GRAFTING

Thesis for the Degree of M. S.

Paul Thayer

1914

GRAFTING.

PRESENTED AS A THESIS FOR THE DEGREE OF

MASTER OF SCIENCE

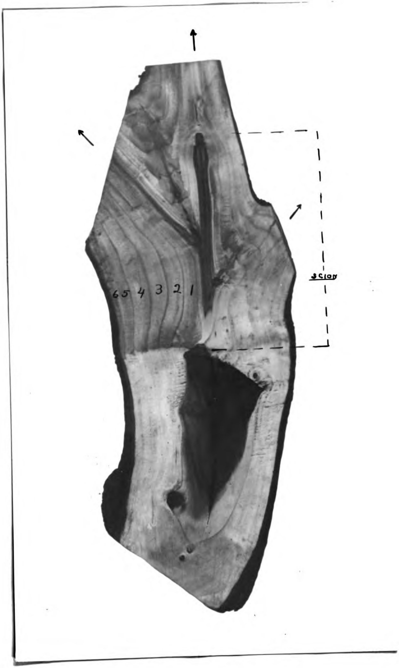
BY

PAUL THAYER.

MICHIGAN AGRICULTURAL COLLEGE.

1914.

THESIS



The Story of the Graft.

Six years ago a scion bearing 3 buds was cleft grafted into a limb. Each of the three buds produced a limb, one going to the right, one to the left and one upward.

103963

- G R A F T I N G -

"You see sweet maid we marry
A gentler scion to the wildest stock
And make conceive a bark of baser kind
By bud of nobler race; this is an art
Which doth mend Nature, change it rather; but
The art is Nature."

- Winter's Tale.

Definition.

Grafting consists of so applying a portion of one plant to another plant, or to another portion of the same plant, that the two parts shall grow together and the processes of life shall have such free course through the point of union that the two parts, once widely separated, shall become to all intents and purposes one. Parasitism is not graftage, although the mistletoe and oak are united almost as closely as the oak with its own branches. A true graft must be, as some one has termed it, a close cooperative organization of stock and scion for mutual benefit, a true marriage, and one must not be a parasite upon the other. Again in a true graft, while the line of demarkation may be distinct, the annual layers of wood must be continuous. We have all seen grafts between uncongenial plants in which the scion, after perhaps several years of growth, would, when sufficient pressure was applied, cleave cleanly away from the stock, showing that while the growth was close enough to permit of absorption between cells yet there was no continuity of annual growth and hence no true graft union.

This definition is a broad one which includes budding as well, for budding is one form of graftage. In a narrower sense when a single bud, taking with it a larger or smaller section of bark and cambium and little or no wood, is transferred, the operation is termed budding; while the use of the entire diameter of the shoot is termed grafting. In grafting there is usually, though not necessarily, a stock and a scion. The stock is the member of the graft union bearing roots or the one which is intended to furnish sap to the other portion. The scion is the member which is more or less dependant upon the stock for its supply of sap.

<u>History</u>.

The origin of the art of grafting is unknown. The Chinese, with all their skill, are believed to have known nothing of this art until it was brought to them by western explorers. We have no record of the ancient people of Egypt, Persia or Syria practicing it. When we come to Rome, however, we find that from the earliest times the Roman horticulturists knew of the art and used it. By them it was spread wherever the Roman arms and law went. St.Paul knew of it and used it in a figurative way in his Epistle to the Romans(*), indicating that the operation was a well known one throughout the Roman Empire at that day. M. Andre Thouin in his "Monographie des Greffes" published in 1821(**) says that the inventor of grafting is unknown but that the Carthagenians and Greeks received a knowledge of the art from the Phoenicians and that the Greeks passed it on to the Romans, by whom it was disseminated over Europe. In Europe, especially in those countries where gardening has been developed into a high art, grafting has been so developed that we find in M. Thouin's book a list of 125 different forms of grafting.

*Romans XI 17-24.

**Translated from the French of Charles D'Albrecht in Gardner's Chronicle for 1851.

Natural Grafts.

Probably the idea of grafting was suggested to the inventor by a case of natural grafting, an occurrence by no means rare. The following cases have come to my attention since taking up this study.

In the Michigan Horticultural Society Report for 1880, page 113, is an account of a natural graft of yellow oak and white oak presented to the Michigan Agricultural College by Frank Hodgeman of Climax, Michigan. The top of the latter grew for some years after all connection was severed with its own roots.

In the American Inventor for 1905, page 33, are illustrations and descriptions of two natural grafts between adjacent sycamore trees.

The Gardner's Chronicle for 1895, page 770, tells of a wall trained pear tree, a branch of which produced fruit year after year after being severed from the main trunk. Investigation showed that a small twig about the size of one's finger had joined itself to the old branch on the top of the wall by friction and was sustaining the severed branch.

Botany of the Graft.

An understanding of physiology, especially the physiology of wood growth, is necessary for a proper understanding of the graft processes. It is with exogens that all, or practically all, grafting work has been done, and perennial exogens grow by the division of the cambium layer, a layer between the bark and wood. Each year by

a multiplication of the cells of this cambium layer a new layer of wood is added to the outside of the wood and a new layer of bark to the inside of the bark. The only way by which great oaks may from little acorns grow except for the simple elongation of the tender growing terminal shoots, is by this activity of the cambium layer. In the body and limbs and twigs of a tree this, and this alone, has the power of change, of growth; has, in this sense, the power of life.

