GRAFT UNIONS IN GRAPES AS AFFECTED BY SEASON OF GRAFTING AND TYPE OF CION

THESIS FOR THE DEGREE OF M. S.

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1933

Grapes
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A Thesis

Submitted to the faculty of the Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

Department of Horticulture

East Lansing, Michigan

1933

Approved May 17, 1933

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THESIS

Introduction

Grapes maturing earlier than Concord have generally brought good prices in Michigan. It seems probable that sales of very early varieties could be extended if varieties of better quality could be offered. This requirement is met, in large measure, by the Campbell Early grape. Unfortunately, this variety is very sensitive to soil conditions and in most locations it lacks vigor, productiveness, and compactness of bunch. Recent studies in New York (45) have shown that Campbell improves markedly in all these respects when grafted on certain other grape varieties. The present paper reports experiments designed to throw light on the practicability of grafting this variety into established vines, on the most suitable period for grafting, and on the type of cion most satisfactory for use.

LITERATURE

Grafting of grapes has been practiced to some extent at least since the beginning of the Christian era. Columella (29), who wrote in the first century, mentioned it with no hint of novelty and disagreed with earlier writers on some details of time and method of executing the operation. Palladius (69), likewise, discussed grape grafting. In 1600 de Serres (85) in France, and in 1672 Sharrock (86) in England, mentioned the matter. Later in the same century, de la Quintinye (74) gave details of the operation. Prince (73) records grafting of grapes in the United States in 1819.

Until the introduction of the phylloxera vastatrix into France (between 1860 and 1870), however, there appeared to be little occasion for grafting grapes. DeSerres (85) stated that propagation by layers and cuttings was easier and that the only occasions was to change over an unsatisfactory variety. Even for this purpose, the utility of grafting is questionable, since a new vine set in place of the old one comes into bearing quickly.

With the advent of the phylloxera, grafting became imperative in most of the European wine area. Since stocks are raised more easily from cuttings than seedlings, clonal rootstocks have been used almost exclusively, and extensive trials have demonstrated various degrees of resistance to phylloxera (81, 95), tolerance to lime and to depth of soil (46,48), and effect on fruitfulness in these various clones (46,50, 79). Outside the region where phylloxera is important, experiments in New

York (43, 44) have shown that certain varieties commonly grown on their own roots succeed much better when grafted on some of the clonal stocks.

Grape grafting has always been invested with more or less uncertainty, and since grafted vines became necessary, methods of grafting have received much attention.

For Vineyard Grafting

1. Type of Graft Preferred

For vineyard grafting the cleft graft seems to have been the most desirable type since the early ages. Columella (29), de la Quintinye (74), and de Serres (85) among the early writers gave preference to the cleft graft. Noel (67) stated that of all methods used to graft fruit trees only two succeed with the grape; cleft graft is the best, and inserting a cion in a hole bored through the stock is fair. André (2) stated, in 1826, that with grape stocks two years old or older cleft grafting is sure if one waits until the first strong flow of sap is over. He stated that Lenné had been grafting for 20 years in German vineyards and that he preferred the cleft. L. H. Bailey (25) directed that the stock be cut below the surface of the ground and two cions inserted exactly as cleft-grafting the apple. J. W. Fischer (40) and Maurer (63) in Germany, Du Brenil (31) in France, Reid (81) in England, Strong (90) and Husmann (48) in the United States, and others (12) mentioned the cleft graft as the most desirable for vineyard grafting.

There has been some opposition to cleft grafting the vine,

and some (82, 5, 7, 75) prefer inarching. Adlum (1) stated that it is better to whip graft stocks over one inch in diameter and cleft graft those under one inch in diameter. His opinion is somewhat different from that of the majority of reporters.

2. Season of Grafting

A diversity of opinion has prevailed as to the most desirable season for vineyard grafting. Some writers prefer grafting early in the spring before bleeding begins, and some prefer waiting until the heavy flow of sap is over. Only a limited number of writers suggest grafting during the heavy bleeding period, and some even suggest grafting in the fall so as to avoid all possibility of bleeding.

EARLY SPRING - Columella (29) suggested grafting the vine in the early spring when it is warm and calm with no wind and before the buds begin to move. William Prince (73) stated, "The period for the operation is when the sap begins to rise, and it seldom fails of success when performed in the ground." A New England writer (4) reported that Mr. Langworth grafts the vine in March, in the same manner as used in grafting an apple tree and applies a paste made of fine clay to the wood. Miller (65) suggested grafting as early in the spring as possible. An English writer (15) stated that the grafting is performed before the sap is in motion. A modern French writer (32) states that grafting continues there from early March until the end of April, and the majority of grape growers of his section prefer to graft early. Another French writer (23) advised

that grafting be done as soon as ascent of sap begins to show and continue until the buds begin to open. According to his statement, that period is in the first fifteen days of March for south France and last fifteen days in March for central to north France.

Ravaz (76) suggested recently that grafting be done early, because if grafted late the vines "weep", emitting a great quantity of sap which leads to the death of the graft by keeping air from the line of union.

Strong (90) stated: "A serious and universal difficulty arises from the excessive bleeding of the vine wherever a cut is made in the spring. When the whole top is taken off, the flow is so free as to drown and rot, or poison the vine in some instances. Some persons do, however, have very tolerable success by commencing quite early, before the flow of sap has become free."

Adlum (1) suggested that vines growing in the open should be grafted about three weeks before the buds begin to break. A number of other writers (22, 5, 59, 27, 19, 31, 51) also suggested grafting in the early spring before bleeding begins. Husmann (48), Miller (64), Marvin (61), and Lodeman (57) suggest either grafting early in the spring before bleeding begins, or waiting until the heaviest bleeding period is over. All the writers mentioned above advise avoidance of grafting the vine during the heavy bleeding period.

BLEEDING PERIOD - Apparently a few grape growers gave very little attention to the heavy flow of sap from the vine while grafting.

Noel (67) stated that the best time for grafting the vine is in the spring just before the buds "burst into leaves", but he says one can graft as late as when leaves are fully out. In Illinois (11), in 1863, Cook suggested grafting when the grape leaves were the size of a dollar, and Dr. Claggett, of St. Louis, suggested grafting in May.

A report of the Illinois Horticultural Society meeting (14), in 1872, states that Mr. Pells Manny grafted some grapes every two weeks from the latter part of winter until July 20 and not more than 10 per cent failed up to June 20, but after that they did not take as well. He tried some in the fall and they failed. Husmann (50) stated that G. W. Campbell, of Ohio, grafted as soon as the first sap movement started, but he preferred to wait until the heavy sap flow was over. One French writer (75) quotes Chaptal as advising grafting the vine just when the sap is beginning to flow. Others (98) advise grafting after the sap has started to flow.

Hisen (33), of California, stated, "The best time for grafting grape vines, as well as for grafting anything else, is when the stock on which we graft has its sap in circulation, and when the cion or cuttings which we are to insert in the stock are yet dormant".

