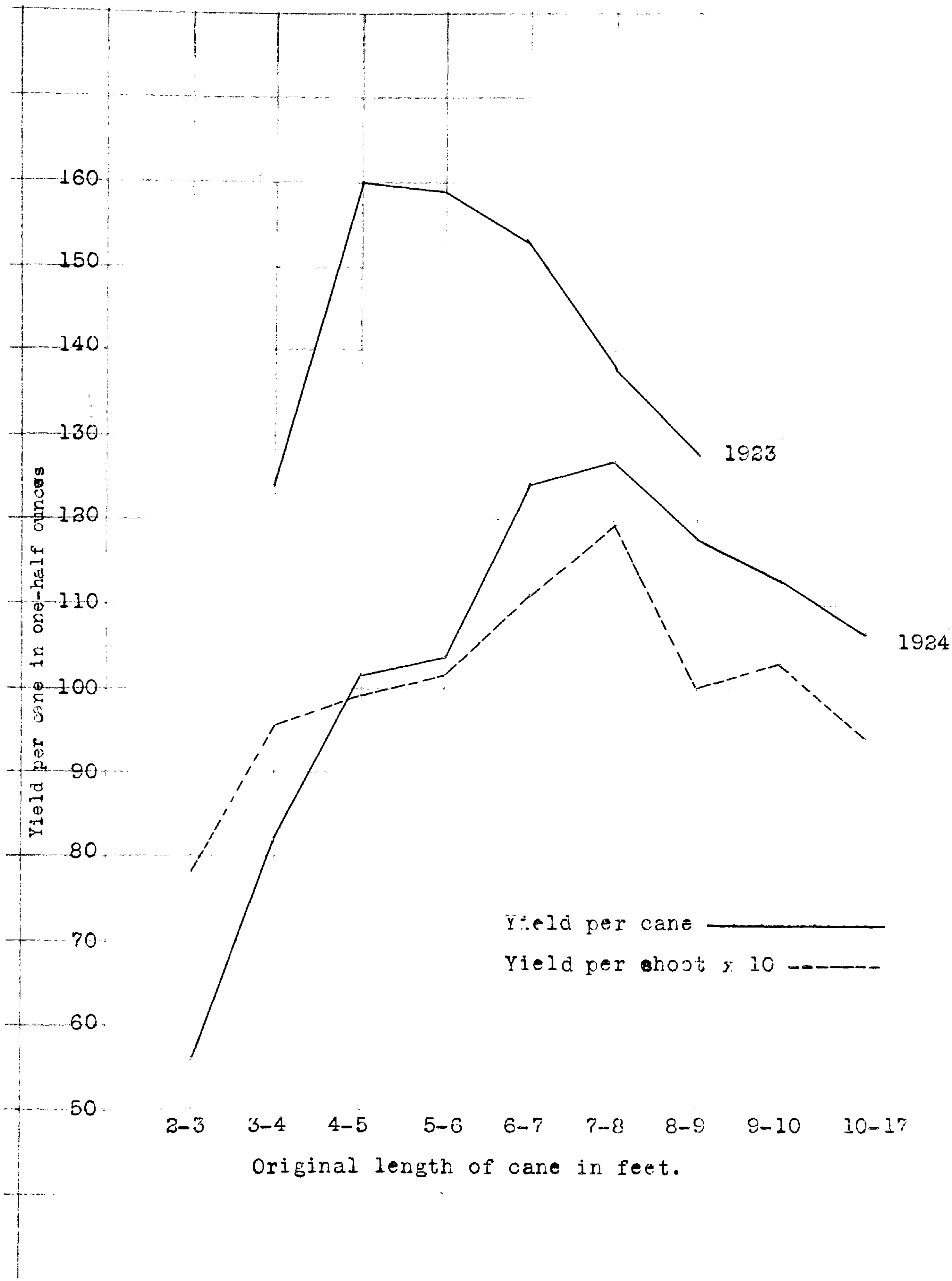
Fig. 1 presents graphically the yield data as given in Tables III and IV. In the 1924 results the yield rapidly increases with greater length of cane up to the 7 to 8 foot length when a decrease of yield occurs with greater length of cane.

TABLE IV

INFLUENCE OF ORIGINAL LENGTH OF CANE GROWTH ON THE FRUITING OF CANES (1924 Results)

Original Length of Cane in feet.	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 17
Number of Canes Averaged	24	47	58	46	45	20	10	10	6
Average Yield per Cane in ½ ozs	56	82	101	104	124	127	118	113	107
Average Yield per Shoot in ½ oz	7.81	9.54	9.93	10.16	11.12	11.95	10.02	10.29	9.41
Average No. of Bunches per Shoot	1.70	2.04	2.14	2.21	2.34	2.54	2.28	2.41	2.29
Average Weight of Bunch in ½ ounces	4.6	4.68	4.64	4.59	4.76	4.59	4.40	4.27	4.13
Average No. of Bunches per Cane	12.1	17.6	21.7	22.6	26.5	26.9	26.9	26.5	25.8
Percent of Buds not starting	4.5	8.8	10.5	12.0	7.1	10.7	6.4	7.6	11.7
Average No. of Buds on un-pruned Cane	7.9	10.5	14.1	17.6	21.5	24.2	24.6	27.7	35.0
Average No. of Buds on Pruned Cane	7.4	9.5	11.4	11.6	12.0	12.1	12.6	11.9	12.8

Figure 1. Showing the influence of original length of cane growth on the fruiting of canes.



Point of Maximum Yield on the Cane.

Various investigators have reported that under average growth conditions the shoots from buds at the base of the cane show a relatively low yields, shoots from the buds 4 to 6 or the middle portion of a cane pruned to twelve buds show the highest yields, and shoots from the buds beyond the 4th to 6th buds show a decrease in yield. Thus the yield on a cane increases from the 1st or basal shoot to the 4th, 5th or 6th shoot and then decreases to the 12th shoot, although the 12th shoot usually bears a greater yield than the 1st shoot.

In order to study the fruiting habit of the Concord vine with respect to the point of maximum yield on the canes, the yield records which were taken in 1923 and 1924 on the canes of varying original lengths were arranged according to the individual shoots from buds 1* to 12 as shown in Tables V, VI, VII and VIII and Figure 1. In Table V and VII, the yields are calculated on a percentage basis, using 100 percent to represent the highest yielding shoot for each group of canes. With a percentage basis, the influence of original length of cane could be noted as regards the point of maximum yield, and the maintenance of yield on the cane beyond the maximum point.

In 1923, the data as arranged in Table V indicate a maximum yield from the 4th bud, that is on the fourth shoot, regardless of original length of cane. The small number of canes on which this data is based lends considerable variation to the results, so no further conclusions will be drawn from this data.

In 1924, a larger number of canes were averaged so that more

Note * The small buds at the extreme basal end of the cane were not considered because these buds are invariably dormant. Colby and Vogele (1924) state recently that from 950 canes these buds were invariably dormant or produced a fruitless shoot.

uniform and dependable results were secured. As presented in Tables VI and VII, this season showed a maximum yield from the 4th to 7th bud. The variations, as noted, cannot be ascribed to any direct relation to original length of cane, although some tendency for the maximum to occur farther out on the cane with greater length of cane than with shorter length of cane can be seen. Another relation to increased length of cane is shown in Table VII in which the longer canes maintain the yield on shoots beyond the maximum at a relatively higher point than the shorter canes. The basal buds on all canes were consistently low yielders.

In Table VIII, the yields from individual buds on all canes were averaged regardless of original length of cane. The 1923 results show again the maximum yield on the shoot from the 4th bud of the cane. In 1924, the maximum yield occurred on the shoot from the 5th bud. By calculating an average for all buds on the cane, or just for buds which produced a shoot, the same result was secured although slight differences in average yield naturally resulted. A selection was made of canes which had produced a bearing shoot from every bud. The average yields of the shoots again were maximum at the 5th bud, although higher average yields per bud were secured due largely to the fact that 75 percent of these canes were of high producing type, namely 6-8 foot length.

The data given in Table VIII are summed up graphically in Figure 2 These curves present clearly the low yielding capacity of the basal bud, and rapid increase in yield to the 4th or 5th bud, and a less rapid decrease in yield beyond the 4th or 5th bud.

The variations in fruitfulness of the buds, as noted, are due to the differences in number of bunches and size of bunches. The relation between the yields of the buds and the number and size of bunches is shown in Table XX and Figure 13. The yield curve practically parallels the curves for number and size of bunches. This relation suggests that the high yielding buds in the middle portion of the cane differentiated more flowers and flower clusters in the year previous.

TABLE V

POINT OF MAXIMUM YIELD ON THE CANE AS AFFECTED BY THE ORIGINAL LENGTH OF CANE (1923)

Calculated on a Percentage Basis

for each Group

Original Length of canes in feet	Shoot 1	Shoot 2	Shoot 3	Shoot 4	Shoot 5	Shoot 6	Shoot 7	Shoot 8	Shoot 9	Shoot 10	Shoot 11	Shoot 12
3-4 Foot Canes (8)	67	82	75	100	97	44	99	80	65	70	50	75
4-7 Foot Canes (25)	53	80	90	100	84	58	68	52	72	74	84	73
7-12 Foot Canes (13)	52	104	52	100	58	69	81	65	86	70	83	73

Numbers in Parenthesis refer to number of canes used.

TABLE VI

POINT OF MAXIMUM YIELD ON THE CANE AS AFFECTED BY THE ORIGINAL LENGTH OF CANE (1924)

Original Length of Canes in feet	Shoot 1	Shoot 2	Shoot 3	Shoot 4	Shoot 5	Shoot 6	Shoot 7	Shoot 8	Shoot 9	Shoot 10	Shoot 11	Shoot 12
2-3 foot canes (24)	6.26	7.26	7.52	8.64	10.90	7.90	7.91	6.11	6.25	6.33	4.00	---
3-4 foot canes (47)	5.82	7.52	9.00	10.22	12.34	10.62	10.26	7.58	7.60	8.04	6.30	7.66
4-5 foot canes (58)	6.00	7.70	10.38	11.76	11.74	11.26	10.98	9.76	9.36	9.02	6.92	6.86
5-6 foot canes (46)	5.48	6.96	9.60	10.62	12.08	12.22	10.80	10.04	9.90	10.14	8.72	7.60
6-7 foot canes (45)	6.36	7.88	10.72	13.04	12.04	12.26	12.58	11.40	11.96	11.08	9.60	9.18
7-8 foot canes (20)	6.42	10.94	9.52	11.56	14.34	15.54	12.54	10.84	13.36	12.00	9.18	11.26
8-9 foot canes (10)	4.80	8.50	8.50	13.30	12.54	11.60	9.90	12.76	9.66	12.88	9.66	10.00
9-10 foot canes (10)	5.54	6.00	8.50	9.66	9.20	11.60	12.54	12.00	12.50	9.62	12.24	12.00
10-17 foot canes (6)	5.60	7.50	8.66	8.50	11.00	13.16	12.80	12.50	6.00	7.50	11.00	8.66

Numbers in parentheses refer to number of canes averaged.