Picture of section of
one year's growth on a graft.

The wood cells are fixed and will not change their form or size as long as they endure; nor have they the power of creating a single new wood cell. The same is true of the bark cells. But, as we have said, the cells of the cambium are different. Look where a limb has been removed and as the summer advances you will see no change in the wood or the bark, but between them you will see a quantity of new growth pushing out to cover the wound and protect the exposed wood.

In grafting it is necessary that the cambium layers of the two parts come together for a union to occur. Wood cannot grow to wood, nor bark to bark, but cambium will grow to cambium, and so coalesce that when a new layer is formed by it both portions of the graft are enclosed in a new continuous layer of wood and the two are joined. The accompanying illustration shows the way in which the scion and stock lose their identity and become merged into a single individual.

Objections to Grafting. There have always been those who objected to grafting, claiming that it was unnatural and even going so far as to say that the world would be better off if grafting had never been known. In an essay entitled "Is Grafting a Devitalizing Process?", Prof. L. H. Bailey(*) takes up this question in reply to sweeping statements made by F. W. Burbage of Dublin, who held that grafting was pernicious, a makeshift, and often a fraud, and that, as own rooted plants were better, healthier and longer lived, it would be best to discard any fruit-bearing or ornamental tree that could not be grown on its own roots. Prof. Bailey could find but three arguments advanced for these denunciations of grafting: (1) the citation of numerous instances in which graftage had given pernicious results; (2) the affirmation that the process was unnatural; and (3) the statement that own root trees are better, i.e., longer-lived, earlier, more virile than grafted trees. His answers are (1) that the pernicious

*Mich. Hort. Society Report, 1891, p.148.

results are usually with ornamentals and the most common is the tendancy to sucker. This is common and yet there are numerous instances in which it does not occur on apple, pear, peach, etc., while it frequently occurs on own root trees as plum, lilacs, etc., grown from cuttings or sprouts. (2) All gardening operations, such as pruning, transplanting and cultivation are unnatural. Grafting is less unnatural than the rooting of a cutting, for it is less unnatural for a wound to heal than for a stem to throw out roots. (3) In answer to the claim that own root plants are stronger and better he says that the union is sometimes the strongest part of the plant and refers to an apple and a peach orchard in which the seedling trees were no longer lived than the grafted trees.

Influence of Grafting on the Seed.

Another objection to grafting is voiced by Downing, in an early edition of "Fruits and Fruit Trees of America", page 4; "But there is another reason for this habit, so perplexing to the novice, who, having tasted a luscious fruit, plants, watches and rears its seedling, to find it, perhaps, wholly different in most respects. This is the influence of grafting. Among the great number of seedling fruits produced in the United States, there is found occasionally a variety, perhaps a plum or a peach, which will nearly always reproduce itself from seed. From some fortunate circumstance in its origin, unknown to us, this sort, in becoming improved

still retains strongly this habit of the natural or wild form, and its seeds produce the same. We can call to mind several examples of this; fine fruit trees whose seeds have established the reputation in the neighborhood of fidelity to the sort. But when a graft is taken from one of these trees, and placed upon another stock, this grafted tree is found to lose its singular power of producing the same by seed, and becomes like all other worked trees. The stock exercises some, as yet unexplained power in dissolving the strong natural habit of the variety, and becomes, like its fellows, subject to the laws of its artificial life."

In a later edition the following footnote is appended to the above paragraph: "The doctrine here advanced has perhaps no foundation in fact, nor has there been any test made, that to our knowledge would controvert it. Observation of many years, however, leads to the belief that the mere engrafting a variety upon another stock in no way affects its habit or capacity for reproducing itself just the same as it would if retained upon its parent root. The great vitality possessed by some varieties, their strong character, etc., prevent them, as it were, from receiving impregnation from a less vigorous sort, and hence, as a strong variety is oftener than otherwise surrounded by those of less vitality, it mainly fertilizes itself from its own blossoms and thus reproduces its leading qualities.

Purposes

While it would be impossible to name all the uses which have been found for the practice of grafting it may be well to enumerate some of the principal ones.

1. Perpetuation of a Variety.

2. The Rapid Multiplication of a Variety. The two purposes are so closely connected that it may be well to consider them together. Many of our fruit trees do not come true to the variety from seed, and propagation from cuttings is slow and uncertain, hence grafting is resorted to. In this way the chance fence-corner seedling, if it is of merit, can be preserved, and in a few years hundreds of acres of the same variety of fruit can be produced. We are not compelled to quit eating Rhode Island Greenings just because the original tree has passed away, for there are thousands of grafted trees producing the same kind of apples the original tree did. When the Colorado Blue Spruce is grown from seed there is a wide range of blueness in the seedlings, only a small proportion being of the desired shade; when propagated by grafting each tree is like the one from which the scion is taken.

The perpetuation of a variety by grafting was disputed by Thomas Knight, who held that, as the scion was a portion of the original tree, every variety of apple or pear was as old as the original tree and was subject to deterioration and decay as was that original tree.(*)

*Knight's Horticultural Papers, 1841, pp.13,81,323.

"Every cutting, therefore, taken from the apple (and probably from ~~any~~ every other) tree, will be affected by the state of the parent stock. If that be too young to produce fruit, it will grow with vigor, but will not blossom; and if it be too old, it will immediately ~~bear~~ produce fruit, but will never make a healthy tree. The durability of the apple and pear I have long suspected to be different in different varieties; but that none of either would vegetate with vigor much, if at all, beyond the life of the parent stock, provided that died from mere old age."

