# TOP-GRAFTING JONATHAN APPLE TREES

by

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## INTRODUCTION

This problem is one of top-grafting apple trees (Pyrus malus or Malus sylvestris) of the Jonathan variety using cions from the Winesap variety.

Red cedar (Juniperus virginiana) trees have grown on the Horticultural Farm of the Kansas Agricultural Experiment Station and adjoining properties for many years. The first planting of apple trees was made in 1911. Additional plantings followed and the list of varieties included Jonathan, Wealthy and Rome Beauty all of which are susceptible to cedar apple rust (Gymnosporangium juniperi-virginianae). The trees began growth without interference by the fungus which made a gradual increase to the time of this writing. About 1920 the infection became serious, and for ten years it was so severe that no crop of any appreciable value grew on the above named varieties. The weather conditions in 1928 made the development of heavy foliage possible and there was an abundance of bloom in 1929, but the infection was so bad during the latter season that no fruits were found that were not deformed and most of the leaves fell long before frost. Leaves that grew on the tips of the shoots late in the summer remained on the trees until after December 1.

When the plantings were first made it was thought that the spray program was furnishing control of the rust because there was almost none present. Later observations indicate that spraying and removal of the galls from the cedar trees fail to control the fungus.

There are approximately 1300 trees of various ages in the orchard of which about 235 or 18 percent are of the Jonathan variety. Since they cannot bear a crop because of the rust, the fungus causes a serious loss to the department.

There were at least three methods of attack in an attempt to solve the problem: (1) Removal of all cedar trees within a safe radius, (2) replacement of the susceptible trees with resistant trees, and (3) top-working of the susceptible trees to a resistant variety.

The first possibility was carried out within the boundaries of the farm. Due to the difficulty of completing that method by cutting trees on adjoining properties, the last alternative was tried in an experimental way. It was desired to ascertain which of several methods of grafting would prove to be the most satisfactory, whether the trees should be worked over in one or in two years, and whether grafting wax could be replaced to advantage by paraffin.

## LITERATURE REVIEW

It is evident that the practice of grafting plants is nearly as old as agriculture. The exact origin of grafting in unknown, but many of the ancient writers describe the process. Virgil (5), by no means the first to write of the operation, described it clearly, and about a century later Pliny (1) described both bark and cleft grafts. Naturally, many superstitions were connected with this process.

Horticultural literature abounds with the subject of plant propagation, but that is quite natural since almost no fruits come true to type when grown from the seed and vegetative propagation is the only recourse. When reviewing the literature on this subject one is prone to think that whenever horticulturalists ran out of anything else to write they began on propagation. One would believe that to be true whether he were reading publications of today or of a century ago. Practically all agricultural and horticultural magazines mention the subject, and many text books and experiment station publications describe the operations. One would expect to find much new and valuable information in all these volumes, but in comparison with the amount of printers' ink used, there is very little aside from repetition of what has been long known and often written and rewritten.

There are two primary objects in top-working fruit trees (15, 23); namely, to provide for cross-pollination in blocks of self-sterile trees, and to change trees to more profitable varieties. Secondary objects (15) are to place weak-growing wood of certain varieties upon strong stocks, to work over seedlings or varieties that are susceptible to certain diseases, and to shape over an old tree top or to fill in after an accident. There are also some minor purposes.

Top-working is objectionable because it involves much loss of time in fruiting (13,22) due to the severe pruning that is necessary both at the time of grafting and subsequent to grafting. The operation has been thought to cause the presence of weakness in the tree. Many times this is true, but when the union is sound there is sufficient strength for orchard conditions. However, the actual breaking load is less at the point of union than immediately above or below it (10).

Without exception it is recommended that cions be cut during the dormant season, and that they be stored in moist packing in a cool cellar or cold storage, or buried in the ground in a cool place. A writer of a generation ago (4) claims that budding in May or June with buds from cions either stored or taken directly from other trees is superior to grafting, but this is questionable. Some persons have thought that with the apple the variety could be improved by bud selection, but the idea is erroneous. Cummings and Jenkins (26) observed no increase in yield after 15 years of selecting cions from high yielding trees. Crandall (14) concluded that large buds are no better than small buds, that robust cions are no better than those of small diameter, and that equally valuable cions may be taken from any part of the tree. However, it is considered good practice to use cions of average size. They should be well matured, and should be packed in moist (not wet) material, preferably moss, and should be stored in a cellar (27). Tozzer (27) observed that apple cions cut and stored in December were only slightly better than those secured in February.