TABLE VII

POINT OF MAXIMUM YIELD ON THE CANE AS AFFECTED BY THE ORIGINAL LENGTH OF CANE (1924)

(Calculated on a Percentage Basis for each Group.)

Original Length of Canes in feet	Shoot 1	Shoot 2	Shoot 3	Shoot 4	Shoot 5	Shoot 6	Shoot 7	Shoot 8	Shoot 9	Shoot 10	Shoot 11	Shoot 12
2-3 foot canes	57	67	69	79	100	72	72	56	57	58	36	--
3-4 foot canes	47	61	73	83	100	86	83	61	61	65	51	62
4-5 foot canes	51	65	88	100	100	87	94	83	80	77	59	58
5-6 foot canes	45	57	77	87	99	100	88	85	81	83	71	62
6-7 foot canes	49	61	82	100	92	94	97	87	92	84	77	70
7-8 foot canes	41	70	61	74	92	100	81	68	86	77	59	72
8-9 foot canes	36	64	64	100	94	87	74	96	73	97	73	75
9-10 foot canes	45	48	68	77	73	93	100	96	100	77	98	96
10-17 foot canes	43	57	66	63	84	100	97	93	46	57	84	66

TABLE VIII

AVERAGE YIELD FROM EACH BUD ALONG A CANE PRUNED TO 12 BUDS

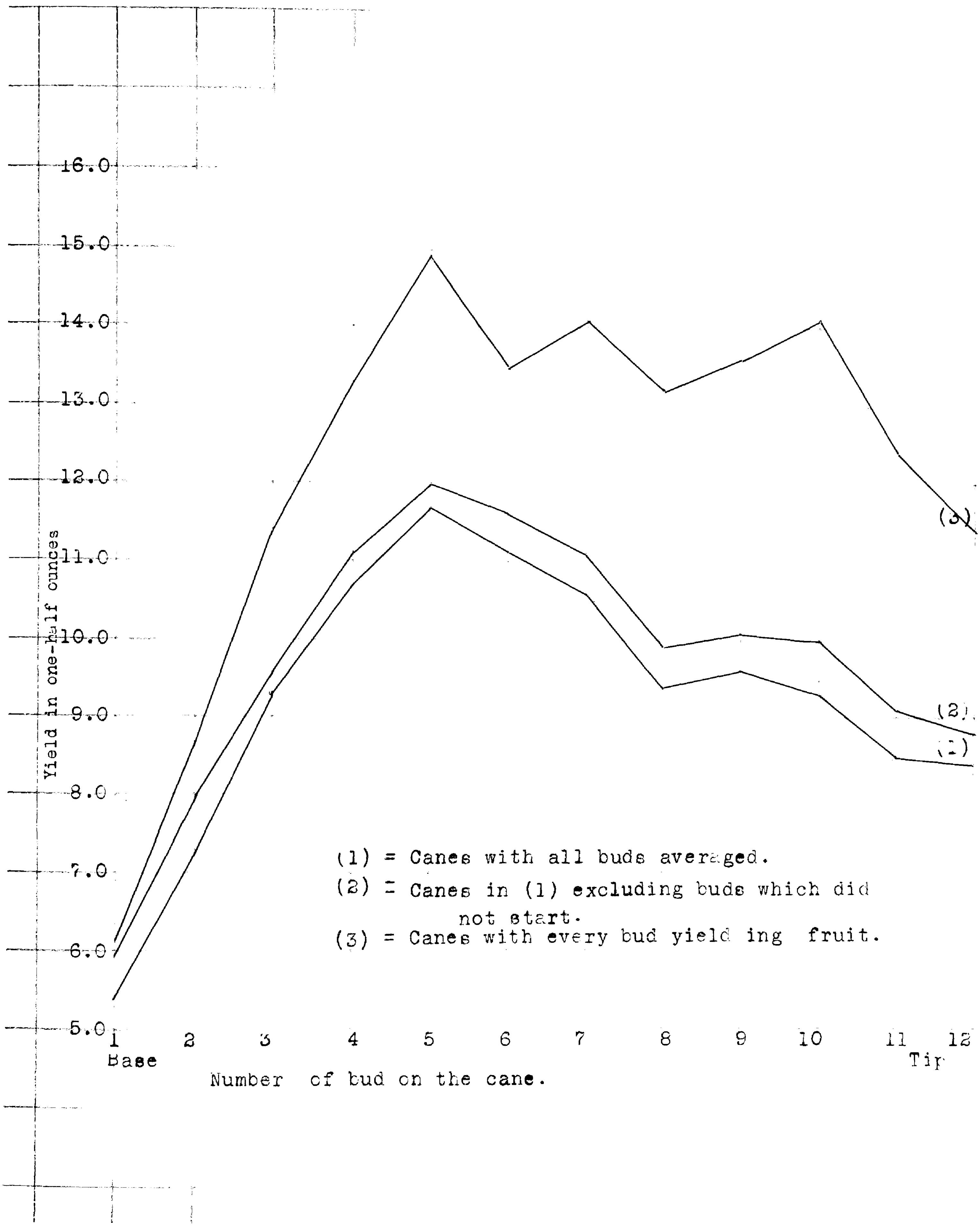
(Yields in $\frac{1}{2}$ ounces).

Number of Shoot bearing the Fruit	1 (Base)	2	3	4	5	6	7	8	9	10	11	12 (tip)
1923 Yields All canes (46) All buds	10.8	13.5	12.1	15.7	12.4	9.2	11.9	11.6	11.8	11.3	12.3	11.5
1924 Yields All canes (265)	5.9	8.0	9.6	1 .1	12.0	11.6	11.1	9.9	10.1	10.0	9.1	8.8
1924 Yields Canes with all buds included (265) *	5.4	7.3	9.3	10.7	11.7	11.1	10.6	9.4	9.6	9.3	8.5	8.4
1924 Yields (40) All buds fruiting	6.1	8.7	11.4	13.3	14.9	13.5	14.1	13.2	13.6	14.1	11.4	10.4

* Buds which did not start are not included.

Note:- Numbers in parentheses refer to the number of canes averaged.

Figure 2. Showing the average yields resulting from each bud along a "pencil-size" cane pruned to 12 buds. (1924)



B. Chemical studies.

TRANSLOCATION STUDIES ON ONE YEAR OLD CONCORD VINES DURING THE DORMANT SEASON

French investigations have reported that the food materials in the canes are translocated to the roots shortly after leaf fall and return gradually to the canes until the buds begin to swell in the Spring. Such findings have been the basis in France for determining the time for pruning and the taking of cuttings for propagation. In order to determine if such translocation takes place, some Concord vines were grown during 1921 in galvanized iron cans according to the method described under general methods. (page 11). During the dormant season of 1921-22, vines were removed from the cans at intervals, four vines at each date, for chemical analysis. On October 4 when the first vines were taken, the vines still possessed nearly all their leaves. All leaves of all vines were stripped off at this time. The roots, including the original cutting up to the top growth, were separated from the top of each vine, and each of the four vines was analyzed separately. The results obtained from the vines agreed rather closely, so an average of the analyses will be reported for each date of sampling. The data are presented in Table IX in percentages of material on a dry weight basis, and in Table X on the basis of obsolute amounts per vine. Fairly uniform moisture content was found for roots and tops so that calculations on a green weight basis are not tabulated.

The analyses show no appreciable transfer of carbohydrate or nitrogenous materials from the top to the roots or vice versa although greater proportion of the carbohydrate reserve of the vine is found in roots both on a percentage basis and on the basis of absolute amounts. Marked hydrolysis of starch occurs in the top of the vine during the winter, reaching a maximum in mid-winter which is followed by the reverse change from sugar to starch. Only slight hydrolysis was found in the roots since the percentage of sugar remains at a nearly constant value and starch decreases only gradually during the winter as shown in graphic form in Fig. 3 A slight rise in starch content of the roots in October might indicate a little translocation to the roots at that time since a corresponding decrease was found in the tops. Sugars are evidently utilized in respiration in the roots and especially in the tops during the winter, as is shown by the decrease in total carbohydrates.

A very marked rise in nitrogen content of the roots occurred between October 4 and November 1, with very little change of nitrogen content in the tops. A seven fold increase of nitrogen in the roots can be seen in Table IX. Analyses at later dates showed no further increase except for a slight increase in March. The nitrogen content of the tops remained fairly constant during the entire dormant period, so that the increase of nitrogen in the roots must be ascribed to an intake of nitrogen from the soil after leaf fall. Further, this nitrogen was not transported to the top in appreciable amounts.

These experiments thus indicate that very little transfer of material occurs from tops to roots in one year old Concord vines during the dormant period although marked hydrolysis of starch was found in the tops in mid winter and large absorption of nitrogen by the roots is evident in early fall.

Further evidence as regards translocation and hydrolysis was found in analyses of the various nodes of the cane during the dormant season. Table XI presents data showing very little change in total carbohydrates of the cane during the dormant period except for a slight loss due to respiration.

The analyses as calculated on the basis of absolute amounts per vine are given in Table X. Although the vines taken in October were larger than the vines taken later, the relative differences between top and roots can be noted. The roots constitute about 70 percent of the dry weight of the vine and therefore greater absolute amounts of reserves are found in the roots with the exception of sugars which are highest in the top (except Oct. 4) due to hydrolysis of starch as noted. Total nitrogen was also lower in the roots on Oct. 4, but the intake of nitrogen in early fall increased the nitrogen content of the roots till about 80 percent of the total nitrogen of the vine is found in the roots. About 75 percent of the total carbohydrates are stored in the roots. Consequently, the roots contain the greater proportion of the reserves of the young vine.