This theory of Knight, that the life of a variety is to be measured by the life of a single tree, is not generally accepted today.

3. Correcting Mistakes in the Selection of Varieties. The practice of top-working undesirable varieties is so universal that comment seems unnecessary.

4. Testing Seedlings. Contrary to the belief of Knight, who held that a scion from a young seedling would not bear fruit until the seedling tree itself reached the age of fruitfulness, it is the usual custom in testing new varieties to top-work them into older trees to hasten the production of fruit. The main objection to this is the fact that it is impossible thus to learn anything of the tree characteristics of the new variety. Thus in the apple breeding work of the New York Experiment Station(*) crosses which were made in 1898 and 1899 and top-worked into bearing trees in 1901, began bearing in 1904; while in 1905 the seedling trees, though crowded in nursery

*Bulletin 330.

rows under conditions which would seem to favor fruition, had not as yet borne.

5. Produce fruitfulness. Knight says(*) "When great difficulty is found in making a tree, whether fructiferous or ornamental, of any species or variety, produce blossoms, or in making its blossoms set when produced, success will probably be obtained in almost all cases by budding or grafting upon a stock which is nearly enough allied to the graft to preserve it alive for a few years, but not permanently."

6. The Production of Several Varieties on the Same Tree. In testing new varieties, or in growing trees upon city

Tree Grafted to 180 Varieties of Apples.

lots where the number of possible trees does not equal the number of varieties desired, it is often convenient to produce several varieties of fruit upon the same tree. The accompanying photograph shows a tree upon which 180 varieties of

*Knight's Horticultural Papers, 1841, pp.222-274.

apples have been grafted, 134 of the grafts living and producing fruit at the present time.

7. Graft in the Missing Sex in Dioecious Trees. While all of our fruits in the temperate zone are monoecious, there are fruit and ornamental trees in the tropics which are dioecious. To insure pollination of these trees it is necessary to plant trees of both sexes, or else to engraft branches of a staminate tree upon the pistillate trees.

8. Grafting to Aid Cross-fertilization. Where solid blocks of one variety have been planted it has been frequently found necessary to topgraft a certain portion to another variety to insure the proper cross-pollination.

9. Change the Size of a Tree. Dwarf trees are so well known that further comment is unnecessary.

10. Change the Form of a Tree. It is possible by combining two plants of different habits to produce plants unlike either. The Catalpa bungei, which is a dwarf bush, when grafted 6 or 8 feet above the ground upon a straight tree of C. speciosa or C. bignonioides makes a round headed tree which is much used in formal or semi-formal gardening. Similarly, our weeping trees such as Camperdown elm, Teas mulberry, weeping ash and some weeping willows, and also our tree roses, hydrangeas, currants and gooseberries are combinations of an erect stem and a spreading or weeping top,

11. Addition of Limbs to Restore Symmetry. In the management of trained trees in England or on the continent, when the symmetry of a tree is destroyed by a branch lacking or dying, it is customary to graft or bud in a new branch to

replace the missing one and restore symmetry.

Weeping Tree.

12. <u>Bracing Limbs.</u> When a weak crotch in a tree gives warning of future splitting, lateral branches extending across the crotch from opposite sides are frequently wrapped around each other. The pressure due to the enlargement of growth causes a union of the branches and a living brace results.

13. <u>Healing Wounds.</u> The best illustration of this use is the bridge grafting used to repair the damage due to mice and rabbits.

14. <u>Reinvigoration.</u> Crozier says (*) "The stock and graft each imparts to the other something of its own degree of vigor or lack of vigor". Other writers say that if there is any difference in the vigor of stock and scion the scion should be most vigorous, as a vigorous scion will increase the vigor of a weak stock, while a weak scion has been known to weaken and even kill a

*Michigan Hort. Soc. Rept. 1891.

vigorous stock. The editor of the Gardner's Chronicle(*) tells of a Mr. Webb who grafted into an old apple tree which was trained arborlike over a path, and which showed signs of decay, (becoming unfruitful, etc.) two scions of a strong growing variety. As a result it yielded for several years a crop of 12 bushels, besides a bushel from the two grafts. M. Charbon grafted some delicate roses of weakly growth on very robust wild stocks to give them vigor; nearly all the grafts died by a kind of plethora or surfeit of sap.

Bridge Grafting.

15. Improve the Quality of Fruit or Flower. The superior quality of some of our finest pears when grown as dwarfs is an illustration of this use.

16. Adapting a Plant to a Soil. It is a well-known fact that peach trees are frequently grown on plum roots on heavy soils, while plum trees are often grown on peach roots on

*1879,p.365.

light, sandy soils. It is said that on moist rich soil the quince is the best stock for the pear, on dryer soils the pear root is used, on light sand the mountain ash is recommended, while on calcareous soils the hawthorne is more successful.

17. Overcoming Insect Attacks. Two examples of this use of grafting are the practice of working peach on plum to avoid the peach borer which attacks the peach roots, and the use of American vines in growing the grape in Europe because the Phylloxera destroys the European grape when ungrafted. Woodbridge Strong(*) tells of his success in grafting quince on the roots of the native thorns, Crataegus crus-galli and C. coccinea, to avoid the injuries of the round-headed apple-tree borer; while the use of Northern Spy roots for apples in regions where the woolly aphis is serious is well known.