Loubat (58), then of New York, stated that one must wait till the sap has got into motion and vine has "dripped" before grafting. He cautioned against grafting white grapes on red. Although Hayne (46) gives preference to early grafting, he states

that some suppose that the cion is "drowned" if grafting is done when the sap is beginning to flow so that the vine "bleeds"; this he states is an error. He mentioned rains as being worse at this time than an excess flow of sap, but an excess of moisture is not as bad as a drouth which is likely to come at a later date.

LATE SPRING - As stated above, some of the writers, (48, 64, 61, 57) suggested grafting in the vineyard either early in the spring before bleeding begins, or waiting until the heavy flow of sap is over in late spring.

A German writer (3) stated that the time for vineyard grafting is when the sap has ceased to run vigorously and the eyes have begun to develop. Andre' (2) recommended waiting until the first strong flow of sap is over. "SL" (89), an English writer, stated that he considered the time to perform the operation to be when the shoots have advanced about two or three feet.

A New York writer (6) advised waiting until the vine is in full leaf. He said that if grafting is done early in the season, the excessive flow of sap will be in the way of success. Another New York writer (7) stated that the difficulty of grafting cions upon old roots of the vine is the great tendency to bleed by the old stock, the sap pushing the cion from its position. A California writer (16) stated that the most favorable time for grafting the grape is when the leaves are started and the vines cease to bleed.

As reported by John Phin (70), "Lindley stated that the

great secret of success in grafting the vine is to keep the cion dormant until the stock has so far developed its leaves and shoots as to be beyond the reach of danger from bleeding".

Husmann (49) suggested keeping the cions dormant until the leaves have expanded on the stock. He stated that the parts will unite more readily after the first rapid flow of the sap is over, and the cion is less likely to be "drowned out". Dawson (30) cautioned against budding or grafting grape vines until the stock plants are in full foliage; otherwise bleeding may ruin the whole work, and even kill the stock plant. Turner (93) stated that if vines are grafted when dormant, no union will take place. He considered the most favorable time for this operation to be after the first flow of sap has passed, or about the time when the vines are in bloom.

Others (45, 83, 17, 9, 97, 53, 24, 26, 60, 50, 66, 8) suggest waiting until the heavy flow of sap is over before grafting the vine. Practically all of them seem to think the vine would be greatly injured if cut during the heavy bleeding period, and that the excessive flow of sap would either kill the cion or prevent any union from taking place.

FALL GRAFTING - Some of the writers that try to avoid both bleeding of the stock, and also grafting too late in the spring for the wood to mature before winter, suggest grafting in the fall. Columella (29) mentioned fall grafting, but without endorsement. Perlet (36) suggested grafting grapes in France in early fall when the first

leaves turn yellow. Strong (90) said that grafting in the fall would eliminate the difficulty of the vine bleeding. For fall grafting he suggested performing the operation about October or November and grafting several inches below the ground level, banking the soil around vine, inverting a flower pot over the graft, filling in with soil up to top of pot, and covering the pot with several inches of leaves.

Eisen (33) stated that grafting may be done in the fall, but advocates grafting in the spring. A New York grape grower (88) described his method of grafting as taking up the stock in the fall, grafting in the winter and keeping graft in sand in the cellar until spring, and then resetting it in the vineyard. He stated that if the stock were grafted in early spring without lifting it, there would be such a flow of sap that it would "sour" and kill the cion.

Lodeman (58) reported that grafting can be done in the fall, early spring, or late spring. He stated that grafting in the fall is good if the grafts are given protection to prevent frost from heaving out the cion; it must be done before the ground freezes and the graft covered with soil and straw.

Fuller (41), of New York, stated that in mild climates, like those of southern Europe, California, and the Southern States in America, grafting vines can be done all through the winter months, and the cion will have time to unite before sap begins to flow in the spring, but the Northern climates are too severe to permit leaving cions exposed all winter. His details of procedure

are essentially those recommended by Strong (90). Batcham (27) also advised fall grafting.

Verge (95) descrives herbaceous grafting of the grape in late summer in which he seems to think the lack of success is due to failure to remove the leaves on the cion and thus check excessive transpiration.

PREVENTING BLEEDING - A New England grape grower (4) took his vines up and reset them in the fall and grafted in the spring. This prevents such a heavy flow of sap in the spring and he thought the parts united better. A New York grape grower (87) transplanted his vines before grafting to prevent bleeding.

3. Type of Cion

BASE OF CANE - De Serres (85) advised selection of cions from the base of the cane and avoidance of the rest of the cane. His reason was that the eyes on the base are more fruitful and make more fruitful vines than those on other parts of the cane. Maurer (63) suggested that one use only young (one-year) wood and only from the lowest part of the cane, for the other part has too much pith. In describing a different, but somewhat related matter, Leissig (55) reported no difference in the rooting of cuttings of Taylor wood taken from the upper, center, and lower parts of the cane; but with Riparia wood, the lower part rooted best in every case.

Adlum (1) stated: "In general, the bottom part of last year's shoot is to be preferred; but in well ripened vigorous wood,

any part of the shoot will answer, provided it be not too long jointed. These cuttings should be preserved in pots filled with light sandy earth, till the grafting season."

Mathien (62) advised that in preparing cions, they be cut in detail, eliminating defective shoots; also eliminating the base, which contain less reserve nutrients, and the tips which generally lack maturity.

CUTTING AND PRESERVING CIONS - Columella (29) mentioned the fact that one should select the ripest cane possible from a vine that is "faithful and generous" to use as a cion. This was with reference to performance, rather than to successful grafting. Prince (73) suggested cutting cions prior to time of grafting and preserving them as cuttings until ready to use. Palladius (69) stated that the cion should be round, firm, and well supplied with buds and short internodes. Husmann (48) advised cutting cion in the autumn just after the first frost has taken the leaves, and keeping them in a damp, but not wet, sand or moss. Loubat (58) advised the selection of the healthiest branches with eyes closest together; cutting them in October and storing in a cellar over winter, keeping them moist. Hayne (46) advised selection of canes for cions from the heavy bearing vines. Others (10, 16, 24, 2, 37, 41, 64, 62) advised cutting cion wood in the fall before freezing and storing it in moist sand or similar material over winter, but cautioned against keeping them too wet.

Leissig (55) compared grape cuttings stored over winter

in peat, peat and sand, sand alone, and sand and charcoal. The pure peat proved unfavorable, but the other three materials appeared to be equally good.

Prott (72) placed some grape vines in an ordinary storage in October, 1900, and kept them there over winter. In June, 1901, the vines were placed in a cold storage and kept until the last of September, and then placed back in the common storage and kept until spring. They were planted and grew well. From this experiment one might conclude that grape wood keeps well in cold storage.

NUTRIENTS AND TREATMENTS - In 1902 Twight (94) ran the iodine test for starch content in grape cuttings. He found that cuttings showing a high starch content by this test gave 264 per cent more rooted cuttings than those showing a low starch content. He also found that treating cuttings with oxidizing agents increased the number taking root.

Ravaz and Bonnet (79) did some rather detailed laboratory work to determine the conditions of grape cuttings, and concluded that the rooting of cuttings and "taking" of the grafts are tied up with the condition of the wood. They advise rejecting canes with large piths, but external characters cannot always be relied upon. Signification and density were determined, but failed to tell the contents of the cells. Canes with a high carbohydrate content made better cuttings than those with a low content. By microscopic examination it was found that the good canes contained

a large number of starch grains as compared with a much smaller number in the poor cuttings.