TABLE IX

CHANGES OCCURRING IN ROOTS AND TOPS OF ONE YEAR OLD CONCORD GRAPE VINES DURING THE DORMANT PERIOD

1921-22

(Percentages on Dry Weight Basis)

Date of Sample	Moisture		Dry Matter		Free Reducing Substances		Sucrose		Total Sugars		Starch		Hydro-lyzable Polly-saccha-rides		Total carbohy-drates		Total Nitro-gen		Sol Mat
	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top	Roots	Top
Oct 4 1921	45.9	58.5	54.1	41.5	1.35	0.63	1.59	0.49	2.94	1.12	13.63	25.92	32.92	35.66	35.9	36.8	0.953	0.234	1
Nov 1 1921	44.9	50.7	55.1	49.3	2.02	0.61	2.65	1.00	4.67	1.61	9.58	28.12	30.29	40.76	35.0	42.4	1.047	1.651	1
Dec 8 1921	43.5	51.6	56.5	48.4	4.68	0.97	? 3.42	0.98	8.10	1.95	6.34	24.07	28.33	38.45	36.4	40.4	0.988	1.548	1
Mar 9 1922	46.9	46.4	53.1	43.6	3.66	0.65	0.49	0.67	4.15	1.32	6.55	22.59	24.45	35.70	28.6	37.0	0.840	1.814	1

TABLE X

ANALYSES OF ROOTS AND TOPS OF ONE YEAR OLD CONCORD GRAPE VINES DURING THE DORMANT PERIOD 1921-1922

(Absolute amounts in Grams per Vine)

Date of Sample	Material	Av. Total Dry Wt. Grams	Free reducing substances (Grams)	Sucrose (Grams)	Total Sugar grs.	Starch (grams)	Hydrolyzable Pollysaccharides grams-	Total carbohydrates (grams)	Total nitrogen (grs)	Soluble Materials (grams)
Oct.4,1921	Top : Roots	37.87 105.94	0.511 0.667	0.602 0.519	1.11 1.19	5.16 27.47	12.47 37.78	13.60 38.99	0.361 0.248	4.18 : 14.30
Nov. 1, 1921	Top Roots	35.54 84.45	0.738 0.515	0.968 0.844	1.70 1.36	3.51 20.32	11.17 34.4	12.79 35.81	0.383 1.394	4.79 12.84
Dec.8, 1921	Top Roots	32.45 81.78	1.52 0.793	1.11 0.801	2.63 1.60	2.06 19.68	9.19 31.44	11.81 33.04	0.321 1.266	5.29 12.66
Mar. 9, 1922	Top Roots	30.18 75.40	1.11 0.490	0.148 0.505	1.25 0.995	1.98 17.04	7.38 26.92	8.63 27.90	0.259 1.368	3.89 12.37

Figure 3. Showing the changes of starch and total sugars in one year old Concord grape vines during the dormant season. 1921-22

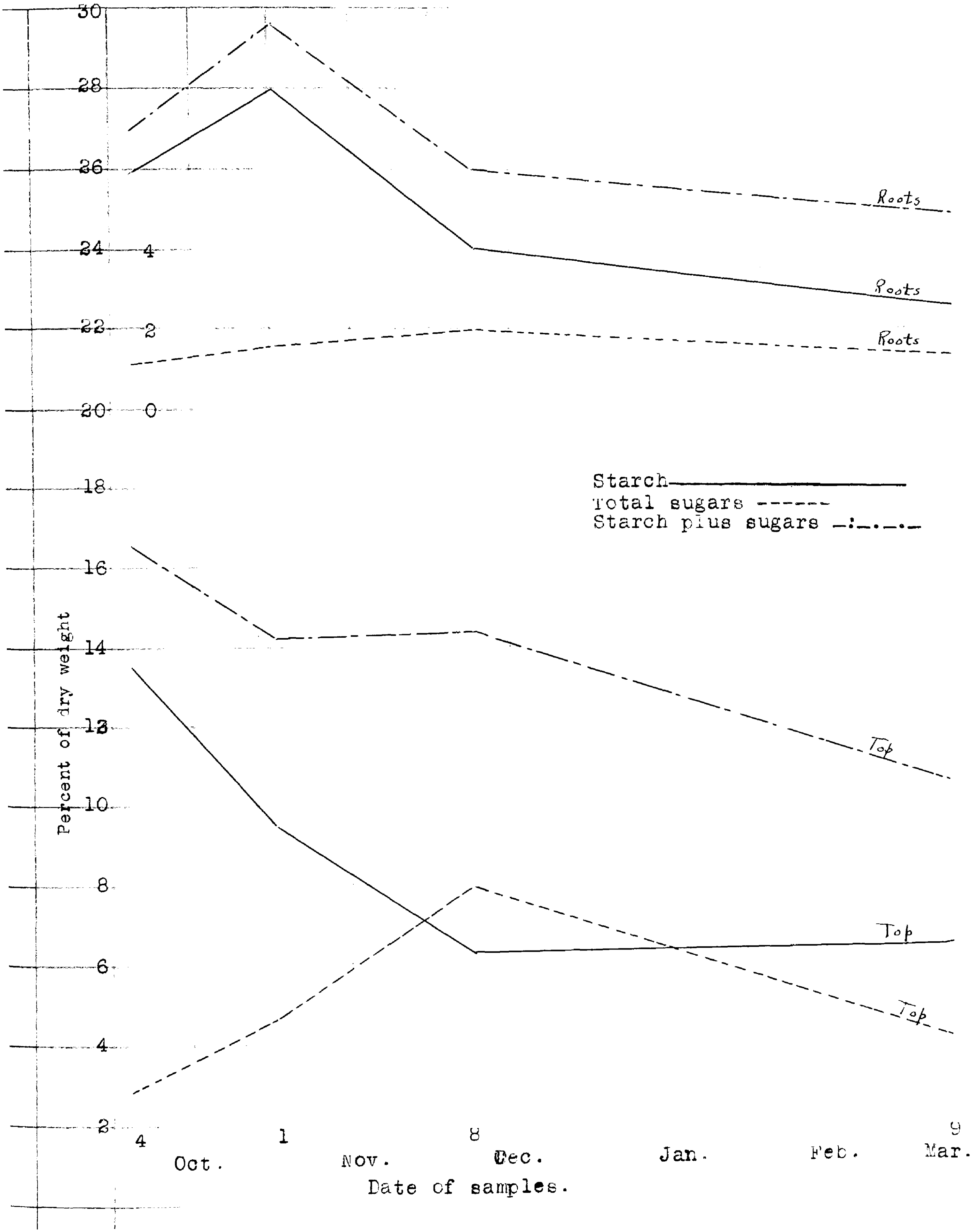
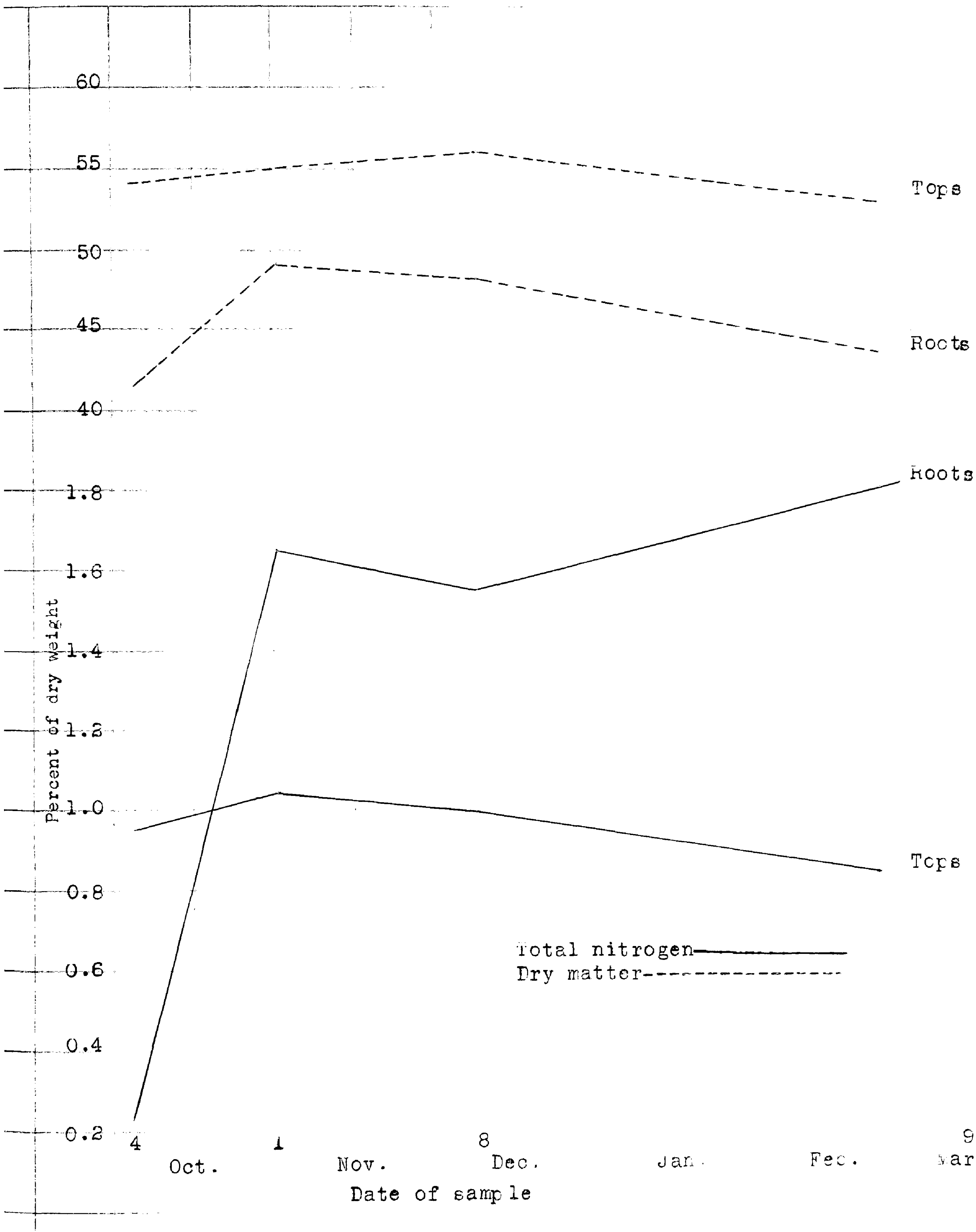


Figure 4. Showing the changes of total nitrogen and dry matter in one year old Concord grape vines during the dormant season. 1921-22.



SEASONAL CHEMICAL CHANGES IN GRAPE SHOOTS.

Since the buds along the cane vary in productiveness, largely due to number of bunches per shoot, it seemed probable that this variation might be associated with chemical differences in the adjacent nodes of the growing shoot at some particular time, probably when flower buds are differentiated. Accordingly, various nodes of the cane (nodes 1 to 9 inclusive) were sampled at various times during the growing and dormant seasons and analyzed for moisture, dry matter, free reducing substances, sucrose, total sugars, starch, hydrolyzable polysaccharides, total carbohydrates, total nitrogen and soluble materials, as detailed under chemical methods. The shoots were about 12 inches in length on May 10 when samples of nodes 1, 2, and 3 were taken. At the next sampling, May 24, the shoot had grown sufficiently (about 23 inches long) for samples of nodes 1 to 6 inclusive. Later samples included nine nodes (1-9).

By averaging the analyses of all nodes at each date the data in Table IX were formulated which may be regarded as the changes which occur in the whole shoot. Table XII presents these results on the basis of absolute amounts of materials. The changes during the dormant season are similar whether reported on percentage basis or absolute basis since the dry matter per node shows little variation during this period. The results of analyses of the individual nodes are given in Table XIII to XX inclusive.

A discussion of the variations of each material probably will serve best in presenting these results.

Moisture. (Tables XI and XIII)

The shoot in the young stage shows the highest moisture content and the more distal node on the shoot has a higher moisture content during the growing season than basal nodes although it will be noted that the nodal differences become slight with nodes 1 to 9 by July 14. Conversely, moisture content decreases as the shoots mature.

Dry Matter. (Tables XI, XII and XIV)

The shoot as a whole shows an increased percentage of dry matter during the growing season, converse to the moisture changes (Figure 5). The basal nodes have a greater percentage of dry matter than distal nodes during the growing season although the differences become less marked (in nodes 1 to 9) as the season progresses. Thus, on July 14th nodes 1 to 9 are practically alike in dry matter percentage. (Table XI and XIII.) A slight increase in percentage of dry matter was found during the dormant season.