The proper stock to use in grafting has been a subject of much debate, and has stimulated a considerable amount of research. The stocks used in this experiment were predetermined, and reference to only Jonathan trees need be made. Jonathan is often used satisfactorily for cions (3, 9, 12), but little is known about its qualities as a stock. Contradictory statements are made by Patten (2) and Powell (7), the former reporting that the Jonathan tree sunscalds and splits badly when top-worked, and the latter claiming that it is not subject to sunscald. Vincent and Luce (31) class apple varieties in three groups with respect to ease of top-working; first, those that top-graft easily; second, those that require more care; and third, those that are difficult to top-graft successfully. They place Jonathan in the intermediate group, Vincent (36) stating that such a classification of this variety is due to the spreading growth of the tree, more upright limbs being more satisfactory for top-working.

The actual work of top-grafting is simple. The procedure is described by so many writers, and it is so well known to horticulturalists that it is deemed unnecessary to describe the operation here.

Tukey (24) mentions three essentials; first, use sound, dormant cion wood; second, match the cambium of the cion with the cambium of the stock; third, carefully cover all exposed surfaces to prevent drying. Of course, it is obvious that the stock and cion must be sufficiently closely related. He recommends that the center of the tree be worked one year and the outer branches the next. Others also advise that only part of the tree be worked during one season (6, 21, 23, 28, 30, 31, 33). The purpose is to provide shade for the large limbs and prevent sun scald.

Top-working has a severe dwarfing effect on the tree. Chandler (22) states that little dwarfing results if done on two-year old trees when set, because the pruning is no heavier than would be the case if grafting were not done. Naturally, the later in the life of the tree grafting is done, the greater the delay of fruiting will be. Most orchardists say that grafting should be done at a place on the limb at which the diameter is less than two and one-half inches. At whatever distance from the trunk the grafting is done, all of the branches should be cut to about the same length. Bailey (16) says that grafting large limbs close down seems to be inadvisable because each graft acts as an individual tree. On the other hand, if the distance from the trunk is too great, the tree will become too tall.

Many kinds of grafts are known. All methods commonly practiced give satisfactory results in the hands of skilled workmen.

The season for grafting depends somewhat on the type of graft. For cleft grafting, the proper time is just prior to the beginning of spring growth. For bark grafting one must wait until the bark loosens. Bailey (16) states that the time may cover a period two months before and a month after the buds begin to open, but that the optimum time is short.

Some controversary has arisen with regard to the relative position of the top bud and the point of contact of the two cambium layers. Roberts (29) contends that grafts in the nursery grow better when the top bud is directly over the point of union of the cambium. His theory is that there is no cross-transfer of food, water and mineral nutrients in the woody stem as Auchter and others have indicated (18). Bennett (25) found little effect from varying the relative position of the top bud and the tongue of the stock. In top-working it is the customary practice to use cions having three or four buds, placing the lowest bud near the top of the stock, and setting the cion so the bud is to the outside of the stock. The theory behind that practice is that the reserve food supply in the region of the bud will form a better callus and consequently a better union (21). It is obvious that the cion must be set right end uppermost (11).

It is apparent that the smaller the limb is when it is grafted, the smaller the wound will be, and consequently the sooner the wound will heal. The greatest objection to grafting large limbs is the delay in healing and the likelihood that the wood will decay before the wound is covered. Actual union of the parts is impossible. However, the tissue that is produced after the graft has been placed develops in such a way as to form the union (8, 32). The enlargement at the point of union is due to callus formation.

In 1902, Bud and Hanson (6) reported that grafting was relatively simple in the more humid climates, but in the hotter, drier atmosphere of the great plains success was not so easy. No doubt, this difficulty was due to desiccation of the cion before union of the two tissues had a chance to form. In the past few years it has been the practice to coat the entire cion with some air and moisture proof material. Waxes of various mixtures, and paraffin have been used successfully (17, 19, 20, 34, 35). Such coatings have been of especial value in obtaining success in top-grafting nut and other trees that are difficult to propagate, and they are used to coat nursery stock that is tender and must be shipped long distances (35).