4. Temperature

According to Kroemer (54) the forces setting cambium into activity are: (1) heat, (2) air, (3) moisture, and (4) nutrients. He states that all unions are formed from the cambium tissue and the more active this tissue becomes the better will be the unions. That is his reason for applying artificial heat to bench grafted grapes. Ravaz (76) states that the principal factor in grafting in the spring is temperature, and he advises banking dry soil around the graft to give more heat than moist soil. With an experiment made with grafted grape cuttings, Ravaz (78) concluded that very little union took place at temperatures lower than 20°C. At 22° its development was more rapid, and at 30° it was extremely rapid. He found temperatures of 30° to 35°C. produced callus tissue most rapidly.

Sitton (88), working with black walnuts, also found the optimum temperature for graft union to be about 28° or 30°C. He got better results by grafting in the summer than in the early spring, which he attributed to the higher temperature at that time.

5. Humidity

There seems to be considerable diversity of opinion as to the importance of moisture content in graft union. If air is as important in the formation of callus tissue as Kroemer (54)

and Hayne (46) indicate, it seems that moisture content would naturally become very important. Loubat (58) advised that fine, dry weather be chosen for grafting, when there is no likelihood of rain. Prince (73) also suggested performing the operation in dry weather.

On the other hand, "R. A." (75) advised grafting on a cloudy day and avoidance of grafting in dry weather, especially when the wind is from the northwest, as that will dry out the cions. John Phin (70) also advised not to graft when a drouth prevails. "S. W. H." (91) states that in the spring where a strong healthy vine has been cut off for cleft grafting, there is such a tremendous flow of sap that the sap "sours" and kills the cions. Another grape grower (19) states that if vines are cut off and grafted while bleeding, the flowing of the water often prevents the cion and stock from uniting.

Ravaz (76) makes the following statement: "Union tissue does not form with water which is not aerated. The injurious role of an excess of sap varies with the weather which prevails; it is very harmful in a rainy season, useful in a very dry season".

Sitton (88) found that, with the black walnut, unions took place more rapidly with an atmospheric humidity almost saturated. However, he did not work with grafts in water-soaked soil.

Hayne (46) stated that the degree of humidity of the soil exerts a very great influence on the successful joining of the graft to the stock. If a cutting or a grafted cane be plunged into water so as to cover the lower parts of the cane,

no cicatricial tissue whatever will form. Grafts covered with fine sand, kept constantly wet by irrigation, may develop young shoots, but never unite. In sand that is kept slightly moist, on the contrary, the best results are found.

Another grape grower (13) reported that he found watering and shading the graft in dry hot weather to be beneficial.

6. Miscellaneous Points on Grafting

According to Oppermann (68), a test in Germany on bench grafts indicated that there was no benefit derived from tying. Some of the grape growers (1, 3, 79, 81) advise tying cleft grafts. However, others (49) think it is not necessary.

J. W. Fischer (40) and Du Breuil (31) advised waxing the wound made by grafting, especially in grafting above ground. Many writers (3, 49, 24), however, advise using no wax, but banking soil around graft. Husmann (50) and others (8, 9, 12) also advise grafting just below the ground level and heaping soil around the graft to prevent the cion from drying out.

Bailey (73) states that the cleft needs no tying or wax, although it is well to place a bit of waxed cloth, or other material, over the cleft to keep the soil out of it, and then to fill the earth tightly around the graft.

Fischer (39) and Oppermann (68) advise placing moss around the graft to keep the wound moist until stock and cion unite.

Jacobs (52) reported that treating stock cuttings with

hot water and $MnSO_4$ prior to grafting stimulates callus formation and results in a greater number of unions than occurs in those not treated.

7. Cion Varietal Peculiarities

Certain hard-wood varieties of grapes, such as the Diana (98) and Delaware (99), have been reported as hard to propagate from cuttings, but graft rather successfully.

Weak varieties, as the Iona and Delaware becomes more vigorous and productive when grafted on more vigorous stocks (22, 97). Jones (53) stated that he had seen Iona improved by grafting on a vigorous stock for several years, but ultimately to lose vigor; this may have been the effect of overproduction. Temple (93) stated that he had seen much good accomplished by grafting some weak varieties on more vigorous sorts, but others he thought were only benefited temporarily.

Campbell Early generally lacks vigor on most soil and is much improved by grafting on certain stocks (44).

Stock to Use

SUITABLE FOR CION - From experience, it is well known that certain grape varieties grow better on certain stocks than on others. Miller (65) stated that one important part has almost been overlooked; one must select stocks of as near similar wood as possible; for instance, Delaware will hardly take at all on a rank Fox, while upon Clinton it takes very freely. A New England grape grower (12) stated that one cause of failure in vine grafting is trying to graft heavy-grained rank growers, as Diana and Concord, on fine-

grained sorts, as the Clinton.

Gladwin (44), working with effects of grafting a number of grape varieties in New York, found that certain stocks were better for certain varieties than other stocks. Clinton and Gloire proved to be superior stocks, of those he used, for Campbell Early.

PHYLLOXERA RESISTANCE - A French writer (96) reported the results of a vineyard set out six years before the appearance of the phylloxera. The insect ravaged all the vinifera vines, but the Clinton, Post Oak, Emily, Ives seedling, Clara,and Mustang all resisted the phylloxera. Delaware and Isabella were not resistant. Ravaz (77) listed some of the grape stocks in the order of decreasing resistance as follows: 1. Rupestris, 2. Riparia, 3. Viala, 4. Taylor, 5. Clinton and 6. Jacquez.

Foex (20), in studying reasons for comparative immunity of American grapes, attributed the power to resist the phylloxera to the structure of the root tissues. He stated that the roots of American vines are more dense and woody than those of European grapes; the medullary rays are narrower and more numerous in the American vines. The puncture of the phylloxera excites a local irritation, which does not pass far beyond the original point of injury and traces of which soon disappear.

Gard (42), working with hybrids of American and European grapes, found that the cane and trunk resembled those of the vinifera more than of American vines. On the other hand, the roots more nearly resembled those of the American grapes, which made them

more resistant to phylloxera.

SOIL ADAPTATION - Some stocks may be well suited to the cion and be resistant to phylloxera, but not suited to the soil. Lime soils of Europe give the grape growers much trouble in securing stocks that will thrive in those soils. Fischer (37), in Germany, stated that between the condition of the grafted plants, on York Madeira, and the lime content of the soil a parallel can be drawn easily. The smaller the lime content, the better the growth of the grapes; with increasing lime content, the development of the grape decreases until death ensues.

Faes (34) found that hybrids of American and European grapes were better suited to adverse soil conditions in the heavy lime soils of France than American grapes. In another experiment (35), he found that Riparia X Rupestris 3309,3306, and 101 were outstanding stocks in all the vineyards where the soils were not too calcareous, too shallow, or too compact. In soils of those types, he found Chasseles X Berlandieri best.