Free reducing substances. (Table XI, XII and XV.)

During the growing season, a maximum in percentage of free reducing substances was found in the young shoot and a minimum in the mature shoot at the end of the growing season. (Figure 7). On an absolute basis, maximum amounts of free reducing substances in the growing season occur on July 14 (Figure 8).

In the dormant season, due to hydrolysis of starch, another maximum of free reducing substances occurs in January followed by a minimum in March just before growth begins. These changes are similar on both a percentage basis and an absolute basis since moisture content of nodes varies but little during the dormant seasons.

With regard to individual nodes it will be noted in Table XV, that on June 14th and July 14th, free reducing substances are relatively low in nodes 1, 2 and 3 and highest in the nodes 6 and 7. (Figure 11)

Total Sugars and Sucrose. (Tables XI, XII and XVI)

These materials exhibited variations very similar to those of free reducing substances, and are graphically expressed in Figure 7. Sucrose reached a very low minimum on September 1.

Starch. (Tables XI, XII, and XVII)

A relatively high percentage of starch was found in the young growing shoot, but no marked changes occurred till after July 14, when marked accumulation of starch is apparent as shown in Figures 6 and 7. A maximum of starch is seen on Oct. 18, although only slight accumulation can be noted between September 1 and October 18.

During the dormant season, hydrolysis of starch was apparent which resulted in a minimum of starch Jan. 11. (Figure 7 and 8.) A reversal of this change took place after Jan. 11 so that another maximum was produced in late March. The analyses of the cane on April 3, 1923 just as growth commenced shows another hydrolysis of starch and consequently another minimum of starch in spring.

The various nodes of the cane exhibit noticeable differences on June 14 as shown in Figure 11. Nodes 1, 2, and 3 are much lower in starch content than the other nodes, and nodes 4 and 5 have the highest starch content.

Hydrolyzable Polysaccharides. (Tables XI, XII and XVIII).

These materials, which include starch, increase in percentage very rapidly in the early period of growth tending to follow the percentage of dry matter, but by the middle of June this percentage increase slows up in rate. (Figure 5). After the middle of July, a rapid increase in percentage of hydrolyzable materials is apparent. On an absolute basis, Figure 6, the accumulation of these materials, when plotted, follow typical S curve for growth, that is, a slow rate of accumulation during the early period, followed by increasing rate of accumulation and a slower rate near the end of the season. After July 14th, these materials increase most rapidly in absolute amounts.

In the dormant period a temporary decrease of polysaccharides was noted in mid winter which is due to the hydrolysis of starch as discussed under starch.

A gradient of hydrolyzable polysaccharides was apparent with young shoots, being highest in the base and lowest in the tip, but this gradient disappeared early in the season, as regards the nodes 1 to 9. On June 14, nodes 1 to 6 showed practically the same percentage of polysaccharides, although widely divergent on May 24. (Figure 10)

<u>Total Nitrogen</u>.(Tables XI, XII and XVIII)

The percentage of nitrogen was highest in the young shoot and decreased rapidly during the first month of the growing period. A minimum was found on September 1. A slight increase in percentage occurred during the dormant season. The absolute amounts of nitrogen did not vary very much during the season, so that percentage changes were due to progressive decrease in moisture content.

In Figure 11, the nitrogen content of the various nodes on June 14 is plotted. The basal nodes have a relatively low nitrogen content, the distal nodes are relatively high whereas the middle nodes 5, 6 and 7 are intermediate.

TABLE XI SEASONAL CHEMICAL CHANGES IN GRAPE SHOOTS. AVERAGE OF ANALYSES OF NODES ONE TO NINE

(Percentage on Dry Weight Basis)

Date	Moisture	Dry Matter	Free Reducing Substance	Sucrose	Total Sugars	Starch	Hydrolyzable polysaccharides	Total Carbohydrates	Total Nitrogen	Soluble Materials
May 10 1923	88.14	11.86	5.93	3.88	9.81	4.67	12.08	21.89	3.010	36.30
May 24 1923	86.52	13.48	4.25	1.38	5.63	6.09	16.03	21.66	2.520	30.18
June 14 1923	79.72	20.38	3.80	1.83	5.63	4.47	20.12	25.75	1.068	17.90
July 14 1923	70.64	29.36	4.40	1.69	6.09	4.32	21.95	28.04	0.693	15.50
Sept 1 1923	48.79	51.21	1.95	0.31	2.26	13.13	32.12	34.38	0.593	8.84
Oct. 18 1923	46.67	53.33	1.70	0.85	2.55	13.42	31.15	33.70	0.698	10.93
Jan. 11 1924	45.72	54.28	4.77	3.17	7.94	6.57	23.07	31.01	0.803	21.78
Mar 28 1924	45.76	54.24	1.63	1.31	2.94	11.57	29.90	32.84	0.974	11.90
Apr. 3 1923	42.92	57.08	4.00	1.14	5.14	9.69	27.52	32.66	0.710	12.41

TABLE XII

SEASONAL CHEMICAL CHANGES IN GRAPE SHOOTS, AVERAGE OF ANALYSES OF NODES ONE TO NINE

(Calculated in Absolute Amounts--Grams of Dry Weight)

Date	Dry Matter	Free Reducing Substance	Sucrose	Total Sugars	Starch	Hydrolyzable Polysaccharides	Total carbo-hydrates	Total Nitrogen
(3 nodes) May 10, 1923	0.170	0.0101	0.0066	0.0167	0.0079	0.0205	0.0372	0.0051
(6 nodes) May 24, 1923	0.212	0.0090	0.0029	0.0119	0.0129	0.0340	0.0459	0.0053
June 14, 1923	0.373	0.0142	0.0068	0.0210	0.0167	0.0750	0.0960	0.0040
July 14, 1923	0.625	0.0285	0.0106	0.0386	0.0270	0.1372	0.1751	0.0043
Sept. 1, 1923	0.950	0.0185	0.0030	0.0215	0.1250	0.3052	0.3266	0.0056

TABLE XIII

SEASONAL CHANGES IN MOISTURE CONTENT IN NODES OF GRAPE SHOOTS .

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept.1 1923	Oct. 18 1923	Jan11 1924	Mar.28 1924	Apr 3 1923
1	88.85	84.26	77.02	71.03	45.60	46.31	46.07	45.69	42.36
2	89.37	85.43	78.10	71.19	45.81	47.66	46.40	47.20	43.59
3	86.21	87.25	78.52	70.32	48.35	48.08	46.15	47.60	44.34
4		87.50	78.89	69.80	50.58	47.31	45.61	45.87	43.80
5		87.96	79.66	69.96	49.25	47.09	45.74	45.74	43.20
6		86.70	80.13	70100	48.28	46.73	45.45	44.54	42.80
7	----	~~----~~	80.87	70.74	50.59	45.63	45.65	43.96	35.76?
8	----	----	81.41	71.21	50.79	45.31	45.39	47.38	41.02
9	~~----~~	----	82.92	71.50	49.88	45.90	45.02	43.90	42.22
Average	88.14	86.52	79.72	70.64	48.79	46.67	45.72	45.76	42.92

TABLE XIV

SEASONAL CHANGES IN DRY MATTER IN GRAPE SHOOTS.

NODE	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct.18 1923	Jan.11 1924	March 28. 1924	April 3 1923
1	11.15	15.74	22.98	28.97	54.40	53.69	53.93	54.31	57.64
2	10.63	14.57	21.90	28.81	54.19	52.34	53.60	52.80	56.41
3	13.79	12.75	21.48	29.68	51.65	51.92	53.85	52.40	55.66
4	----	12.50	21.11	30.20	49.42	52.69	54.39	54.13	56.20
5		12.04	20.34	30.04	50.75	52.91	54.26	54.26	56.80
6		13.30	19.87	30.00	51.72	53.27	54.55	54.46	57.20
7			19.13	29.26	49.41	54.37	54.35	56.04	64.24?
8			18.59	28.79	49.21	54.69	54.61	52.62	58.98
9			17.08	28.50	50.12	54.10	54.98	56.10	57.78
AVERAGE	11.86	13.48	20.28	29.36	51.21	53.33	54.28	54.24	57.08

TABLE XV

SEASONAL CHANGES IN FREE REDUCING SUBSTANCES IN GRAPE SHOOTS.

(Percentage on Dry Weight Basis)

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct 18 1923	Jan 11 1924	Mar 28 1924	Apr 3 1923
1	6.46	4.64	3.19	3.88	1.82	1.54	4.86	1.27	3.84
2	6.65	4.56	3.51	4.05	1.62	1.79	4.84	1.66	4.32
3	4.67	4.22	3.48	4.13	1.97	1.69	5.17	1.80	4.21
4		4.04	3.61	4.19	1.97	1.86	4.76	1.84	4.41
5		4.72	3.60	4.40	1.96	1.77	4.75	1.26	3.95
6		3.34	4.25	4.97	1.97	1.63	4.99	1.38	3.02
7			4.40	4.89	2.01	1.55	4.35	1.59	4.22
8			3.91	4.62	2.05	1.50	4.99	2.02	4.21
9			4.21	4.50	2.15	1.93	4.26	1.91	3.84
Average	5.93	4.25	3.80	4.40	1.95	1.70	4.77	1.63	4.00

TABLE XVI

SEASONAL CHANGES IN TOTAL SUGARS IN GRAPE SHOOTS.

(Percentage on Dry Weight Basis)

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct 18 1923	Jan 11 1924	Mar 28 1924	Apr 3 1923
1	9.84	5.71	4.04	5.46	2.31	2.57	7.39	2.46	6.06
2	10.78	5.72	5.31	6.29	2.25	2.64	8.03	2.70	5.76
3	8.80	5.35	5.30	5.86	2.25	2.58	8.09	3.23	5.45
4		5.81	5.45	5.97	2.33	2.68	7.37	3.64	5.12
5		5.32	4.74	6.32	1.97	2.57	7.57	2.08	4.86
6		5.84	5.50	6.41	2.00	2.23	8.51	2.63	4.96
7			7.98	6.40	2.47	2.49	8.66	2.72	4.97
8			6.37	6.09	2.43	2.97	8.15	3.26	4.36
9			5.98	5.97	2.35	2.36	7.65	3.78	4.26
Average	9.81	5.63	5.63	6.09	2.26	2.55	7.94	2.94	5.14

TABLE XVII

SEASONAL CHANGES OF STARCH IN GRAPE SHOOTS.

(Percentage on Dry Weight Basis)

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct. 18 1923	Jan 11 1924	Mar 28 1924	Apr 3 1923
1	4.67 *		3.99	4.13	12.67	12.87	5.08	11.26	9.00
2		5.61	3.38	3.99	13.80	12.41	7.60	12.11	8.98
3		6.50	4.08	4.20	13.47	13.27	6.11	11.68	10.10
4		6.18	4.94	4.32	13.94	13.91	7.15	11.68	9.99
5			5.44	4.23	14.17	14.17	6.36	12.00	9.57
6			4.62	4.26	13.41	13.64	6.84	12.22	9.11
7			4.66	4.49	13.25	13.59	6.86	11.51	9.93
8			4.67	4.41	12.09	13.76	6.56	10.83	9.67
9			4.46	4.93	11.43	13.17	6.60	10.87	10.86
Average		6.09	4.47	4.32	13.13	13.42	6.57	11.57	9.69

* This analysis included nodes one and two. Sample of node three was not analyzed for starch.