18. Overcome Diseases. It has been recommended that English gooseberries be topgrafted on long cuttings of the buffalo currant(Ribes Aureum), or Ribes Palmatum to raise the plants above the ground and avoid the mildew which is so serious a hindrance to the growth of this fruit. The most common illustration of grafting to prevent disease is the custom of top-working Grimes Golden and King to avoid the collar rot which is apt to attack the lower portion of the trunk. Crozier(**)quotes the following from Prof. J.L.Budd: "In our interior climate trees doing well under forest conditions as to shade of stem may utterly fail when the stems are exposed to the direct

*Country Gentleman, Mar. 20, 1890.
**Mich. Hort. Soc. Rept., 1891, p. 133.

rays of the sun and hot southwest winds when located on the open prairie. As an instance, the buffalo berry, Shepherdia Argénta, is plentiful on the banks of the upper Missouri, growing thickly like hazelbrush, but when planted by itself in our yards with a stem 3 feet in height, it is certain to be dead ón the southwest side of the stem in three years. But topworked on the Asiatic species, Eleagnus augustifolia, even at a height of six feet, its stem will remain perfect."

The point must be kept clearly in mind that this immunity is not due to any effect of the stock upon the scion or the scion upon the stock, although this may sometimes occur indirectly through a chage in vigor of the plant, but rather to the replacing of a portion of the plant especially susceptible to a certain disease with a variety or species which is unsusceptible. That susceptibility or resistance is not transmissible, except indirectly, I saw recently in a tree bearing two varieties of apples and standing in close proximity to a cedar tree; one portion of the tree showed many leaves marked with the cedar rust while the other variety seemed immune. Another instance noticed was a plum tree, its leaves showing little or no shothole injury, while a graft on the tree showed leaves fairly peppered with shothole fungus.

19. Sugar Beet Grafting. A rather uncommon use for grafting is mentioned in the Experiment Station Record(*). In the production of sugar beed seed the yield of seed from a single "mother" beet of superior quality may be much

*E.S.R. XI, p.334.

increased by taking the little crowns from the mother beet and transplanting them into other beets. Thus as high as 31 beet plants have been obtained from a single beet root.

20. Graft Hybridization. So far as I know the only grafting done with hybridization in mind has been experimental work, largely with herbaceous plants, and in an effort to ascertain the laws of graft hybridization rather than the production of new species or varieties. The entire matter of graft hybridization will be taken up in a later portion of this paper.

Methods of Grafting.

While herbaceous grafting may be performed at any time of year, so the plants are in the proper condition or stage of development, the grafting of woody plants is usually done in the winter and early spring. The scions may be cut any time during the period that the plants are fully dormant, and consist of well ripened wood of the previous year's growth. Watersprouts may be used, although they are open to two objections; the wood is apt not to be well matured, and the buds, especially toward the base, are apt not to be well developed. When a fall unfavorable to the proper maturing of the new growth is followed by a winter of low temperature there is a distinct advantage in cutting scions before severe winter sets in, as anything which lowers the vitality of the scion weakens the graft.

The storage of scions is somewhat of a problem.

They must be kept dormant; they must not be allowed to dry out; and they must not be allowed to become "water-logged." During the winter they are frequently kept packed in damp (not wet) moss, sawdust or sand, in a cold cellar, and during the spring they are frequently kept in an icebox until ready for use.

In grafting, the scion should be dormant, or nearly so, and the more difficult the species is to graft, the greater the importance of this rule. In no case should the scion be further advanced than the stock. The earliness in the spring at which grafting may be done depends upon the temperature, as the weather must be warm enough for the wax to work well and the stock warm enough for the wax to adhere; the lateness depends upon the length of time that the scions may be kept dormant, although the slipping of the bark in late spring renders cleft-grafting difficult and uncertain.

Grafts are classified according to their position as root, crown and top grafts.

Rootgrafts are usually made indoors during the winter and are the only grafts so made. They constitute one of the principal methods of propagating the apple and pear. The seedlings, one or two years old and 1/4 to 5/8 inch in diameter, are dug in the fall and stored until time permits of grafting. The tops are cut from the seedlings and either the entire root used as a stock or else the root is cut in sections and each section used as a stock. These two modes are known as "whole root" and "piece root"

grafts. The whip or splice graft is the one generally used. The grafts are then stored until spring and then set in the nursery.

The honor of inventing the root graft is claimed for both America and England. Mr. Joseph Curtis (*) who started the first nursery in Illinois in 1818 is said to have originated the idea of grafting upon roots. A man who learned it from him is said to have gone to the eastern states and instructed people in this "secret process" at $100 apiece. Lindley(**) claims that Thomas Knight was the discoverer of root grafting about 1811.

Root Graft

Crown or Collar Grafting is the term applied to a similar union when the roots are not dug but the grafting is done in the field in the spring, the scion being placed, as in the previous case, at the crown or

* Ill Hort Soc. Rept. III(1869), p.238

the place where the root and stem meet. Some form of side or cleft graft is generally used.