Burnat (28) stated that it is known that the Riparias do not endure high contents of lime, but in dry climates of America , they resist lime better than in a rainy climate. He states that if it were not the question of lime, one could plant Riparia Gloire almost anywhere.

CLINTON - When the phylloxera became so destructive in France, Clinton was introduced as a stock for the vinifera, and it proved to be entirely phylloxera resistant in some cases (18, 96), but

Ravaz (77) listed it fifth among six stocks named. Piper (72) found the Clinton to be resistant in America. Working in the Great Lakes region, where phylloxera is not important, Gladwin (44) found the Clinton a satisfactory stock for the Campbell, and others (65, 59) have found it to be satisfactory for the Delaware. One grape grower (21) states that if a Delaware is grafted on a Clinton, the grapes will be darker for a few years. However, he does not base his statement on conclusive evidence.

RIPARIA GLOIRE DE MONTPELLIER - Twight (85) states that in California Riparia Gloire de Montpellier seems to be the best stock for vinifera grapes. It is stout and has good "affinity" with vinifera. Hedrick (47) describes the Riparia Gloire as a hardy plant with numerous hard roots that feed near the surface of the soil. He states that it grows best in deep rich soils that are neither too wet nor too dry. It imports its vigor to the vines worked on it, and is very resistant to phylloxera. The main defect of this stock seems to be that it is exacting as to soils. This defect of Riparia Gloire was brought out by Fischer (38) in Germany. He found that the stock failed in one vineyard because the soil had a hard pan and was wet above the hard pan after rains. Burnat (28) found that it would not endure much lime in the soil. Where the soil is suitable it makes a good stock. (44).

RIPARIA X RUPESTRIS 101 - According to Sahut (83), Riparia was one of the first American stocks used in France to resist the

phylloxera. It was highly resistant, and was satisfactory for a few years,and then the vigor of the grafted vines began to decline.

Leissig (56) states that Riparia has a shallow root system and is suited to a rather moist loam soil, and Rupestris has a deep root system and is suited to a strong soil that is dry on top. When they were crossed, it was found that the hybrid was suited to a wider range of soil types than either of the parent species. The Riparia X Rupestris 101 has proven to be a good stock, being highly resistant to phylloxera; it roots and grafts well, and is hardy (85). It has been entirely satisfactory as a stock in the vineyards at Vaud, France (28), and has mostly replaced Riparia Gloire there.

ARAMON X RUPESTRIS GANZIN NO. 1 - This stock has given satisfaction in some vineyards of France, but not in Switzerland (47). It was not outstanding in the State trials at Vaud (35). However, it has proven satisfactory on clay soils in California (94).

Discussion of Literature

Stock and cion relationships and soil adaptation are touched upon only casually in this review. The citations presented are probably numerous enough to constitute a representative sample of opinion as to the operation itself among men experienced in grape grafting.

The opinions quoted seem to offer no serious conflict with reference to the type of graft used, or the manner of executing it. The clash of opinion is chiefly on the most suitable time for grafting. Unfortunately, few of the expressions of opinion analyze this question into its components, such as temperature and humidity, and none throws clear light on the conflict resulting from the fact that the conditions favoring union of grafts also favor transpiration. Hence, doubtless, arises the conflict between "early" and "late" grafting.

Most eastern American grape grafting has been concerned simply with utilizing a vine of undesirable kind as a means of securing quick production in a cion of a desirable kind; it has not been done to secure resistance, soil adaptation or stock vigor. Consequently, the chief concern has been to get the cion to grow, and if the cion formed roots of its own the matter was considered of no consequence. It is probable that many cases of supposedly successful grafting in America have been principally cases of rooting of cions with little or no graft union. European practice, since phylloxera became so destructive to vinifera grapes, has had to guard vigorously against cion rooting. For this reason,

European reports have perhaps more reliability than American. Furthermore, European practice has had more definite aim and more careful scrutiny of results, than American. It is clear, therefore, that the most precise information available is derived from European experience with vinifera cions.

Methods and Materials

Data reported here were secured at Grand Rapids, Michigan, in 1932. Four stocks were used, namely: Clinton, Riparia Gloire de Montpellier, Riparia X Rupestris 101, and Aramon X Rupestris Ganzin No. 1. These stocks had been growing for five or six years on a medium heavy clay loam soil, and all were rather vigorous. In 1929 they were grafted just above the ground level, but the grafts failed to grow. In the work here reported most of the grafting was done at a point just below the ground level.

Cions were all of the Campbell Early variety. Whole canes, ranging from 8 to 15 feet in length, were cut about April 1, and stored in a barn basement storage room with moist burlap over them to prevent desiccation.

The original planting was laid out in rows 10 feet apart and 400 feet long with the plants eight feet apart in the row. Since there were some vacancies, the number of plants per row varied from 30 to 40. There were eight rows of Clinton, two rows of Gloire, and only a part of a row of each of the other two stocks. Most of the data reported here is based on results secured from the Clinton stocks, of which two rows were grafted at

each of the four different periods.

Cions for three grafts were taken from each cane, from the butt, center, and tip portions, respectively. The cions from these three portions of the cane were placed, in the order named, on successive stocks in the row. This arrangement was repeated throughout each row to ensure good distribution of cions from each portion of the canes.

There was some soil variation from one end of the rows to the other, but less from one row to another. It seems, however, that the distribution of cions in the rows eliminated soil variation as a factor affecting results with cions from various portions of the canes.

Grafting

Grafting was done at four periods, namely: (1) April 16-18, just before bleeding began in the stocks; (2) May 17-18, when bleeding was about at its maximum; (3) June 6-7, when bleeding had subsided somewhat; and (4) July 5-7, one month after bleeding had subsided. The cleft graft was used in all cases. The stocks were cut off just below the ground level and the cleft made by sawing down the stock about two inches with a sharp saw. Use of the saw in making the clefts was necessitated by the twisted nature of the wood. Two cions, containing two buds each and taken from the same portion of the cane, were placed in each stub. Each cion was cut in a wedge shape with the outer side slightly thicker than the inner side and with the lower bud on the outer side. The cleft

in the stock was opened and both cions placed in it with the cambium of the stock at a very slight angle to make certain that the two cambiums made contact. The upper part of the stub was then tied securely.

A small piece of paper was placed over the top of each stub to prevent dirt from falling into the cleft; no wax was applied. Then loose moist soil was banked around the vine, covering all but the two inches of the cion containing the upper bud, to prevent drying out. No wax was applied to the exposed cut ends of the cions.

Analytical Work

At each period of grafting samples for carbohydrate analysis were taken from the butt, center and tip portions of the canes, and also from the stocks about one inch above the point of grafting. Both nodes and internodes were taken from the canes. Samples were taken the same day the grafting was done at each period. Sample materials were cut into small pieces, mixed thoroughly and duplicate samples, of 50 grams each, put into regular sample bottles and preserved in 70 per cent ethyl alcohol. The bottles containing the samples were kept at boiling temperature in a hot water bath for 30 minutes and then corked, sealed with hot paraffin, and stored until the analyses were made.