TABLE XVIII

SEASONAL CHANGES IN HYDROLYZIBLE POLYSACCHARIDES IN GRAPE SHOOTS.

(Percentage on Dry Weight Basis)

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct 18 1923	Jan 11 1924	Mar 28 1924	Apr 3 1923
1	13.15	18.49	31.03	22.15	33.42	30.42	24.21	28.80	26.61
2	13.45	18.11	21.12	22.38	32.65	30.72	22.70	30.06	27.58
3	9.65	17.46	21.11	22.26	32.65	31.59	23.03	29.56	25.93
4		16.07	20.57	23.37	32.52	31.40	23.17	28.53	26.94
5		13.39	20.26	21.11	33.16	31.74	22.58	30.07	27.56
6		12.65	20.57	21.42	33.08	31.94	22.99	29.88	27.02
7			19.62	22.62	31.55	30.56	22.70	29.86	28.38
8			18.55	22.20	30.73	31.27	24.01	29.99	28.48
9			18.24	20.00	29.29	30.68	22.21	31.01	29.19
Average	12.08	16.03	20.12	21.95	32.12	31.15	23.07	29.90	27.52

TABLE XIX

SEASONAL CHANGES IN TOTAL NITROGEN CONTENT OF GRAPE SHOOTS.

(Percentage on Dry Weight Basis)

Node	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept 1 1923	Oct 18 1923	Jan 11 1924	Mar 28 1924	Apr 3 1923
1	2.51	1.59	0.721	0.680	0.565	0.525	0.795	.785	.733
2	2.95	2.17	0.842	0.760	0.549	0.636	0.770	.963	.704
3	3.58	3.69	0.949	0.780	0.575	0.641	0.816	1.000	.705
4		2.26	0.939	0.650	0.511	0.669	0.814	1.270	.753
5		2.45	1.09	0.621	0.490	0.764	0.852	1.010	.800
6		2.97	1.18	0.663	0.570	0.759	0.801	.900	.727
7			1.12	0.651	1.059?	0.719	.809	.888	.723
8			1.45	0.685	0.677	0.787	.795	.983	.579
9			1.32	0.747	.807	0.782	.774	.965	.647
Average	3.01	2.52	1.068	.693	.593	.698	.803	.974	.710

TABLE XX

THE RELATION BETWEEN THE YIELD PER BUD AND THE NUMBER AND WEIGHT OF BUNCHES

Number of Bud producing shoot on cane.	Bud 1	Bud 2	Bud 3	Bud 4	Bud 5	Bud 6	Bud 7	Bud 8	Bud 9	Bud 10	Bud 11	Bud 12
Average Yield Per Fruiting Shoot in ½ oz	6.15	8.08	10.10	11.65	12.50	12.22	11.71	10.45	10.94	10.89	9.57	9.28
Average Number of Bunches	1.72	1.98	2.21	2.40	2.46	2.48	2.39	2.29	2.33	2.19	2.18	2.21
Average Wt. of Bunch in ½ ounces	3.57	4.08	4.57	4.85	5.09	5.01	4.89	4.56	4.70	4.97	4.38	4.19

Figure 5. Showing seasonal cahnges of drymatter, Total carbohydrates and hydrolyzable polysaccharides in grape shoots.

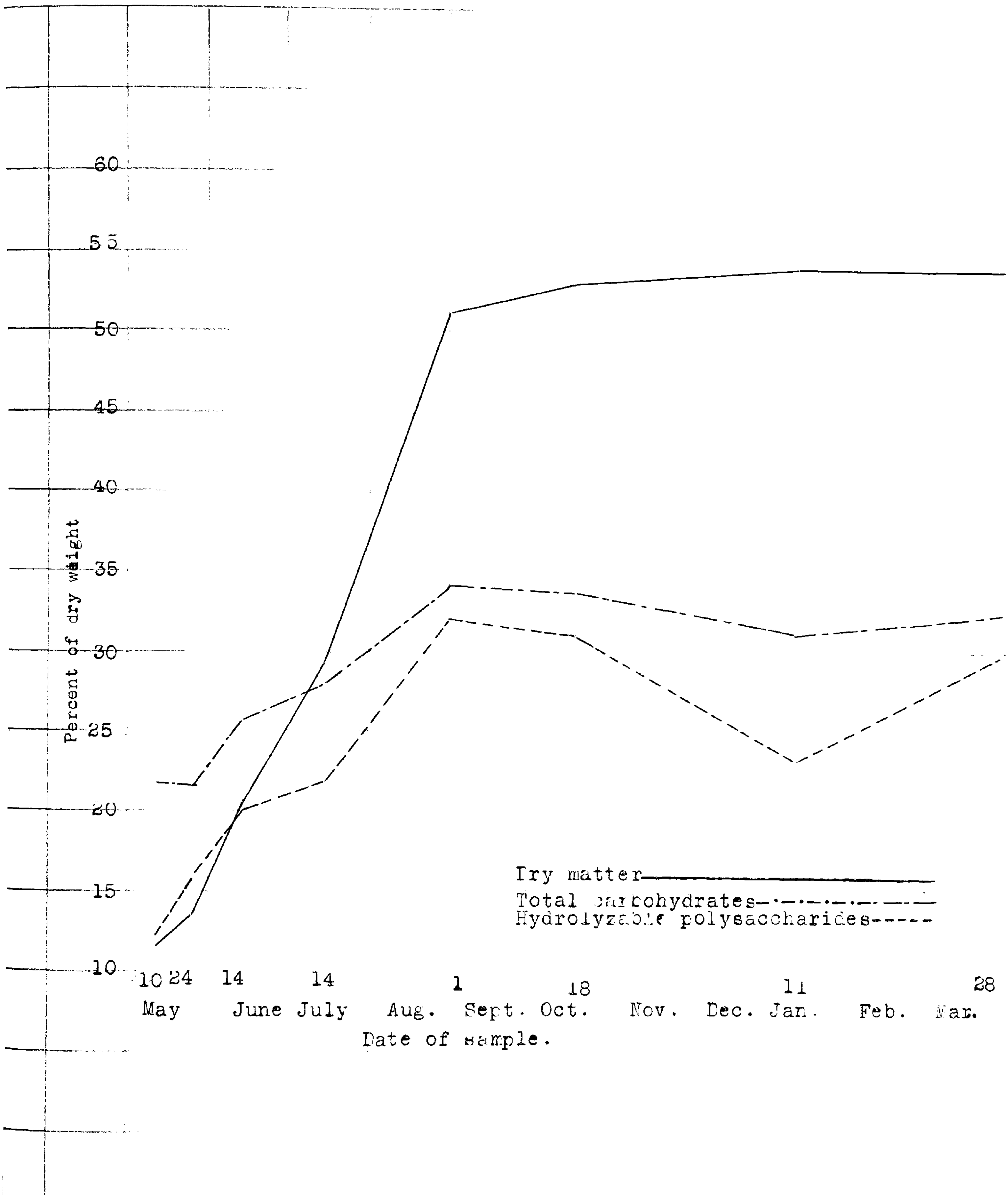


Figure 6. Seasonal changes in absolute amounts of starch, total carbohydrates and hydrolyzable polysaccharides in grape shoots. 1933

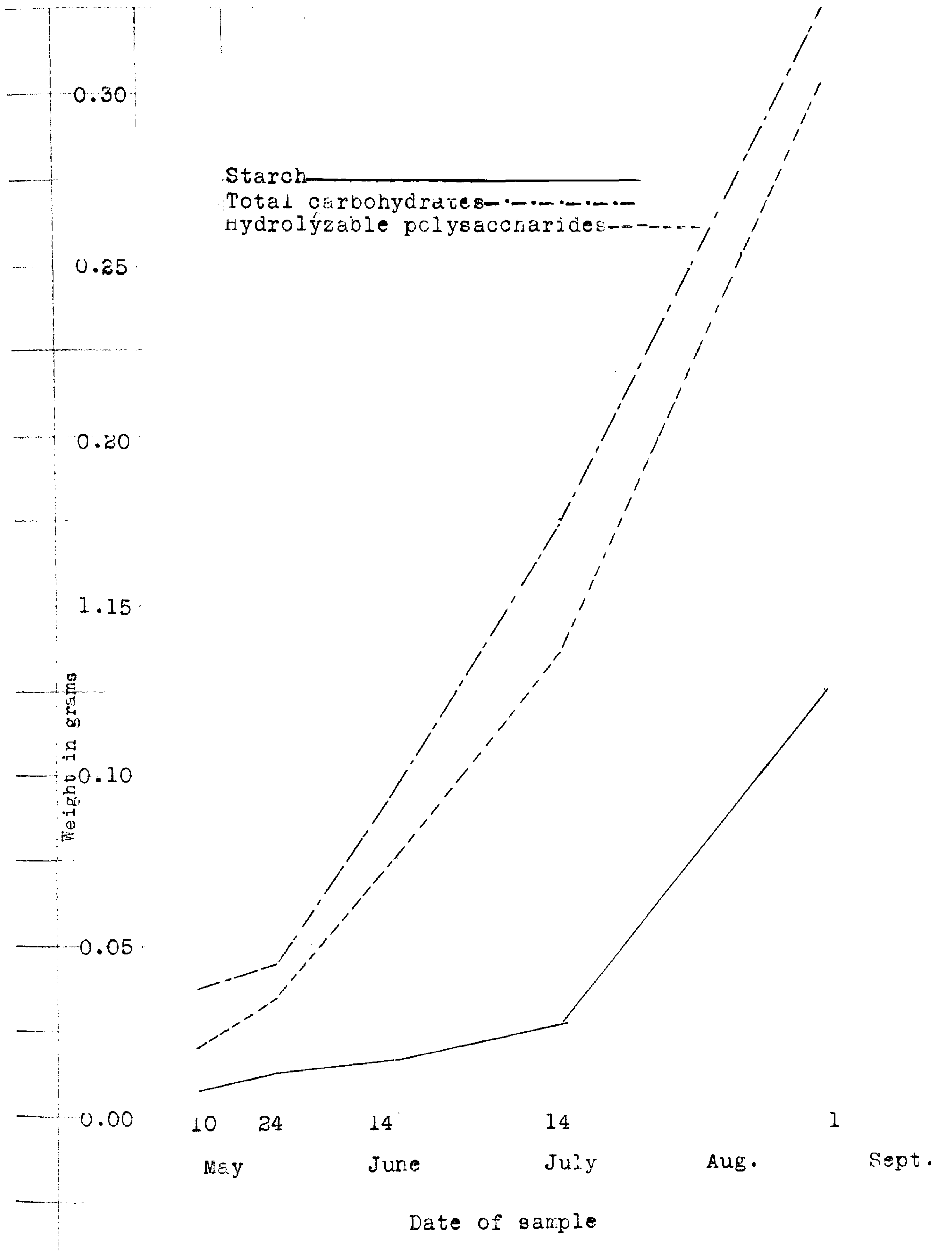


Figure 7. Seasonal changes of starch, free reducing substances, sucrose and total sugars in grape shoots. 1923-24