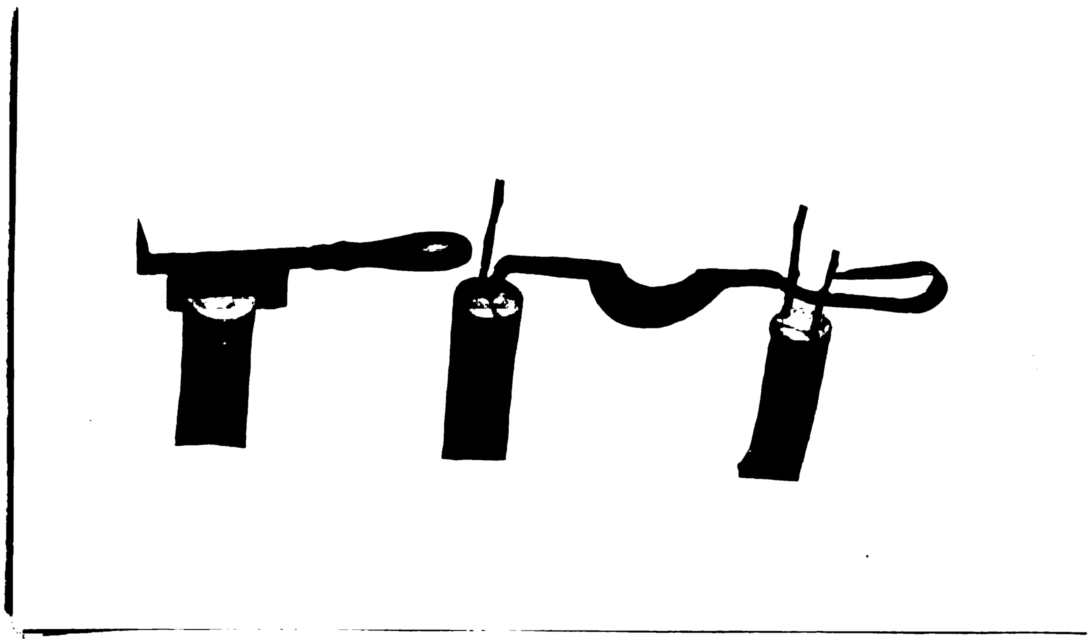
Topgrafting is always performed in the spring. When one or two scions are placed in the body of a little tree to form the top the term bodygrafting might be applied, but the term topgrafting is generally used to cover both this and the grafting of the limbs.

To accomplish these different purposes there are a great variety of grafts used. One French writer describes and illustrates 125 different grafts. Of course some of these are but slight modifications of others, while some are designed for special pusposes.

Cleft Graft. This graft is one of the simplest grafts and is almost too well known to need description. It is used in topworking almost exclusively. I know of one nursery which used it in root-grafting but this is the exception. It is best used on stocks between 3/4 and 3 inches in diameter. The stock or limb issawed off square, using a sharp saw. It is then carefully split so as not to loosen the bark from the wood. Two scions are prepared(one if the stock is very small) by taking well ripened wood of the previous year's growth and trimming the basal end to a slender wedge, having one edge slightly thinner than the other, and so made that a bud shall be at the base of the wedge, upon the thicker edge. The scion is then cut off above the third bud. The cleft in the stock is then opened with a wedge or the grafting tool, and the two scions inserted with the thicker sides cutwards and the lower buds on the outside and opposite the top of the stock. Great care must be taken in setting the scions that the cambium of scion and stock coincide, as without this all the work is useless. Sometimes the scion is slightly slanted so that the line of cambium on the scion must intersect the cambium on the stock. When the grafting tool or wedge is removed the spring of the wood should hold the scions firmly in place. The wounds are then covered with grafting wax to prevent drying out and the entrance of disease organisms. Usually one of the two scions is cut off after a year or two of growth, its object being to

Cleft Root Graft.

insure a stand and to assist in healing the wound. On small stocks where a single scion is used the side of the stock opposite the scion is cut sloping. Some of the requisite conditions for success in topgrafting are: good vigorous scions, neither sappy watersprouts nor stunted twigs; dormant or nearly dormant scions, expeditious work so that the scions may not dry out; careful work so that there is good connection through the two cambiums; careful covering of all exposed surfaces with wax.



Cleft Graft.

In changing grape vines the cleft graft is the one most commonly used. In this case the work may be done in the fall, early in the spring before the sap starts, or late in the spring after the rush of sap has abated. The vine is cut off below the surface of the ground, and the graft made as described above, except that no wax is used, but instead the graft is covered with earth.

Grape Graft.

Kerf Graft. One objection urged against the cleft graft, especially where large stocks are used, is that the wound requires several years to heal over and, as the sides of the stock heal before the top heals over, if the top is not kept carefully covered with wax, the cleft in the heartwood offers an exceptional opportunity for disease to start. To obviate this weakness some one, a few years ago, suggested the kerf graft, especially for large stocks.

The limb is cut off as for cleft grafting but is not split. Instead, a longitudinal kerf is sawed in the stock, entering it in a slanting direction from the base upwards and only deep enough to receive the scion. This, after it is smoothed out with a sharp knife, gives a kerf in which to insert the scion, which is prepared as for cleft grafting and inserted in the same manner, except that, in place of therreleased spring of the limb holding the scion in place, it is tapped into place with a mallet.

Kerf Graft.

One advantage of the kerf graft is, if the limb cut off is a large one, four or five or more scions may be set around the stub, favoring a rapid healing of the wound, the surplus grafts being removed as the would heals over. The same waxing is necessary as for cleft grafting.