## MATERIALS AND METHODS

The stocks used in this experiment were Jonathan apple trees, row 47 in the Horticultural Station orchard. The following is an outline of the arrangement of the plots, and it is followed by a description of the terms:

| Tree | Cut | Portion | Graft | Treatment |
|---|---|---|---|---|
| 1 | Short cut | Entire tree | Cleft graft | Grafting wax |
| 2 | Medium cut | Entire tree | Cleft graft | Grafting wax |
| 3 | Short cut | Half tree | Cleft graft | Grafting wax |
| 5 | Medium cut | Half tree | Cleft graft | Grafting wax |
| 6 | Short cut | Entire tree | Bark graft | Grafting wax |
| 7 | Medium cut | Entire tree | Bark graft | Grafting wax |
| 8 | Short cut | Half tree | Bark graft | Grafting wax |
| 9 | Medium cut | Half tree | Bark graft | Grafting wax |
| 10 | Short cut | Entire tree | Cleft graft | Grafting wax |
| 11 | Medium cut | Entire tree | Cleft graft | Grafting wax |
| 12 | Short cut | Half tree | Cleft graft | Grafting wax |
| 13 | Medium cut | Half tree | Cleft graft | Grafting wax |
| 14 | Short cut | Entire tree | Bark graft | Grafting wax |
| 15 | Medium cut | Entire tree | Bark graft | Grafting wax |
| 16 | Short cut | Half tree | Bark graft | Grafting wax |
| 17 | Medium cut | Half tree | Bark graft | Grafting wax |

18 Short cut, half tree, various grafts, grafting wax

19 Medium cut, entire tree, bark grafts, grafting wax, Parapin grafting wax, paraffin

21 Medium cut, half tree, various grafts, grafting wax

No hard and fast rules could be set and adhered to in this experiment because of the variation between trees. At all times the ultimate effect on the trees was considered and the cuts were made accordingly. However, the following is the ideal sought after in the methods:

"Short cut" means that the limbs were cut relatively short, this being at a point at which the diameter was three inches or more, and on primary or secondary branches, depending upon the relative heights of the various limbs. When keeping the future shapes of the trees in mind, neither the diameter nor position on the branches could be rigidly held to.

"Medium cut" means that the limbs were cut at points on secondary, tertiary or quarternary branches. The heights above the trunks and the diameters of the stocks varied with the individual trees.

"Entire tree" means that all the main branches of the tree were grafted. That small growth that did not interfere with the development of the cions was allowed to remain to shade the large branches and to feed the tree while the cions were becoming established. Subsequent to grafting some additional pruning was necessary.

"Half tree" means that approximately one-half of the tree was grafted in 1930, the other half being left until 1931. The southeast half of the tree was grafted the first year.

The well known cleft graft was used according to the above outline. Bark grafts were made, the cions being secured in place by one-half inch brads, usually one per cion. After the bark grafts were waxed they were tied with raffia. Trees 1 to 3 and 5 to 9 inclusive constituted one plot, and trees 10 to 17 inclusive constituted a duplication.

The wax was made in the laboratory, the following formula being used: 4 pounds resin, 2 pounds beeswax and one pound tallow. This wax is later referred to as R.-B.-T.

Kerf grafts were made in addition to cleft and bark grafts on trees 18 and 21. The cions were fastened with brads, waxed and tied the same as bark grafts.

Tree 19 was grafted by using the bark graft. About one-third of the grafts were waxed with R.-B.-T., one-third with paraffin, and one-third with Parapin grafting wax. The paraffin was material made by the Standard Oil Company and sold at 15 cents per pound under the trade name "Parowax". The Parapin grafting wax was obtained from the Edwin C. Tyson Co., Flora Dale, Pa., at 50 cents per pound. In all cases, the wounded surfaces of the stocks and the entire cions were covered with wax. The Merribrooke Melter was used to keep the wax melted.

Tree 4 appeared to be a weak tree and was not included in the experiment, but it was cleft grafted. Tree 20 was a young tree, probably three years old, and it was not included, but was whip grafted. Both of these trees were grafted to make the entire row of one variety.