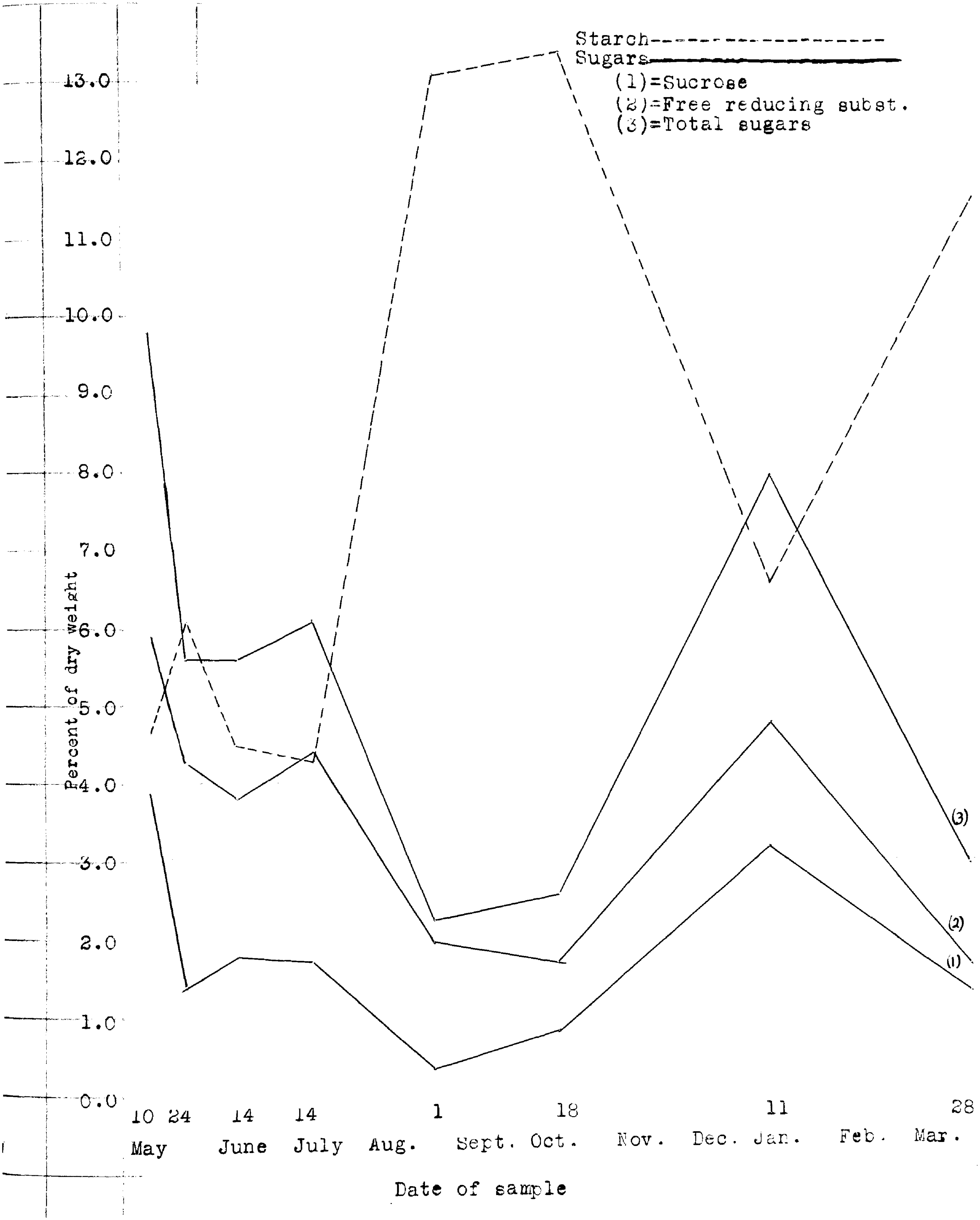


Figure 8. Seasonal changes of absolute amounts of starch and total sugars in grape shoots. 1923-24

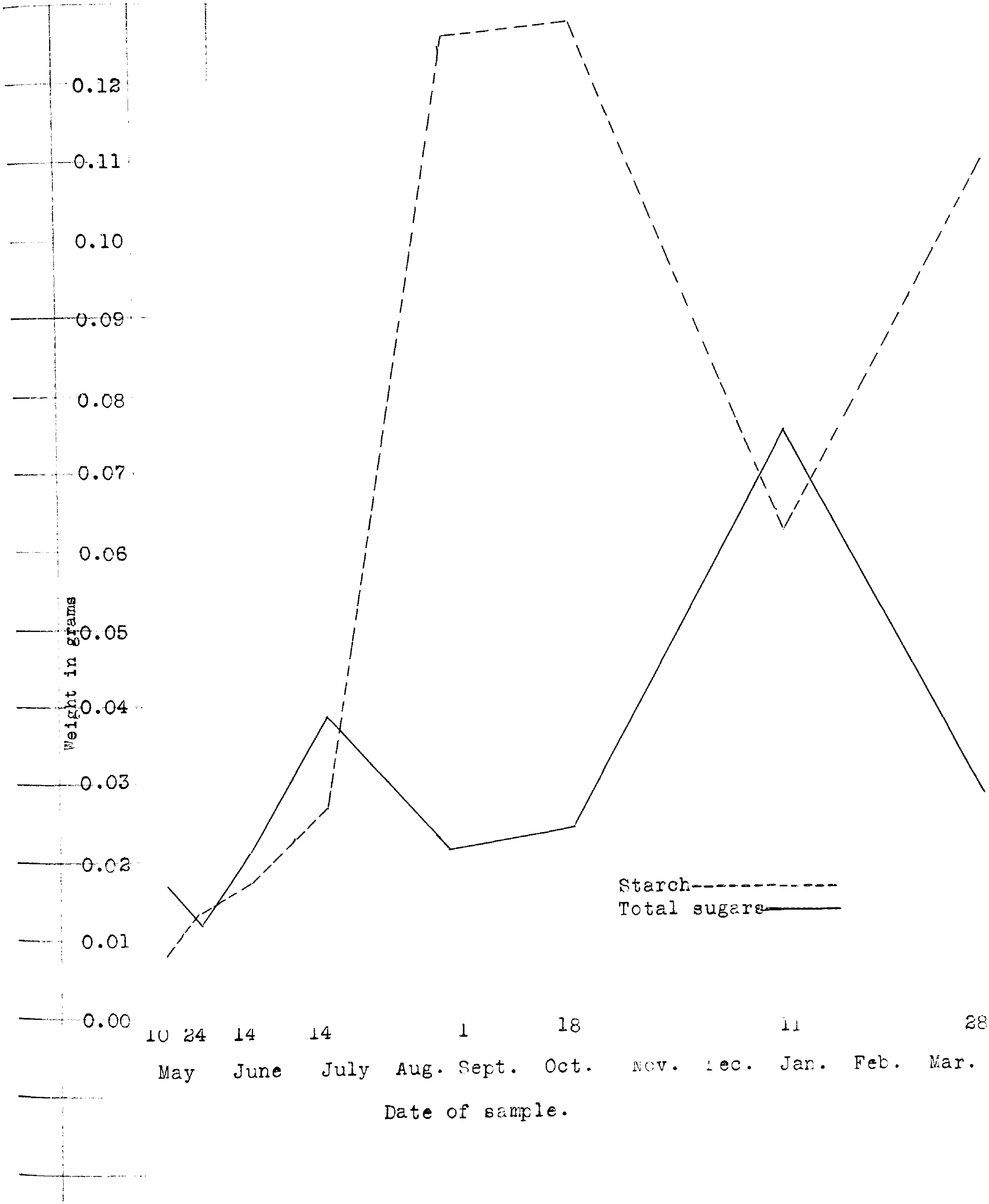


Figure 9. Seasonal changes of percentage of total nitrogen in grape shoots. 1923-24.

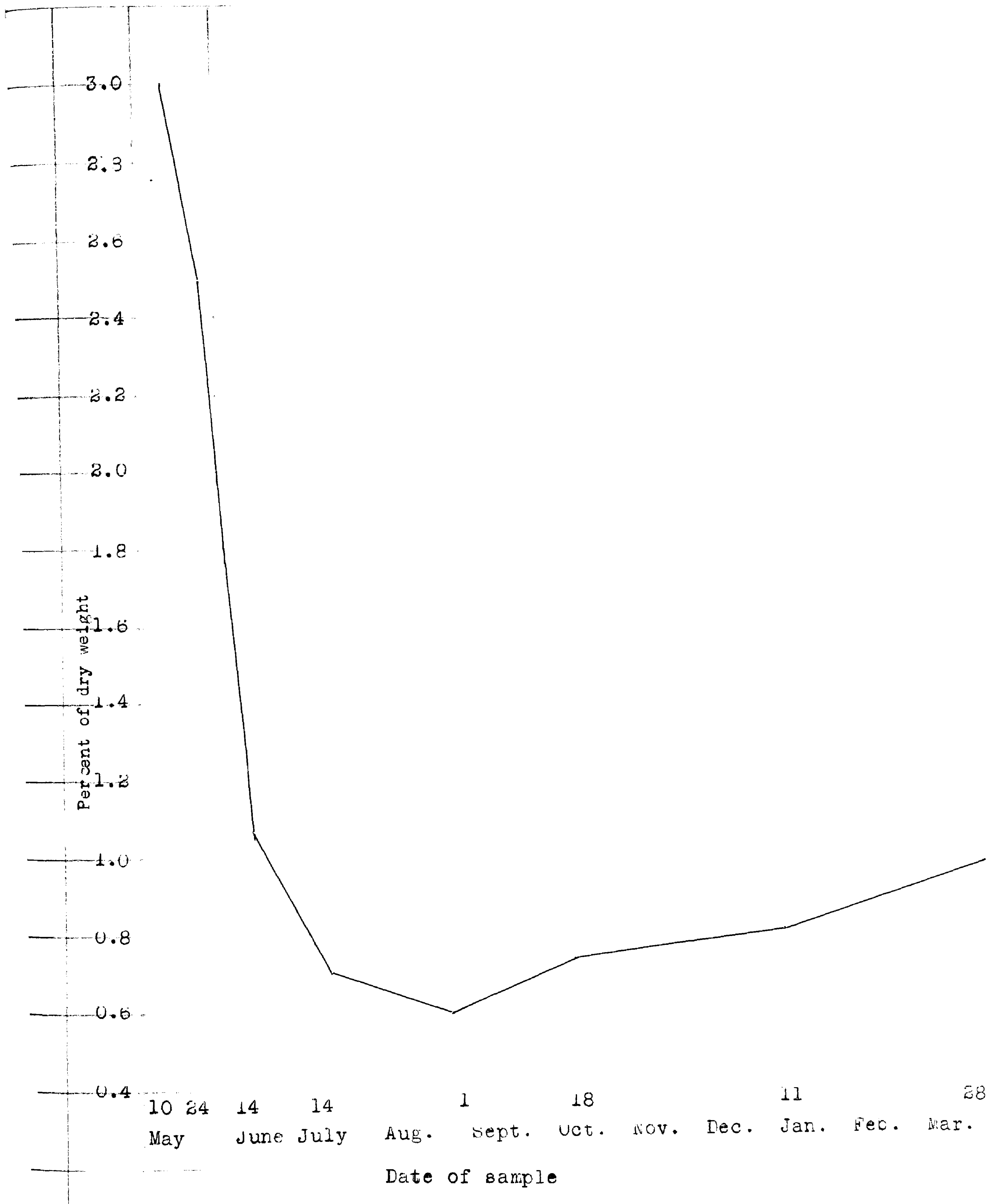


Figure 10. Showing how the hydrolyzable polysaccharides in nodes 1 to 6 tend to reach the same percentage on June 14 in the developing grape shoot, 1923.