When analytical work began, the samples were opened, alcohol extract filtered off, the samples washed several times with 80 per cent alcohol and filtered. The alcohol extract was

made up to volume and saved. The sample was dried in an oven at 70°C. until a constant weight was reached. They were cooled in a desiccator, weighed and ground so that they would pass through a 60-mesh screen. One-tenth of each sample was weighed out and the remaining sugars extracted from it with 80 per cent alcohol. This alcohol extract was combined with one-tenth of the original alcohol extract from the same sample, which made a tenth aliquot of the whole sample for sugar analysis. Both total and reducing sugars and the starches were determined by the regular Shaffer and Hartman method. A portion of each sample was dried at 95°C. and weighed to obtain the absolute dry weight for the whole sample. Percentages of sugar were calculated from the dry weights.

RESULTS

Percentage of Unions

The percentages of stocks with living cions for the different periods of grafting and on the different stocks are shown in Table 1. Some of the stocks included in this table had two cions growing and some had only one; both are counted alike in this tabulation. This table shows that there was a higher percentage of total unions in the May period, those grafted during the heavy bleeding season, than at any other period. This was true of all three stocks that were used for grafting at this time. However, there is very little difference in the April and May periods on the Clinton stocks and the number on each of the other two stocks is too small to permit any definite conclusions. The data show definitely that the two early periods have greater percentages of unions on three stocks than the later periods.

Table 2 shows the total percentages of live cions on each stock from grafting at each period. Judged by this criterion, also, the April and May periods produced greater percentages of successful grafts than did the later periods. The May period has three per cent less total cions living on the Clinton stocks than the April period, and there is very little difference in percentages of total cions living on the Riparia X Rupestris 101 stocks that were grafted at the April and May periods. If, therefore, both the stocks with live cions and the total living cions are considered, there seems to be very little difference in the results obtained from the April and May periods of grafting, but important differences

Table 1.
Percentages of Stocks with Live Cions in October, 1932, from Grafts Made at Various Times

Date of Grafting	Clinton		Riparia Gloire		Riparia X Rupestris		Aramon X Rupestris	
1932	No. Grafted	Per cent Living	No. Grafted	Per cent Living	No. Grafted	Per cent Living	No. Grafted	Per cent Living
April 16-18	75	85	26	65	12	33	-	-
May 17 - 18	60	88	-	-	12	58	8	88
June 6 - 7	75	67	27	44	-	-	8	75
July 5 - 7	75	52	27	30	-	-	-	-

Table 2.
Percentages of Cions Living in October, 1932, on Various Stocks From Grafts Made at Various Times

Date of Grafting	Clinton		Riparia Gloire		Riparia X Rupestris		Aramon X Rupestris	
1932	No. Grafted	Per cent Living	No. Grafted	Per cent Living	No. Grafted	Per cent Living	No. Grafted	Per cent Living
April 16-18	150	67	52	42	24	33	-	-
May 17 - 18	120	64	-	-	24	38	16	88
June 6 - 7	150	50	54	31	-	-	16	56
July 5 - 7	150	39	54	20	-	-	-	-

Table 3.
Percentages of Clinton Stocks with Live Cions Taken from Various Parts of the Cane and Grafted at Various Times

Date of Grafting	No. Grafted Of Each	Butts	Centers	Tips	Total
April 16-18	25	88	88	80	85
May 17-18	20	90	95	80	88
June 6 - 7	25	84	80	36	67
July 5 - 7	25	68	60	28	52

between these and the later periods.

Table 3 shows the percentages of successful graft unions on the Clinton stocks made at each period from each portion of the cane. In every case the tips were inferior to the butts and centers. The average diameters at the time when grafts were set of the three portions of the canes, in inches, were as follows: butts 10/32, centers 8/32, and tips 5/32. For the April and May periods there seems to be no material difference between cions taken from the butts and those from the centers, but for the later periods of grafting the butts seem slightly superior to the centers.

Percentages of cions living on the Clinton stock at various times taken from different portions of the canes are shown in Table 4. Data for this table were taken as soon as the majority of buds had opened in each grafting period. This table shows that the butts set in April were very slow in opening. Perhaps the buds on the basal end were more dormant than those on the other parts of the cane. The tips started opening much sooner and the majority of them were open by June 1, while the buds on the butts kept opening until about July 15. Perhaps this difference in opening of buds accounts, at least in part, for the consistently poorer results secured with cions from the tips. The buds on the tips open and transpiration starts before there is any union between stock and cion to conduct water. In every period the majority of buds on the tips opened first and the buds on the butts opened somewhat later, with the centers opening at intermediate dates.

This tendency is shown clearly in Table 5. Those set in

Table 4.
Percentages of Cions from Various Parts of Cane Growing on Clinton Stocks at Various Dates

Date of Grafting	Part of Cane	May 20	June 5	June 16	June 27	July 7	July 20	July 30	Aug. 10	Sept. 15	Oct. 20
April 16-18	Butts	14	50	58	70	80	84	80	80	72	72
	Centers	54	82	82	80	86	84	84	84	72	72
	Tips	56	76	74	68	66	66	62	62	58	58
	Total	41	69	71	73	77	78	75	75	67	67
May 17-18	Butts		62	72	80	80	74	77	77	72	72
	Centers		82	85	80	85	80	82	80	70	70
	Tips		72	80	62	67	57	57	57	50	50
	Total		72	79	74	77	72	72	72	64	64
June 6 - 7	Butts			50	80	84	84	82	80	70	70
	Centers			70	90	88	64	64	62	56	56
	Tips			46	64	62	32	34	32	24	24
	Total			53	78	78	60	60	58	50	50
July 5 - 7	Butts						44	60	62	52	52
	Centers						46	66	70	44	44
	Tips						46	40	40	22	20
	Total						45	55	57	39	39

Table 5.
Number of Days from Time of Grafting to Opening of First and Majority of Buds

Date of Grafting	Date of First Buds Opening	Days to First Opening	Days to Opening of Majority
April 16 - 18	May 10	24	34
May 17 - 18	June 2	16	19
June 6 - 7	June 14	8	10
July 5 - 7	July 15	10	13

April were almost twice as long in opening as those set in May, and those set in May twice as long opening as those set in June. Probably this is one reason the later grafting was not as successful as the earlier.

That time of starting of buds, as compared to time for callus growth, is a factor in poorer results with the tip-cions is further indicated by the proportion between tip-and butt-cions succeeding at various periods. In the first period, the tips produced 80.6 per cent as many successful grafts as the butts; in May, 69.4 per cent; in June, 34.3 per cent; and in July, 38.6 per cent.