The following table gives the tree numbers, dates grafted, kinds of grafts made, number of stocks grafted and the number of cions set:

Table I. Grafts Made.

| Tree Number | Date Grafted | Kind of Graft | No. of Stocks | No. of Cions |
|---|---|---|---|---|
| 1 | March 22 | Cleft | 13 | 26 |
| 2 | April 2 | Cleft | 25 | 50 |
| 3 | March 22 | Cleft | 10 | 20 |
| 5 | April 2 | Cleft | 24 | 48 |
| 6 | April 5 | Bark | 20 | 47 |
| 7 | April 5 | Bark | 23 | 52 |
| 8 | April 5 | Bark | 7 | 22 |
| 9 | April 5 | Bark | 9 | 20 |
| 10 | April 3 | Cleft | 12 | 24 |
| 11 | April 4 | Cleft | 17 | 34 |
| 12 | April 3 | Cleft | 6 | 25 |
| 13 | April 4 | Cleft | 14 | 30 |
| 14 | April 7 | Bark | 10 | 27 |
| 15 | April 7 | Bark | 15 | 35 |
| 16 | April 7 | Bark | 10 | 31 |
| 17 | April 7 | Bark | 14 | 36 |
| 18 | April 7 | Various | 8 | 30 |
| 19 | April 8 | Bark | 26 | 64 |
| 21 | April 8 | Various | 11 | 33 |

Ordinarily the number of cions set as cleft grafts on stocks of the prevailing size should be twice the number of stocks grafted. Exceptions are with trees 12 and 13, in which cases the stocks were large and bark grafts were set to supplement the cleft grafts to aid in keeping the stocks alive and in healing the large wounds made in grafting. The number of cions set as bark grafts was determined by the size of the stocks, and ranged from two to six. It was necessary that only one cion on each stock should grow, but more than one was set to increase the chances of getting unions, and for the reasons given above.

When the first cleft grafts were made on March 22, the bark was beginning to loosen. Under such conditions there is a tendency for the bark to split and pull away on each side of the cleft instead of the split in the bark following that of the wood. Therefore, the cleft grafts were made first. Inclement weather caused a delay of eleven days after the first two trees were grafted. The remaining work was completed within the following week.

The cions were taken from Winesap trees in rows 39 and 40. They were secured on January 30, and were packed in moist sphagnum moss in apple boxes and stored in a cellar. Approximately 1100 cions were stored, but only about half of them were used.

On February 15 the cions were inspected and the moss was considered to be too dry. Some water was added and the cions were repacked. Neither on the above date nor on March 13 was there any callous formation on the cut surfaces. However, on May 3 the remaining wood showed an abundance of callus, and some of the buds, particularly those located apically, were making growth.

When a detailed record was made of those cions that were growing on May 3, it was observed that more failed to grow on tree No. 1 than on any other tree. Seven bark grafts were made on that tree at that time. One stock on tree No. 19 had been overlooked when waxing, and the cions on it failed to grow. On the same date, two bark grafts were made on that stock.

On May 12 all trees were carefully checked over and wherever twigs were interfering with the cions, the former were removed. On the same date, the raffia ties were cut, except those on tree No. 19 on which growth seemed to be slower than on the other trees. On June 4 the remaining ties were cut, and interfering growth of Jonathan shoots was removed.

The following is an itemized cost account of the field work of the project:

1. Time (estimated):

| | |
|---|---|
| Collecting and packing cions | 7 hours |
| Inspecting and re-packing cions | 4 hours |
| Grafting | 65 hours |
| Pruning (subsequent to grafting) | 8 hours |
| Taking records | 8 hours |
| | 92 hours |
| Ninety-two hours @ 40¢ | $36.80 |

2. Materials:

| | | |
|---|---|---|
| Waxes | | |
| 1. R.-B.-T. | 4½# @ 50¢ | $2.25 |
| 2. Parapin | ¼# @ 50¢ | .13 |
| 3. Parowax | ¼# @ 15¢ | .04 |
| Alcohol (for wax melter) | | .25 |

3. Rental on tools 1.00

$40.47

The following photographs, Figures 1 to 15 inclusive, show typical examples of the trees before grafting, after grafting, and after the cions had been in place for about eleven weeks.

Figure 1. Tree No. 1, photographed during the fall of 1929.
Note the sparse foliage which is a result of cedar apple rust.