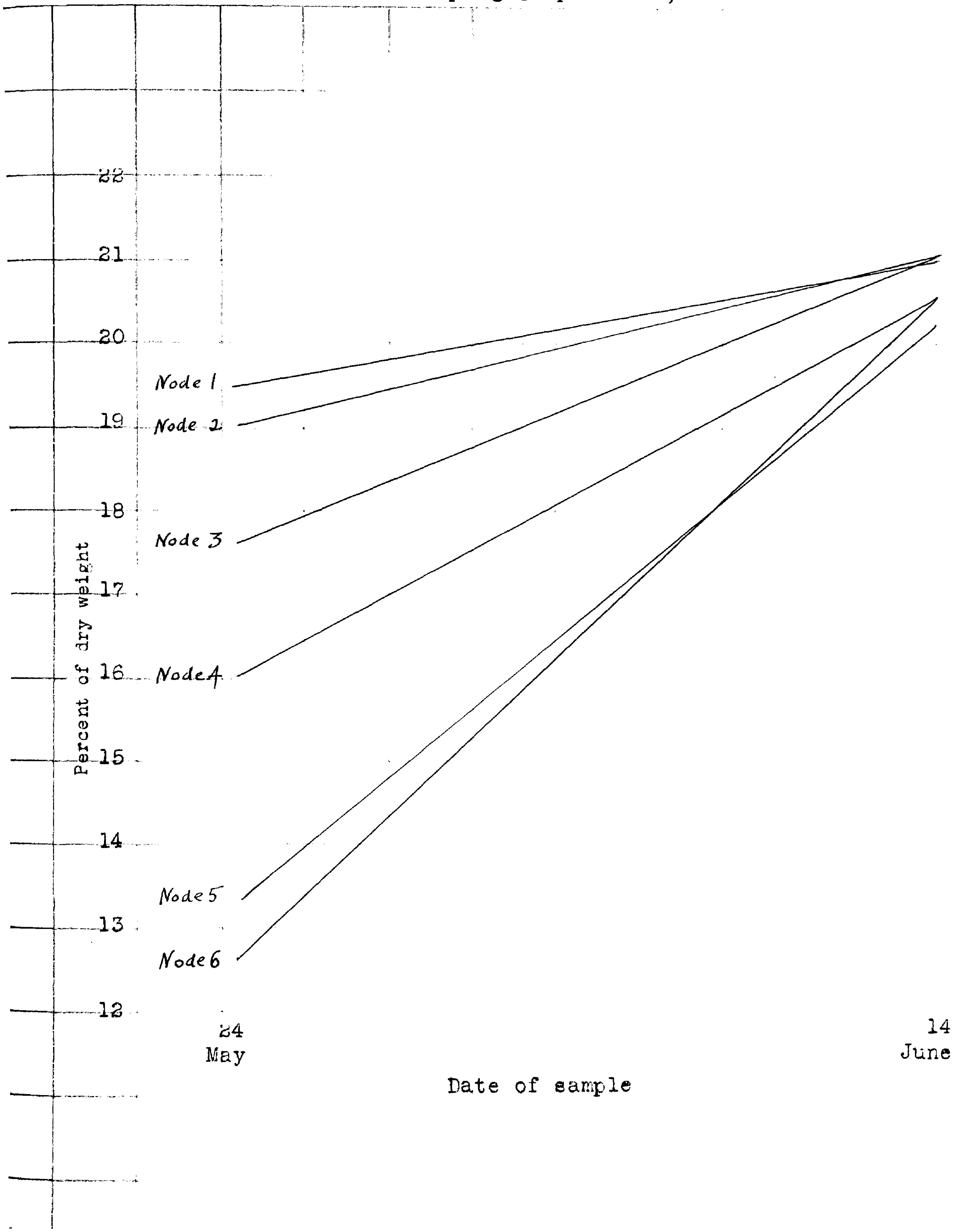


Figure 11. Showing the percentages of starch, total sugars, free reducing substances and total nitrogen in nodes 1 to 9 of a Concord grape shoot on June 14, 1923.

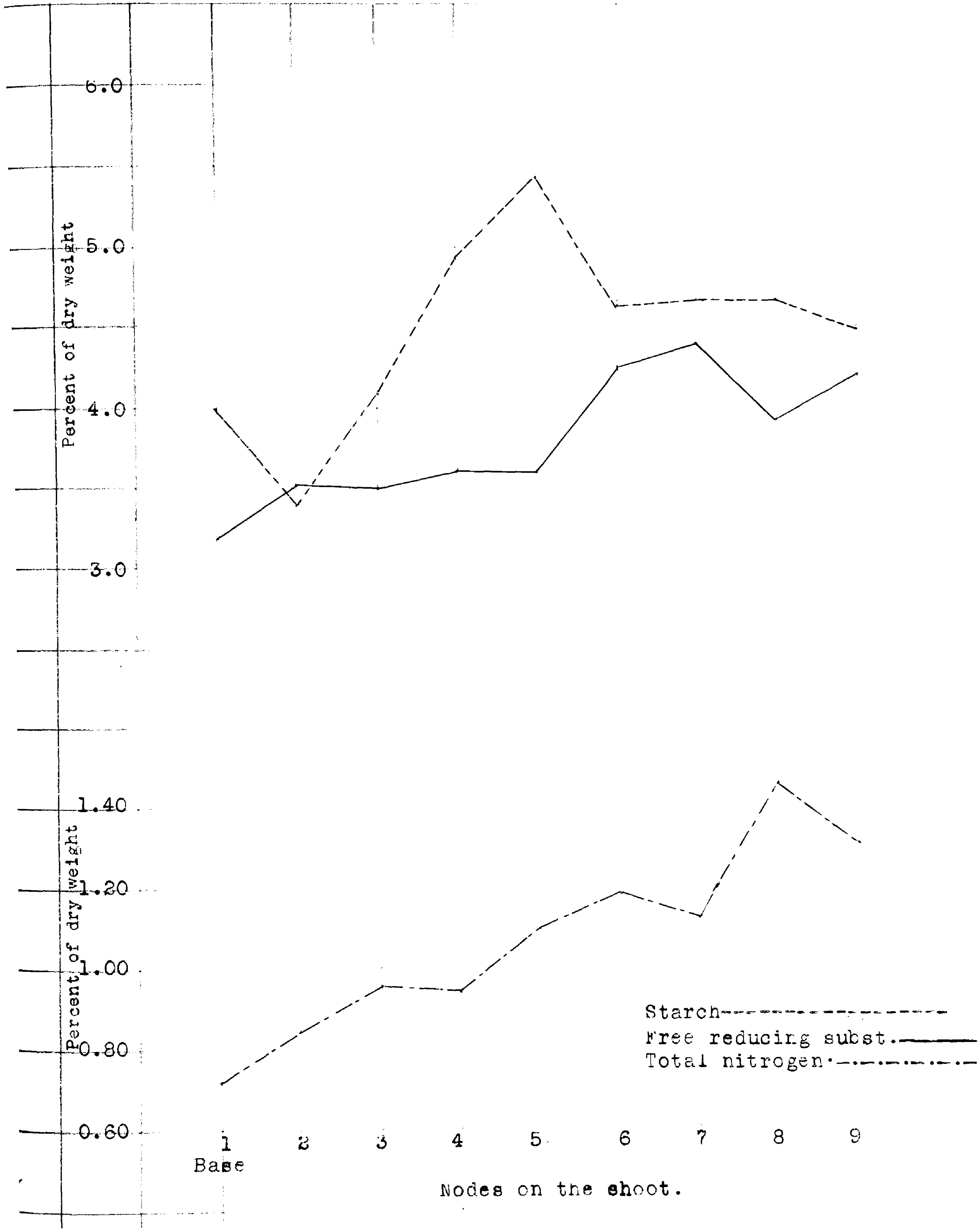
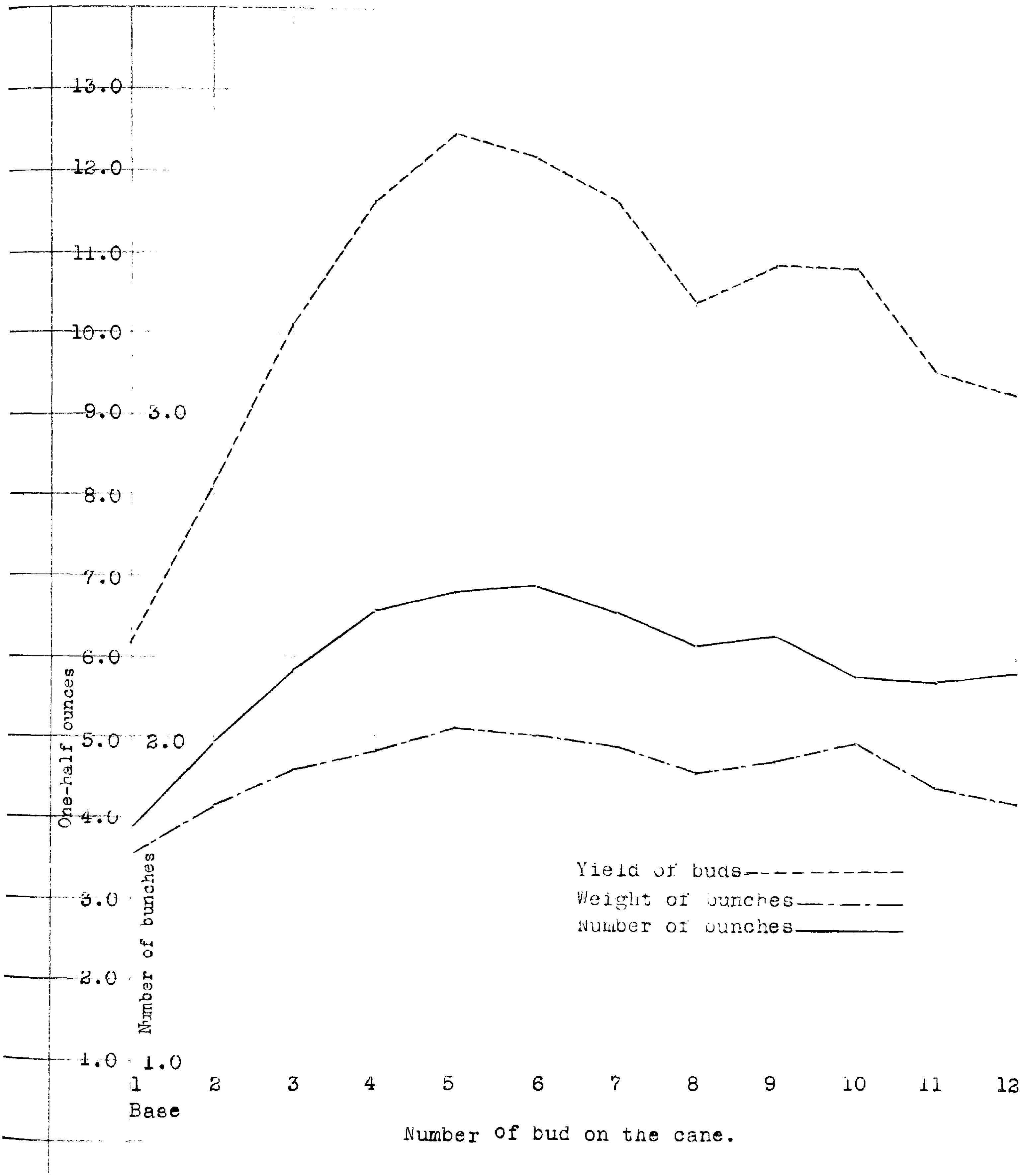