Growth

The shoot growth curves (Figure 1) were drawn from the average total shoot growth at various dates as measured in inches. This graph shows the terminal shoot growth to be greater on the early grafted grapes than on those grafted later. The graph indicates that the cions set in April made more shoot growth than those set in May. Since, however, the standard deviation of the shoot lengths from this line of data taken in October was very great, due to the wide variation of lengths and small number of individuals, the small difference in the April and May graphs may be insignificant. The cions set in June and July made significantly less shoot growth. Those set in July never made the rapid growth that those set early did because the unions were not complete before the most rapid growing season was over. The

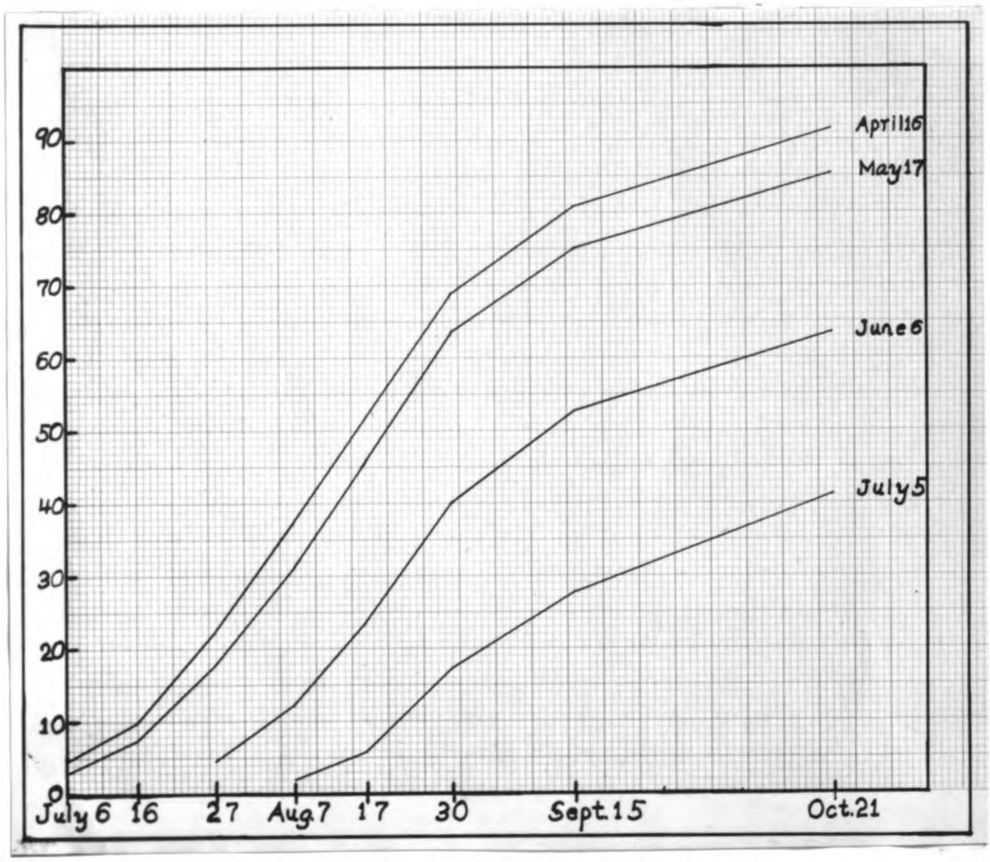

Fig. 1 - Terminal shoot growth in inches, at various dates, of cions set at various dates.

shoots that did grow in this period did not have time to mature the wood before fall, and did not survive the winter as well as those that were grafted earlier. The percentages of grafts that winter-killed were as follows: April grafts 9% kill, May grafts 9% kill, June grafts 15% kill, and July grafts 35% kill.

Table 6 shows the number of shoots that fall in the growth classes indicated. The classes are given in inches with an interval of 20. This table shows that the tips made about as much growth as the butts and centers. The part of cane the cions are taken from seems to make no difference in terminal shoot growth of the grafts that unite. Evidently, the most important thing with the cion is to establish a good union rather early so that it will have a long growing season.

Incidental Observations on Field Work

From observations made in the field, it appeared that weather conditions had a great influence on buds opening and then dying. With rain and high temperature, the buds of the newly set cions opened and developed two or three leaves, apparently independently of any graft union. Most of these shoots remained in this condition for two or three weeks, if they lived. When there came a few windy days with high temperatures while the cions were in this stage, many of the young shoots perished. More of this occurred on the tip-cions than on the butt-and center-cions. This seems clearly to have been due to excess of transpiration over absorption capacity. If the cion united with the stock before this

Table 6.

Frequency Distribution of Growths (in inches) in 1932 of Cions From Various Portions of Canes Set at Various Times

Date Grafted	Part of Cane	1-20	21-40	41-60	61-80	81-100	101-120	121-140	141-160
April 16-18	Butts	3	-	1	5	8	13	6	1
	Centers	5	3	1	4	6	8	8	1
	Tips	4	2	2	3	4	5	5	5
	Total	12	5	4	12	18	26	19	7
May 17-18	Butts	3	-	5	4	7	4	4	-
	Centers	3	2	1	5	5	6	7	-
	Tips	2	-	1	4	5	4	3	1
	Total	8	2	7	13	17	14	14	1
June 6 - 7	Butts	9	2	5	8	7	4	-	-
	Centers	1	4	6	6	5	4	2	-
	Tips	2	-	5	1	3	1	-	-
	Total	12	6	16	15	15	9	2	
July 5 - 7	Butts	6	7	7	6	2	-	-	-
	Centers	7	6	4	4	1	-	-	-
	Tips	4	2	1	3	-	-	-	-
	Total	17	15	12	13	3	-	-	-

initial shoot died, the absorption capacity would be increased and the shoot would start rapid growth. After the shoots started this rapid growth, they usually continued to grow for the rest of the season. Some of the shoots that had died back were replaced by new ones.

Bleeding started in some of the main stems of the stocks April 18, but in the canes it did not begin until two days later. It increased very rapidly until May 8, and then increased more slowly for the next seven days. It was at its maximum about May 15 in 1932, and the young shoots on the stocks were about one inch long at that time. McIntosh apple trees were in full blossom, and the petals were falling from Montmorency sour cherry blossoms when bleeding was greatest in the grape stocks.

Clinton and Aramon X Rupestris Ganzin No. 1 seemed to be better stocks for Campbell Early than Riparia Gloire de Montpellier or Riparia X Rupestris 101, so far as grafting success is concerned. The two former had higher percentages of graft unions and longer terminal shoot growth at the end of the season than the two latter. This does not agree with the state trials at Vaud, France (35), where Riparia X Rupestris was found a better vineyard stock than Aramon X Rupestris.

Analytical Data

Figure 2 shows the sugar content in percentages for each portion of the canes at each period of grafting. This graph indicates that the canes are rather high in total sugars in April,