Figure 2. Tree No. 1, photographed in May 1930. This tree has been top-grafted, and it is an example of "short cut, entire tree".

Figure 3. Tree No. 1, photographed June 21, 1930, showing the growth made by the cions.

Figure 4. Tree No. 11, photographed in April, 1930, before it was top-grafted.

Figure 5. Tree No. 11, photographed just after grafting. This is an example of "Medium cut, entire tree".

Figure 6. Tree No. 11, photographed June 21, 1930, showing the growth made by the cions.

Figure 7. Tree No. 13, photographed in April, 1930, before it was top-grafted.

Figure 8. Tree No. 13, photographed just after grafting. This is an example of "Medium cut, half tree".

Figure 9. Tree No. 13, photographed June 21, 1930, showing the growth made by the cions.

Figure 10. Tree No. 18, photographed in April, 1930, before it was top-grafted.

Figure 11. Tree No. 18, photographed as it was cut to be top-grafted. This is an example of "short cut, half tree".

Figure 12. Tree No. 18, photographed June 21, 1930, showing the growth made by the cions.

Figure 13. Tree No. 18. A close-up photograph of the stocks before the cions were set.

Figure 14. Tree No. 18. A close-up photograph of the stocks after the cions were set.

Figure 15. Tree No. 18. A close-up photograph made on June 21, 1930, showing the growth made by the cions. Note that the leaves are curled, due probably to leafhoppers.

## OBSERVATIONS AND RESULTS

Final observations and measurements were made on June 23. Table II gives the number of cions set, the number growing on May 3 and on June 21, the percentage growing on the latter date, and the maximum, minimum and average length of growth in inches from all the buds on a cion.

Table II. Summary of Data Relative to Results of Top-working.

| Tree No: | Treatment | Cions set Number | Cions Growing 5-3. No. | Cions Growing 6-21. No. | Cions Growing Percent | Growth per Cion - Inches Max. | Min. | Ave. |
|---|---|---|---|---|---|---|---|---|
| 1 | Cleft entire tree, short | 26 | 22 | 24 | 92.3 | 87.00 | 36.00 | 72.27 |
| 2 | Cleft entire tree, medium | 50 | 48 | 50 | 100.0 | 77.25 | 32.00 | 55.95 |
| 3 | Cleft half tree, short | 20 | 20 | 20 | 100.0 | 85.00 | 45.75 | 67.02 |
| 5 | Cleft half tree, medium | 48 | 48 | 48 | 100.0 | 72.50 | 17.75 | 45.27 |
| 6 | Bark entire tree, short | 47 | 47 | 46 | 97.8 | 77.00 | 24.00 | 49.70 |
| 7 | Bark entire tree, medium | 52 | 52 | 52 | 100.0 | 73.75 | 20.00 | 55.62 |
| 8 | Bark half tree, short | 22 | 21 | 21 | 95.4 | 102.50 | 43.25 | 72.80 |
| 9 | Bark half tree, medium | 20 | 20 | 20 | 100.0 | 63.25 | 30.25 | 45.20 |
| 10 | Cleft entire tree, short | 24 | 23 | 21 | 87.5 | 77.00 | 36.25 | 62.42 |
| 11 | Cleft entire tree, medium | 34 | 34 | 34 | 100.0 | 69.25 | 47.50 | 55.10 |
| 12 | Cleft half tree, short | 12* | 11 | 11 | 91.6 | 79.50 | 25.00 | 56.27 |
| 13 | Cleft half tree, medium | 28** | 28 | 28 | 100.0 | 91.00 | 46.50 | 70.42 |
| 14 | Bark entire tree, short | 27 | 27 | 25 | 92.6 | 69.75 | 27.25 | 51.67 |
| 15 | Bark entire tree, medium | 35 | 35 | 35 | 100.0 | 65.25 | 13.50 | 42.05 |
| 16 | Bark half tree, short | 31 | 29 | 31 | 100.0 | 71.00 | 11.75 | 44.65 |
| 17 | Bark half tree, medium | 36 | 36 | 36 | 100.0 | 56.75 | 21.50 | 39.82 |
| 18 | Various half tree, short | 30 | 29 | 29 | 96.6 | 86.75 | 8.75 | 58.44 |
| 19 | Bark entire tree med. wax | 64 | 62 | 61 | 95.3 | 79.25 | 0.25 | 35.77 |
| 21 | Various half tree, medium | 33 | 32 | 32 | 96.9 | 97.00 | 23.25 | 48.40 |
| | | *13 Bark | 12 | 12 | 92.3 | | | |
| | | **2 Bark | 2 | 2 | 100.0 | | | |
| | Replaced Cions | | | | | | | |
| 1 | | 7 | | 7 | 100.0 | | | |
| 19 | | 2 | | 2 | 100.0 | | | |
| | Totals and Averages | 663 | 638 | 647 | 97.58 | 77.82 | 26.86 | 50.96 |