Crown Grafting. Another method which is especially valuable for large wounds is crown grafting. This consists in slipping the scion down between the bark and the wood of the stock. For this purpose the scion may be either cut with a single long bevel and slipped in with the cut surface toward the wood, or it may be cut 1/2 or 2/3 off and the remaining portion cut to a long slender bevel. Until they are well established crown grafts are liable to be broken out and accordingly should be securely tied in place. The ends of the stock should of course be carefully waxed. Like the kerf graft, as many scions as thought best can be used on a single stock.

<u>Saddle Graft</u>. While this style is not very common in nursery or orchard work, it is used in the grafting of some ornamentals, especially soft wooded plants. For saddle grafting the stock and scion should be of the same size. The end of the stock is cut off in the form of a wedge; the base of the scion has a corresponding V cut out of its centre; the scion is then placed astride the stock and tied and waxed or else wrapped with waxed tape. This form of grafting has the merit of exposing practically no cut surface and affords a chance for a perfect cambium contact. Its disadvantages are that it requires more care and exactness than some other forms and hence it is more slowly made.

<u>Side or Bark Graft.</u> There are innumerable ways in which this graft can be made. The scion is cut wedge shape, usually, though not always cutting all from one side. In some cases a T-shaped cut is made in the bark as for budding and the scion slipped down between the wood and bark. In other cases a vertical slit is made in the bark, the bark on one side lifted, and the scion pushed laterally and downward between the bark and the wood. A modification of this is recommended

by Theodore Williams, the eminent Nebraskan horticulturist:* "In this method we like scions three or four inches long, getting them from the new growth as soon as the terminal buds have been formed in June. We slope these scions with a sloping cut and run them beneath the bark of the tree we wish to improve, by the aid of two cuts less than an inch long. The first cut is made on a line with the growth of the tree; the second parallel with the first, one-fourth of

Bark Graft.

an inch away and three-fourths of an inch lower down. Across the top of the upper cut the knife is drawn, raising the bark, behind which the scion is pushed between the two cuts, a piece of bark tying it in. It is necessary that the tree that is grafted should be in an active state of growth with plenty of descending sap which

*Amer.Breeders'Assn.,1906,p.186.

spreads over the cut surface of the scion. Healing and growth begins instantly. No waxing or tying is used."

Prof. Waugh(*) says that good success is had in grafting young seedlings, especially of plum, in situ or in the grafting room, by bending them over and making a slanting cut downward and inward near the surface of the ground, inserting a scion sharpened on both sides, the spring of the top holding it fast. After growth starts the top of the stock may be cut away.

The resemblance of side or bark grafting to budding makes it possible to do the work either in the spring or in midsummer at the usual time for budding.

Veneer Grafting. The relative size of stock and scion is not of especial importance in this graft. It is used sometimes in root grafting and may be used in topgrafting as well. The stock is cut off. A transverse cut is made an inch or so below the end and a thin tangential sliver of wood and bark split off. A similar slice is cut from the scion and the two cut surfaces placed together, tied and waxed. E. S. Crandall(**) prefers this to the whip graft because less wood is exposed to decay and there is much more contact of the cambium. It has the objection of being easily disarranged and requiring careful wrapping.

Bridge Grafting. Frequently young trees which would otherwise be destroyed by mice may be saved by the operation of bridge grafting. Scions are cut slightly

*Gardners Chron.1903,p.407. **Amer.Garden II,p.64.

longer than the distance across the wound. Sockets are cut on the upper and lower margins of the wound to receive the ends of the scions and the scions slipped into place. Usually the spring of the scion is sufficient to keep it in place, although tying is sometimes resorted to. The scions are placed 2 or 3 inches apart around the trunk of the tree and the ends waxed to prevent drying out. As the scions enlarge and meet, the wound disappears and in a few years one would not suspect the tree having ever been injured.

Splice, Tongue or Whip Grafts. With the possible exception of the cleft graft this is the most common form of grafting known. Practically all root grafts are made by this method and it is successfully used in topgrafting upon young trees. One requisite is that stock and scion shall be of approximately the same diameter.

Whip Graft.

The graft may be made by cutting both stock and scion with a long bevel cut and applying the two cut surfaces to each other. As it is somewhat difficult to hold the stock and scion when thus prepared, it is customary to cut a tongue upon each piece. The stock and scion are first prepared as stated above; a tongue is then cut upon each by starting on the cut surface one-fourth of the distance from the point and splitting the wood carefully for a short distance parallel to the bark. When the two cut surfaces are placed together the tongue of each is caught under the tongue of the other and the two forced together lengthwise. The graft is then wrapped with waxed cloth, although, if well made, this is not necessary.

Inlaying. This form of grafting is often used in inarching or grafting by approach. It is usually performed with a special tool, although it can be done with ordinary tools. Where it is intended that the tops and roots of both members of the union shall be retained, at least for a season, a triangular groove is cut in the body of the larger member, parallel to the line of growth; this groove starts at the surface of the bark and gradually deepens until it attains its maximum depth when it becomes gradually shallower toward the other end. The scion is cut at the same angle so as to fit into the stock perfectly, and the two are bound together. This is sometimes used in topgrafting, in which case the triangular groove gradually deepens to the end of the

stock and the scion is sharpened to a triangular point at the base. Mr. Martin Ernst(*) finds this a good method in grafting stone fruits and E. G. Lodeman(**) describes it as one method of grape grafting.