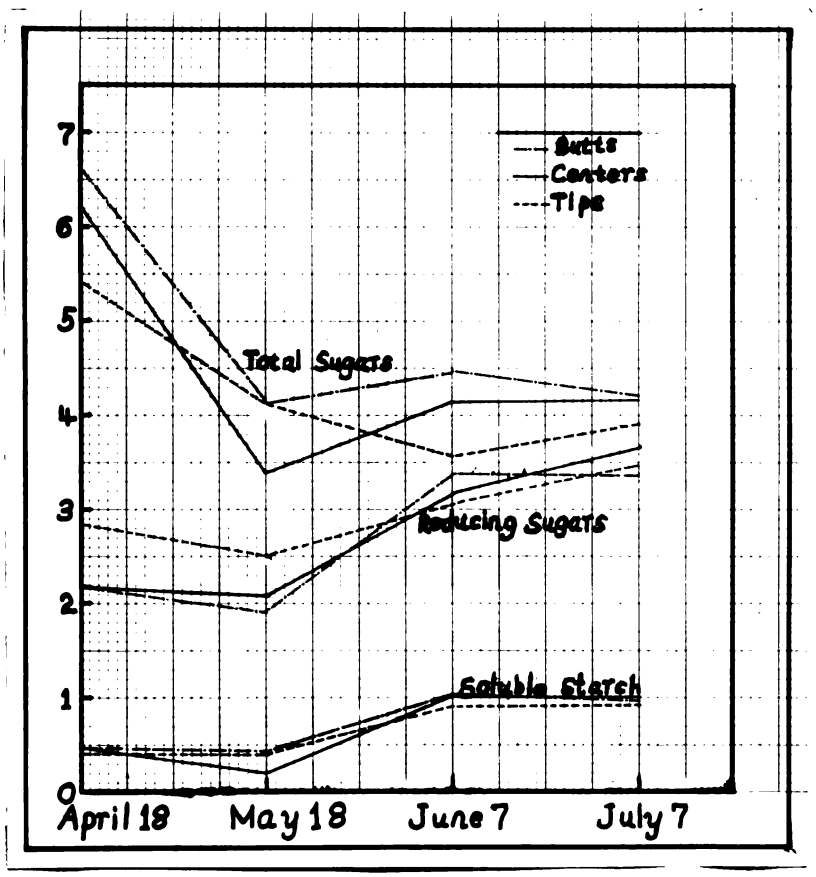

Fig. 2. Percentages of sugars in the canes at various dates.

and decrease in total sugars as the season advances. The reducing sugars increase, which indicates that sucrose is being changed to reducing sugars with no growth to consume these sugars. The soluble starch increases slightly, but this increase is hardly significant. There seems to be very little differences in percentages of total sugars in the various portions of the canes. The sudden drop in the curves at the May period is probably due to experimental error, either in sampling or in the analyses. In general, the tips might be slightly lower in percentage of total sugars than the butts and centers, but the differences are very small.

The decrease in both total sugars and reducing sugars is very noticeable in the stocks as the season advances (Figure 3). As sucrose is being changed to reducing sugars the growing plants are consuming them, which causes a decrease in both. Soluble starch also increases in the stocks slightly, as in the canes. The figures on insoluble starch were very inconsistent in both the stocks and canes, and the results are not presented.

The percentages of unions, as indicated in the graph, have a general tendency to decrease as the season advances and this tendency seems to be associated with the decrease of total sugars in both stocks and cions. There seems to be some possible relation between total sugar content and percentages of graft unions.

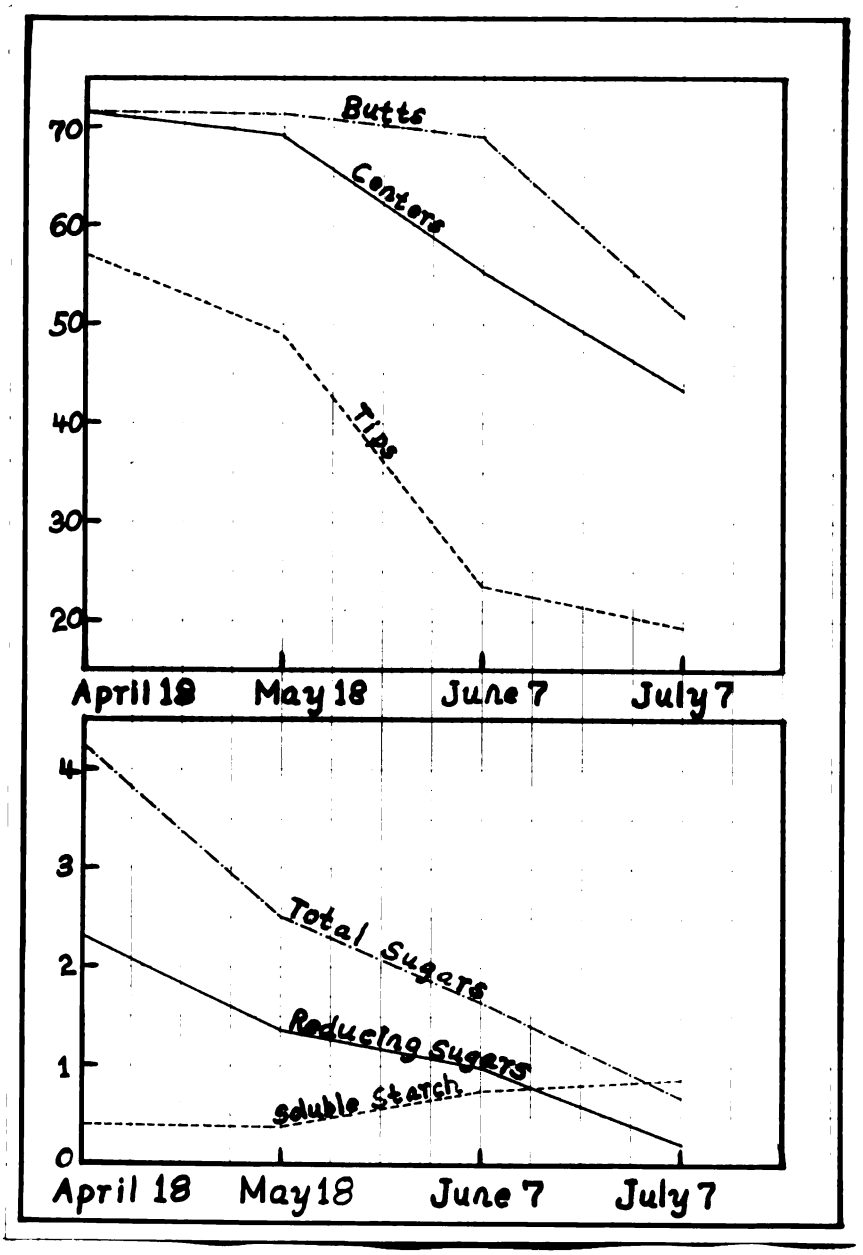

Fig. 3. Below: Percentages of sugars in the stocks at various dates. Above: Percentages of successful unions in grafts set at the same dates.

Discussion

When grafting is attempted on plants which are hard to graft, experienced propagators usually have recourse to one special procedure or another. Fundamentally these fall into procedures designed to hasten callus formation by increased temperature, or to check transpiration by maintaining a high atmospheric humidity. With grafting in the field, high temperature can be insured only by grafting in late spring; this is successful with the black walnut. (88). Humidity control is more difficult, once buds have opened, and desiccation becomes an increasing factor with late grafting. Whether sugar or other carbohydrate content of cion or stock has any relation to successful unions cannot be determined readily from field study, because of the changing temperature and humidity conditions.

In vineyard grafting, so far as this study shows, desiccation overbalances any advantage that might be gained from more rapid callus formation attendant upon late grafting. Whether the amount or the character of grape leaves accounts for the difference between the walnut and the grape in this respect cannot be stated from available information. The relation of early and late grafting to tyloses formation cannot be stated definitely. That it is common is shown by Figure 4; but it seems probable that this is a minor, rather than a major, factor.