Six hundred sixty-three cions were set and 647 or 97.58 per cent were growing on June 21. The average maximum, average minimum and average growths were 77.82 inches, 26.86 inches and 50.96 inches respectively. These measurements are the total growth per cion. The last figure is based on 283 measurements. Measurements of ten cions chosen at random were made on the first sixteen trees, and all cions were measured on the last three.

Only a few terminal buds had been formed, hence, the accuracy of the measurements was reduced. A common yard stick was used and readings were made to the nearest quarter of an inch. The uppermost shoot was measured and recorded first, and the others were measured progressing downward on the cion.

In placing the cions, the lowest bud was always placed toward the outside of the stock. In a number of cases, the bud just above this lowest one made a very short growth. This was particularly true though not entirely consistent on trees No. 11 and No. 12, and more so on cleft grafts than on bark grafts. This phenomenon is explained by the fact that there is little crosstransfer of food in a woody stem (18).

Trees 1 to 3 and 5 to 9 inclusive comprise one plot, and trees 10 to 17 inclusive comprise the duplicate plot. By combining the measurements of growth on trees 1 and 10, 2 and 11, 3 and 12, etc., the results given in Table III are obtained.

Table III. Results obtained by combining measurements of growth on respective trees in duplicate plots.

| Tree No. | Code | Cut | Ave. Growth per cion-inches | Part of tree grafted | Kind of graft |
|---|---|---|---|---|---|
| 1 and 10 | A | Short | 67.34 | Entire | Cleft |
| 2 and 11 | B | Med. | 55.52 | Entire | Cleft |
| 3 and 12 | C | Short | 61.64 | Half | Cleft |
| 5 and 13 | D | Med. | 57.84 | Half | Cleft |
| 6 and 14 | E | Short | 50.68 | Entire | Bark |
| 7 and 15 | F | Med. | 48.84 | Entire | Bark |
| 8 and 16 | G | Short | 58.72 | Half | Bark |
| 9 and 17 | H | Med. | 42.51 | Half | Bark |

The following calculations are based on the figures in the above table:

Short cut Compared with Medium cut:

A minus B equals plus 11.82
C minus D equals plus 3.80
E minus F equals plus 1.84
G minus H equals plus 16.21

plus 8.42 ± 2.27

Entire tree Compared with Half tree:

A minus C equals plus 5.70
B minus D equals minus 2.32
E minus G equals minus 8.04
F minus H equals plus 6.33

plus 0.42 ± 2.32

Cleft graft Compared with Bark graft:

A minus E equals plus 16.66
B minus F equals plus 6.68
C minus G equals plus 2.92
D minus H equals plus 15.33

plus 10.40 ± 2.25

The difference between short cut and medium cut, and the difference between cleft graft and bark graft are significant, but the difference in growth between cions on entire trees and on half trees is not significant. That is, cions on short stocks made longer growth than cions on stocks of medium length; cleft grafted cions made longer growth than bark grafted cions; and cions on entire trees and half trees made growths of similar length.

Before field work on this experiment was begun, forty (40) twigs chosen at random were selected and the growth made during the season of 1929 was measured. It was assured that the data thus obtained gave an indication of the relative vigor of the individual trees. The differences in vigor were found not to be significant, and the conclusion was drawn that the differences in growth of cions under the various methods were due to inherent differences of the methods employed in grafting and not to the vigor of the trees.

Table IV contains the data on a comparison of the kinds of grafts.