Other Grafts. One method, which has been used for supplying limbs where they are lacking is the plug graft. A hole is bored into the stock at the desired point, using a bit the exact size of the scion without its bark. The bark is then removed from the base of the scion for a distance equal to the depth of the hole and, after fitting, the scion is driven into place.

Bud Grafting consists of taking from the stock, by a sloping and a transverse cut, a triangular patch of bark and a little wood, and replacing it with a similar patch containing a bud, tying and waxing the same. "F.M." in Gardners Chronicle(***) reports that this method is taking the place of budding for roses.

In propagating grapes in Europe many of the vine growers(****) instead of grafting on rooted vines, graft on cuttings, so that the healing of the graft and the rooting of the cutting takes place simultaneously. The New York Experiment Station(#) found this a good method of grape grafting.

Thus far we have spoken entirely of grafting with detached scions. There is another form of grafting known as inarching or grafting by approach. In grafting by this method the scion is not separated from its roots

*Country Gentleman, LXV(1900)p.304. **Cornell Ex.Sta.Bul.77.
***1906,p.367. ****Garten & Blumenzeitung - Quoted in Gard.Chron.1889,p.631.
#Bulletin 350.

until it has effected a union with the stock. This method of grafting is much used in trained trees, in which the branches are made to assume geometrical shapes, and it is also used in herbaceous grafting in cases in which it is difficult to secure a union with detached grafts. Thus M. Daniel(*) claims by this method to have secured grafts of kidney bean and cockle bur, kidney bean and castor oil bean, sunflower and melon, cabbage and tomato, chrysanthemum and tomato, Jerusalem artichoke and black nightshade, coleus and acaranthus, cineraria and tomato, aster and phlox, coleus and tomato, maple and lilac, zinnia and tomato.

For grafting by approach the veneer graft or the method of inlaying is the one generally used.

Mixed Grafting. Before leaving this discussion of modes of grafting the subject of mixed grafting should be considered. M. Daniel in his experiments in the grafting of vegetables conceived that by allowing a portion of the growth on the stock to remain, the equilibrium of sap between root and top might be better maintained and unions otherwise impossible might be secured, as well as the reciprocal action of scion and stock changed. He termed a graft in which a portion of the foliage of the stock was permitted to grow a mixed graft. In an experiment(**) in which he grafted Black Belgian Haricot(bean) on Soissons Haricot using both the ordinary and the mixed graft, when grafted in the ordinary way the plant resembled quite closely the ungrafted Black Belgian, while the scions

*Ex.Sta.Rec.XII,p.642. **Gard.Chron.(1898)XXIII,p.84.

of the mixed graft showed characteristics somewhat intermediate between those of the stock and scion.

Tools, Waxes, Etc.

For whip grafting the only tool necessary is a sharp knife; for cleft grafting a knife, saw and mallet, besides a heavy knife for splitting the stock and a wedge to hold the cleft open for the insertion of the scions. The heavy knife for splitting and the wedge are frequently combined in a single tool, and this forms the only special tool used in the work. For inlaying a knife with a blade like the edge of a corner chisel(of which there are several types) is advantageous. Other tools have been invented. Ashael Foote(*) tells of a tool invented by him for splitting stocks in cleft grafting and F. A. Waugh(**) tells of another tool invented by a Frenchman which makes the oblique cut for a splice graft readily and the tongue awkwardly, but neither of these tools are of any practical value. L. H. Bailey in his "Nursery Book" shows two other tools designed to split stocks for cleft grafting, but the only two special tools in general use in grafting are the combined knife and wedge for cleft grafting and the special tool for inlaying.

To hold scions in place in certain forms of grafting, various things have been used or suggested as rubber strips, strips of cloth, raffia, basswood bark or bast, and thread. The use of some waterproof covering

*Downings Horticulturist II(1847),p.341.
** Vt.Ex.Sta.Rept.,1896,p.122.

to protect cut surfaces from decay has always been followed and this has been combined with the wrapping of grafts by impregnating the cloth or thread with grafting wax or by first wrapping the graft and then applying the wax. In making waxed thread the ball of thread is placed in hot wax long enough for the wax to penetrate. It is then taken out and drained and is ready for use. In preparing waxed cloth the cloth may be first dipped in hot wax and then cut up, or, better yet, it may be torn into strips, wound, not too tightly, on a ball, and the ball put in the melted wax.

Prof. Bailey found in his experiments in herbaceous grafting(*) while in some instances there was much benefit from the application of grafting wax to the union, probably due to the checking of undue evaporation, in other cases the wax seemed to have a decidedly injurious effect on the tissues when it came in direct contact with the cut surface. H. Von Schrenk(**) is of the opinion that the wax exerts a deleterious influence on the tissues when brought in contact with them, as a result of his experiments in wrapping apple rootgrafts. In the test a number of whip grafts were carefully made and then wrapped with various materials. After a year's growth the roots were examined and carefully graded, separating the smooth from those showing signs of rootgall or hairy root. After grading, the percentage of smooth roots was as

*Cornell Bul. 25.
**U.S.Bur.Plant Industry Bul. 100, pt.2.

follows: wrapped with rubber strips, 83.5; wrapped with cloth, with just enough wax on the outside end of the strip to hold it in place, 85.1; waxed paper, 70.6; plain thread, 68.5; waxed thread, 63.7; plain thread with the graft afterward waxed, 44.2; unwrapped, 54.8.