Figure 12. Showing how the yield from the buds on a cane varies directly with the number of bunches and weight of bunches. 1924.



DISCUSSION.

The pruning experiments on young Concord vines as outlined in the preceding pages apparently warrant the conclusion that the severe pruning to two buds as practiced by vineyardists on young vines during two or three seasons before forming the framework of a vine is an unnecessary delay in bringing the young vines to full bearing. If young vines make sufficient growth in the first season, which should be possible to obtain upon fertile soil with proper cultural care, a cane can be brought to the top wire of the trellis to form the trunk, after the first season's growth. By removing the buds below the lower wire and keeping the sucker growth removed from this lower portion of the trunk, a complete framework will be formed in the second season which can be used to produce a full crop in the third season. The yield records of two seasons obtained from vines pruned according to the above method show that commercial yields were obtained in the third year in comparison to the usual practice which brings the vine into full bearing in the fourth or fifth year. Reduction of the number of buds by using two canes instead of four only served to reduce the yield for that year.

Another method of developing a full bearing vine by the third season resulted from these experiments on pruning. In this method the vines were pruned to two buds at the end of the first season's growth but only one shoot was allowed to develop during the second season which was brought up on the trellis to form the trunk. Under the conditions of the experiment, this one shoot made a very vigorous growth with numerous long laterals. By utilizing the laterals for fruiting canes, a complete framework was placed on the trellis at the end of the second season. A full crop resulted in the third season although a considerable drop in yield occurred in the fourth season. Hence, this method is not recommended as desirable at present, although a noteworthy thing about this experiment is the fruitfulness of the lateral canes, showing that this type of growth may be used as a fruiting cane. By pruning these vines to three canes instead of four at the end of the second season, the yield did not drop so markedly in the fourth season.

The third method used in the pruning experiment on young vines brought a single cane to the lower wire of the trellis at the end of the first season. The trunk was extended to the top wire at the end of the second season and two fruiting canes were placed on the lower wire. As will be seen in the data, these vines produced nearly a full crop in the third season but dropped in yield the fourth season, instead of increasing as would be expected. This decrease in yield can probably be ascribed to the poor cane growth which occurred on the "extension" of the trunk. Plate V shows that this extension of the trunk was dwarfed by the growth of the lower part of the trunk. Since many of the vines show this dwarfing effect, the above method of pruning is not as good as the first method of bringing the cane to the top wire for the four cane Kniffin system of training although it is probably suitable for the Fan system, or for vines which have not made sufficient cane growth in the first season to reach the top wire.

The studies on root growth as reported indicate that the severe pruning to two buds at the end of the first season does not favor root development, contrary to the theory that such pruning favors root development. On the other hand, the data show that unpruned vines have a larger root system than vines pruned to two buds. Chandler (1923) reports similar results in pruning investigation with young nursery trees.

The selection of fruiting wood in the pruning of the bearing vine has been based largely upon observations and experience without actual records. The investigation of Partridge (1922) on the relation of diameter to fruitfulness of the cane has shown that diameter can be used as a criterion in the selection of fruiting wood, and that "pencil-size" canes are more fruitful than other types of canes. Colby and Vogele (1924) confirmed the results of Partridge under Illinois conditions. However, the original length of these "pencil-size" canes to be selected is also important as a further index of fruitfulness as the results of the present investigation show. In the two seasons work on this point the medium length canes have given the greatest yields under the four cane Kniffin system with all canes pruned to 12 buds. When the original length of the canes were short the yields per bud and per cane were reduced in the greatest degree. The long canes yielded more than the short canes but less than the medium length of cane. These differences are due largely to differences in the number of bunches per bud, thus the moderate growth in length appears to be correlated with a greater differentiation of flower primordia. It is probable that no definite length of "pencil-size" cane can be given which will be the most fruitful for all vines regardless of the growth conditions of the vines, although the 6 to 8 foot length of cane was found most fruitful under average growth conditions that prevailed in this experiment. The suggestion has been made by the writer (1923) that under a given vegetative condition the following relations between the growth in length of a "pencil-size" cane and its fruitfulness will prevail:

I. Strongly vegetative canes have buds of low fruiting capacity.

II. Medium vegetative canes have buds of maximum fruiting capacity.

III. Weakly vegetative canes have buds of low fruiting capacity.

The above types are only relative and are not sharply defined but probably merge into one another asshown by Figure 1. The medium vegetative cane may vary according to the vegetativeness of the vine but it will be medium vegetative for a given vine. In recent work, Colby and Vogele (1924) confirmed these results previously reported by the writer (1923)

The studies on the point of maximum yield on the cane, verify the observations and results of other investigators as regards the fruitfulness of the buds. The basal buds of the cane are least fruitful, under all conditions, and the middle buds of the cane are most fruitful under average growth conditions. A definite relation was shown between the yield of the buds and the number and size of bunches. The data reported herein indicate that in the more vegetative type of cane the point of maximum yield may shift farther from the base of the cane, and the work of Par trige (1922) shows that the more vegetative vines do not have a maximum yield in the middle portion of the cane but the buds increase in fruitfulness from the base to the tip of a 15 bud cane. Thus his work indicates that it may be possible to increase the yield of vines by increasing the vegetative growth of the vine and leaving more buds per cane on the vine. Kovessi (1901) has reported that a knowledge of the fruitfulness of the buds is quite important under certain conditions in

Europe when the canes do not mature since the basal buds of the immature canes may be unfruitful, and hence canes must be pruned longer than ordinarily.

Contrary to the investigation of Vidal (1911), the present work shows no appreciable transfer of carbohydrates to the roots or vice versa during the dormant season. A marked hydrolysis of starch occurs during midwinter in the tops of young vines and in the canes of bearing vines with a subsequent reverse change toward spring but the total carbohydrates (sugars plus total hydrolyzable materials) show no significant change except for slight loss due to respiration. Similar results on one year old Concord vines were obtained by Richey and Bowers (1924) coincidentally reported with the writer.(1924). Less marked hydrolysis occurred in the roots in midwinter and no significant change in total carbohydrates was noticed. Richey and Bowers (1924) however, reported more marked hydrolysis in the roots than the writer found. From a practical standpoint, these results suggest that the time of pruning or taking of cuttings is not dependent upon carbohydrate changes in the cane, as has been held by some French investigators.

Calculations on an absolute basis show that a large proportion of the carbohydrates and nitrogen of a one year old vine are found in the roots in the dormant season. About 75 percent of the total carbohydrates and 80 percent of the total nitrogen of the young vine was found in the roots after November 1. The large amounts of reserves which occur in the roots of the young vine would probably account for the comparatively slight reduction in root growth following a heavy pruning of the top.

The roots of young vines apparently absorb large amounts of nitrogen in early fall following the fall of the leaves. Little change in the nitrogen content of the tops of young vines occurs during the dormant season. The intake of nitrogen by the roots in fall may be of some significance in regard to fall application of nitrogen to fruit plants, although this point needs further investigation.

The developing shoot on a bearing cane shows an accumulation of carbohydrate reserves which is greatest from midsummer to September. The developing shoot and fruit evidently retard the accumulation of the reserves in the stem during the early part of the summer. From September to leaf fall there is only slight increase in the reserves, possibly due to lessened activity of the leaves during this period. Following the polysaccharide reserves during the entire year, we find a minimum occurring in spring, a maximum in fall, a second minimum in midwinter, and second maximum in late winter.

Assuming from the limited literature on the fruit bud formation of the grape, that the flower primordia are started in early summer there appears to be a correlation between the chemical constitution of the various nodes of the shoot on June 14 and the subsequent fruiting behavior of the buds. Thus, in Figure 11, the starch content of the three basal nodes is relatively low, the nitrogen content and sugar content are also low. The fourth and fifth nodes are relatively high in starch and medium in sugar and nitrogen. The sixth, seventh, eighth and ninth nodes are medium in starch content, relatively high in sugars and high in nitrogen. Following the postulations of Kraus and Kraybill (1918) that certain relations of carbohydrates and nitrogen are associated with fruitfulness, the above differences might be associated with differences in fruit bud formation in the various nodes at the middle of June. The close relation which was found between the fruitfulness (yield) of the buds and the number and size of bunches indicate that corresponding differences in fruit bud differentiation in the previous seasons are probable.

Conclusions.

1. Concord grape vines can be brought to full bearing condition in two season's growth (bearing in the third season) by forming a trunk to the top wire at the end of the first season, instead of pruning to two buds as usually practiced.

2. The usual pruning practice of pruning young vines to two buds in the first two years does not favor root development but tends to retard it.

3. The original length of the "pencil-size" cane before pruning serves as a further index for selecting the fruiting wood at pruning time. Under average growth conditions in Maryland the 6 to 8 foot canes were most fruitful.

4. The point of maximum yield on the cane appears at the fourth or fifth bud under average conditions of cane growth in Maryland. Basal buds are low yielders.

5. The fruitfulness of the various buds on the cane is directly correlated with the number and size of bunches per bud.

6. Since chemical differences were found on June 14, among nodes 1 to 9 inclusive on the shoot, it is suggested that these chemical differences, especially as regards starch, are correlated with variations in the differentiation of flowers and flower clusters at this time, as reflected by the subsequent differences in number and size of bunches. This correlation might then be applied to the observed differences in fruitfulness of the buds.

7. No appreciable transfer of reserve materials occurs during the dormant season in young vines from top to roots or vice versa.

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APPROVED E. C. Auchter

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