Table IV. Comparison of Grafts.

| Kind | Cions set Number | Cions Growing Number | Cions Growing Percent | Growth Per Cion-Inches Max. | Growth Per Cion-Inches Min. | Growth Per Cion-Inches Ave. | Measurements No. |
|---|---|---|---|---|---|---|---|
| Cleft | 257 | 250 | 97.27 | 91.00 | 17.75 | 59.27 | 94 |
| Bark | 375 | 367 | 97.86 | 102.50 | 0.25 | 44.10 | 159 |
| Kerf | 27 | 27 | 100 | 97.00 | 8.75 | 60.74 | 27 |
| Side | 2 | 2 | 100 | 67.50 | 28.75 | 48.12 | 2 |
| Whip | 1 | 1 | 100 | 53.75 | | | |

The kerf graft gave the best results. That type gave 100 per cent of unions, and 1.47 inches more growth per cion than the cleft graft. The bark graft gave 0.59 per cent more unions than the cleft graft, but the latter had an advantage of 15.17 inches in growth. The variation in the record of the average growth for cleft grafts and bark grafts given in Table III and in Table IV is due to the difference in the number of measurements. The results in the former table are based on 80 measurements of each type of graft; the latter is based on 94 measurements of cleft grafts and 159 bark grafts.

Table V shows the growth of sions when waxed with different materials.

Table V. Comparison of Waxes.

| Kind of Wax | Number Cions set | Number Growing June-21 | Growth per Cion-Inches Max. | Min. | Ave. |
|---|---|---|---|---|---|
| R.-B.-T. | 23 | 22 | 79.29 | 2.00 | 42.59 |
| Parapin | 23 | 23 | 64.75 | 13.50 | 36.91 |
| Parowax | 16 | 16 | 52.50 | 0.25 | 26.98 |

A wax made of resin, beeswax and tallow proved to be the best by giving the longest growth, Parapin was second, and Parowax was poorest.

Parapin wax, when fresh, has a definite orange color. It was thought there would be no difficulty in distinguishing between Parapin and Parowax, but upon exposure to light the Parapin turned almost colorless. No record of which stocks were treated with these two dressings was made at the time of grafting; hence, there may be an erroe present, but the writer is fairly confident that the measurements were listed under the correct headings.

The Parapin used on Tree No. 4 cracked and pulled away from the wood badly.

No injury to the large limbs due to sunscald was observed, and no breakage of cions occurred due to wind or other causes. At the time of writing it could not be determined whether or not stocks of large diameter could be successfully and satisfactorily grafted. This will require several years' observations.

## CONCLUSIONS

From the evidence given above the following conclusions are drawn:

1. It is better to cut the tree as low as possible because longer growth is obtained, and the trees will have a decided tendency to be less "leggy". The effect of large diameter of the stock on the resulting tree could not be determined at the time of writing.

2. The cleft graft makes more rapid growth than the bark graft and is easier to make than the kerf graft.

The cleft graft is probably stronger than the other two types of grafts. The percentage of unions of the three types of grafts is so nearly the same that the difference is not considered significant.

3. There is no apparent advantage of working half of the tree one year and the other half the next year. A tree grafted entirely in one year will probably come into maximum production earlier than one grafted during two years.

4. Grafting wax made of resin, beeswax, and tallow proved to be more satisfactory than Parapin or Parowax by giving longer growth and by less cracking and pulling away from the wood.

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LITERATURE CITED

1. Bostock, J. and Riley, H. T.
1855. The Natural History of Pliny. (English Translation). Henry G. Bohn, London.

2. Patten, C. G.
1890. Stock, Grafting and Top-work. Iowa State Hort. Soc., Vol. 25. pp. 165-170.

3. Patten, C. G., Gaylord, E., and Hansen, Prof. N. E.
1893. Top-grafting the Apple. Top-grafting. Iowa State Hort. Soc., Vol. 28. pp.203-210.

4. Bomberger, W. M.
1894. Top-grafting. Iowa State Hort. Soc., Vol. 28. pp. 153-156.

5. Davidson, , and Buckley, T. A.
1895. The Works of Virgil. (English Translation). Georgics II. p. 52. Harper and Bros., N. Y.