That there may be some connection between total sugar content and percentage of successful grafts, cannot be denied. Since, however, reducing sugars accumulate while the percentages of success-

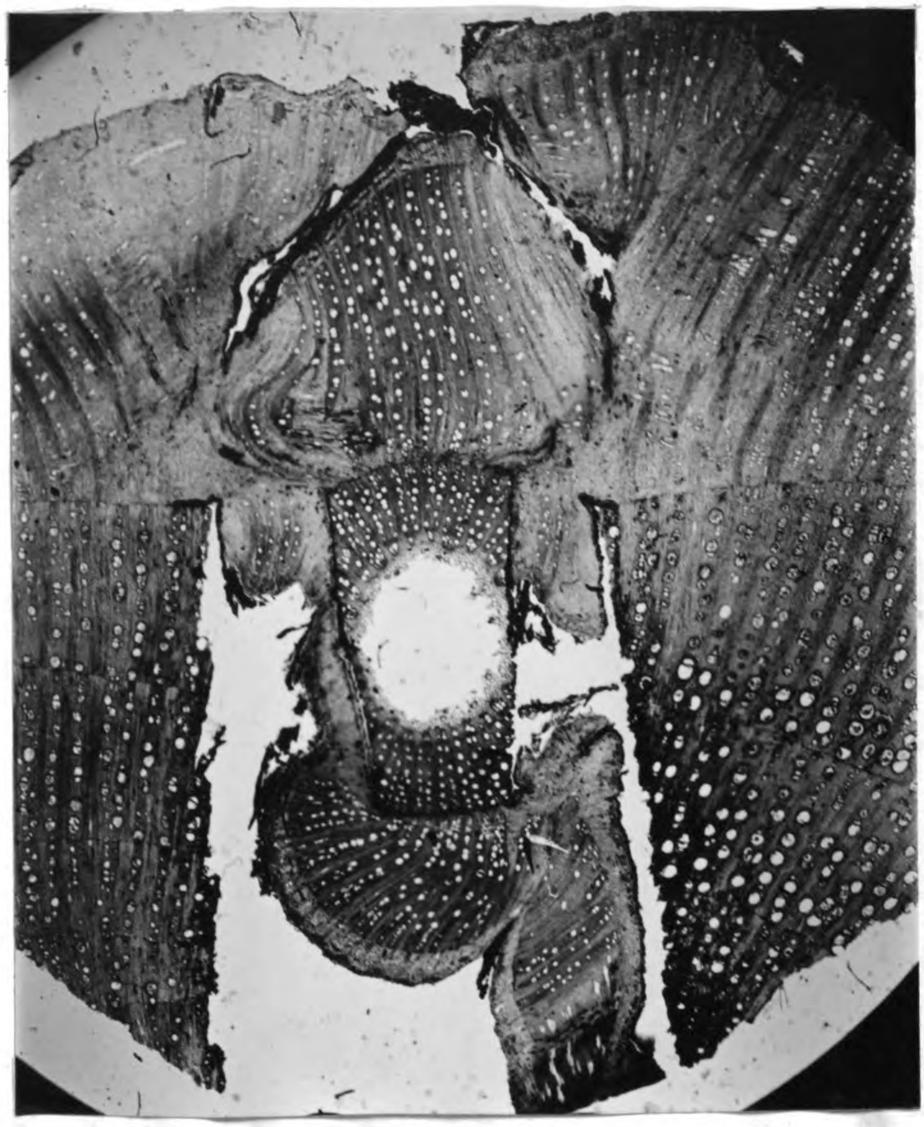

Fig. 4. Cross section of a grape graft, Campbell grafted on Aramon X Rupestris Ganzin No. 1, set June 7, 1932. Note the formation of tyloses in the vessels.

ful unions decrease, relationship under field conditions seem slight. Certainly, though the seasonal picture might suggest a plausible relationship, the differences in sugar content between tips and butts through the season seem too small to explain the differences in successful unions. There remains the possibility that absolute amounts available at the union, rather than percentages, might explain these differences; the data recorded permit no statement on this point.

Of the various possible factors affecting success, the present study indicates that rapidity of opening of buds, with resultant desiccation, is the most important under field conditions. Late grafting seems to increase the rate of bud development more rapidly than it increases the rate of callus formation. Whether this could be offset by covering the grafts with bell jars or boxes is uncertain.

Possibly the difference between these results and the general opinion in Europe, favoring late grafting (70,89,2, 93), may be explained by the more intense heat and greater desiccation in America at the time of late grafting in Northern vineyards. Although the results here reported indicate that heavy bleeding of the stock does not interfere with graft union, no explanation is offered for this divergence from the usual avoidance of grafting during the heavy bleeding period.

As a practical matter, vineyard grafting may or may not be feasible. As compared with establishment of vineyards with bench grafted vines, it is costly. The stocks used here had stood

in the vineyard longer than would be necessary to produce bearing vines. They had been grafted once without success. At present, from 12 to 48 per cent of the vines must be regrafted. Bench grafted plants, even if a large number must be used, would have produced enough grapes in the meantime to more than offset the difference in cost.

Whether established vineyards of undesirable varieties can be worked over profitably cannot be definitely stated. Their performance as stocks would be uncertain. The majority of growers would have but moderate success in grafting, and regrafting would extend over a considerable period. In view of the short period necessary to bring new plants into bearing, working over of established vineyards is not to be given general encouragement. That it is possible, is shown by the results reported.

If further studies in vineyard grafting are to be undertaken, it is suggested that covering of the cions with bell jars, boxes, or similar devices to check transpiration, be tried. Microscopic studies, particularly with reference to tyloses formation, may be valuable. Keeping cions in cold storage should be compared with ordinary storage. When these points are clearer than they now are, chemical studies may be undertaken with better prospects.

Summary

1. Campbell Early can be successfully grafted in the field, provided suitable stocks are used and grafts made with the proper care.

2. Clinton and Aramon X Rupestris Ganzin No. 1 seem to be satisfactory stocks for this variety. Riparia Gloire de Montpellier and Riparia X Rupestris 101 appear less desirable, though results with them are not considered conclusive.

3. The early part of the season appears to be more satisfactory for grape grafting than the period after bleeding. For Michigan it is recommended that grafting be done between April 20 and May 20, depending on the season. Graft before the shoots are six inches long on the stocks.

4. Cions from the tips of the canes did not give satisfactory results in percentages of graft unions. Cions from the centers seem to be about asgood as those from the butts, if grafting is done early. If grafting is delayed until June, the butts are preferred.

5. Late grafting apparently increases desiccation more rapidly than it increases rate of callus growth.

6. Under field conditions in Michigan; atmospheric humidity may become a more important factor in successful grafting than the sugar content of cion and stock or than the rapidity of callus formation.

Acknowledgements

The writer wishes to express his sincere appreciation to Professor F. C. Bradford for assistance in planning the work, presenting the data and corrections in the manuscript, and to Dr. J. W. Crist for assistance in the analytical work. He also wishes to thank H. P. Gaston and W. C. Dutton for helping prepare and make the photographs. Thanks is due Professor V. R. Gardner and Dr. R. E. Marshall for corrections and suggestions in the manuscript.

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