6. Budd, J. L., and Hansen, N. E.
1902. American Horticultural Manual. pp. 66-92. John Wiley and Sons, New York.

7. Powell, G. H.
1902. Top-working Orchard Trees. U. S. D. A. Yearbook 1902. pp. 245-258.

8. Waugh, F. A.
1904. The Graft Union. Mass. (Hatch) Agr. Exp. Sta. Tech. Bul. 2.

9. Card, F. W.
1906. Double Working Apples. Proc. Am. Soc. for Hort. Sc., 1906. p. 47.

10. Booth, N. O.
1913. Some Investigations in Grafting. Proc. Am. Soc. for Hort. Sc., 1913. pp. 144-

11. Palladin, V. I., and Livingston, B. E.
1914. Plant Physiology. p. 331. P. Blakeston's Son and Co., Philadelphia.

12. Stewart, J. P.
1915. Experimental Results in Young Orchards in Pennsylvania. pp. 10-11. Pa. Agr. Exp. Sta. Bul. 134.

13. Fraser, Prof. S.
1917. Top-working not Desirable. Orange Judd Farmer 62:8. Feb. 17, 1917.

14. Crandall, C. C.
1918. Apple Bud Selection: Apple Seedlings from Selected Trees. Ill. Agr. Exp. Sta. Bul. 211.

15. Brown, W. S.
1919. Art of Top-working and Bridge Grafting Fruit Trees. Better Fruits 13:12-12. Feb. 1919.

16. Bailey, L. H.
1920. The Nursery Manual. pp. 151-171. MacMillan Co., New York.

17. Morris, R. T.
1921. Grafting With the Aid of Paraffin. Rural New Yorker. 80:363. Mar. 5, 1921.

18. Auchter, E. C.
1923. Is There Normally a Cross-transfer of Food, Water and Mineral Nutrients in Woody Plants? Md. Agr. Exp. Sta. Bul. 257.

19. Kinnison, A. F.
1924. Top-working Fruit and Nut Trees by the Biederman Bark Graft Method. Ariz. Agr. Ext. Circ. 49.

20. Morris, R. T.
1924. Nut Growing. pp. 63-121. MacMillan Co., New York.

21. Cardinell, H. A., and Bradford, F. C.
1925. Grafting in the Apple Orchard. Mich. Agr. Exp. Sta. Sp. Bul. 142.

22. Chandler, W. H.
1925. Fruit Growing. pp. 413-415. Houghton Mifflin Co., New York.

23. Schrader, A. L., and Whitehouse, W. E.
1925. Budding and Grafting of Fruit Trees. Md. Agr. Exp. Sta. Bul. 278.

24. Tukey, H. B.
1925. Top-working Apple Trees. Rural New Yorker. 84:453. Mar. 14, 1925.

25. Bennett, H. D.
1926. An Account of an Experiment with Piece Root Grafts in the Apple and Pear and of the Influence on Growth of the Position of the Top Bud of the Scion to the Graft Union. Proc. Am. Soc. for Hort. Sc., 1926. pp. 255-259.

26. Cummings, M. B., and Jenkins, E. W.
1926. Apple Cion Selection. Vt. Agr. Exp. Sta. Bul. 255.

27. Tezzer, C. W. Unpublished Manuscript.
1926. A Study of Some Phases of Plant Propagation by Means of Cuttings and Grafts. K. S. A. C., Hort. Dept. Files.

28. Neilson, Jas. A.
1927. Grafting Fruit Trees. Ontario Dept. of Agr. Bul. 324.

29. Roberts, R. H.
1927. Factors Effecting the Variable Growth of Apple Grafts in the Nursery Row. Wis. Agr. Exp. Sta. Res. Bul. 77

30. Gardner, A. K.
1928. Top-working Apple Trees: A Manual Describing When and How to Graft. Me. Agr. Exp. Sta. Bul. 177

31. Vincent, C. L., and Luce, W. A.
1928. Propagation of Fruit Trees. Wash. Agr. Exp. Sta. Pop. Bul. 141

32. Bradford, F. C., and Sitton, B. G.
1929. Defective Graft Unions in the Apple and the Pear. Mich. Agr. Exp. Sta. Tech. Bul. 99.

33. Kimball, D. A.
1929. After-Grafting. The Canadian Horticulturalist. LII:6. p. 179. June, 1929.

34. Miller, C. H.
1930. Tree Grafting is Easy. Capper's Farmer. p. 18. Jan., 1930.

35. Neilsen, Jas. A.
1930. Correspondence.

36. Vincent, C. L.
1930. Correspondence.