Wax. In topgrafting it is necessary to cover the wounds with some preparation to prevent evaporation and exclude moisture and disease germs. Grafting clay was formerly much used for this purpose. It was composed of varying proportions of clay and fresh cow manure. While it proved very satisfactory, its use has largely given way to grafting waxes of various kinds.

The different formulae for grafting wax are almost countless but they may be divided into two classes called, for want of a better term, American and French waxes. The American waxes are based on a combination of resin, beeswax and tallow, while the French waxes include such substances as pitch, bitumen, alcohol and turpentine and might be further divided into those rendered plastic by heat and those which are already liquid and harden by the evaporation of some volatile ingredient. The following are a number of French waxes(*):

(1) Beeswax 75, purified resin 125, turpentine 36, rape oil 12, venice turpentine 25, zinc white 25, color yellow with tumeric.

---

*Reprinted in Gard. Chron.,1899,p.184, from Pharmaceutische Zeitung.

(2) Japan wax 100, yellow wax 300, resin 800, turpentine 400, hard paraffine 100, suet 300, venice turpentine 600.

Fluid Waxes

(1) Resin 1250, pitch 200, linseed oil 120, turpentine 50, yellow wax 130. Melt with a gentle heat, stir continually until cold and then add methylated spirit 400 fluid parts.

(2) Burgundy pitch 500, is melted slowly, removed from the fire and mixed with alcohol 70 to 80. Put in wide-necked glass bottles or in tins.

(3) Turpentine resin 1, methylated spirit 4.

Another fluid wax is: (*) made as follows: "Melt one pound of rosin gently, then add 1 oz. beef tallow, stir it well, take it from the fire, cool off a little, then mix with it 1 tablespoonful spirits of turpentine and add 7 oz. of alcohol 95% proof. This will cool down so rapidly that it will be necessary to put it on the fire again, stirring it constantly, taking care that it does not inflame; remove from the fire as soon as the lamp begins to melt again and stir until thoroughly mixed, It will appear like strained honey. Apply with a brush."

The standard or commonest American wax is made by melting together 4 lbs. resin, 2 lbs. beeswax and 1 lb. tallow, thoroughly mixing them by stirring and then pouring the mixture into a pail of water to cool it enough for pulling, pulling until it is smooth and bright straw-colored. While this wax remains fairly hard at ordinary temperatures,

*Country Gentleman, 1870, p. 346.

on a warm spring day it can be warmed sufficiently by a little manipulation in the hand to spread nicely. It is usually found necessary in using the wax to first grease the hands slightly to prevent sticking. The Horticultural Department of the Rhode Island Experiment Station made a test a few years ago(*) with various modifications of this formula. They found that 2 parts of resin to 1 of beeswax was the best proportion. More or less tallow or oil can be used to render the wax less or more hard. Adding tallow to a good wax does not bring lumps if not used in too great quantities. Adding resin to a soft lumpy wax will render it smooth and pliable.

In an experiment made last spring to test the effect of substituting paraffine for beeswax and raw linseed oil for tallow, the cost of the different waxes was:

4 lbs.	resin	2 lbs. beeswax	1 lb. tallow	per	lb.	23½¢
4 "	"	2 " "	1 pt. oil	"	"	25 ¢
4 "	"	2 " paraffine	1 lb. tallow	"	"	9 ¢
4 "	"	2 " "	1 pt. oil	"	"	10½¢

The substitution of 2 lbs. of paraffine for 2 lbs. of beeswax or the substitution of 1 pint of oil for one pound of tallow made a softer wax. Especially was this true in the wax containing both oil and paraffine. This could be corrected by increasing the proportion of resin.

---

*R.I.Exp.Sta. Rept.1906,p.161.

Stocks

As practically all the trees in our orchards are grafted or budded it may be well to discuss the stocks used.

APPLE.

French Crab. The word crab is here used in the sense of a small wild apple, just as we commonly speak of the Pyrus coronaria or native wild apple as a wild crab. The French crab belongs to the same species as our cultivated apples. The stocks are imported or the seed is imported and the seedlings are grown in Kansas, Nebraska and Iowa by men who make a specialty of growing stocks.

Paradise

Doucin These are the two dwarfing stocks for the apple and are simply dwarf growing varieties of the Pyrus malus or common apple. Prof. Waugh speaks of the fact that dwarf growing apples are frequently found among miscellaneous seedlings along roadsides which would serve equally well as dwarfing stocks. The terms Paradise, French Paradise, Dutch Paradise, English Paradise, Broad-Leaved Paradise and Nonesuch Paradise are confusing and do not always refer to the same variety, the terms English Paradise and Broad-Leaved Paradise frequently referring to the Doucin. The true French Paradise is a very dwarf growing apple propagated by mound layering or cuttings while the Doucin is a half-dwarf stock propagated in the same manner. Upon these stocks as upon the preceding, the apple may be budded or grafted.

Pyrus baccata or Siberian crab. There are two species of apple known as Siberian crab, the small fruited crab, P. baccata, a comparatively rare species in America, and the large fruited P. prunifolia, the ancestor of all our crabapples of the orchard. Both of these are valuable stocks for apples in the cold northwest. The P. baccata is especially valuable as it comes from near Lake Baikal where the climate is purely continental - dry and cold with little or no snow, the precipitation for the entire winter being only half an inch. Coming from a climate so similar it has proven very successful experimentally as a stock for the hardy varieties of apples in the Dakotas and Iowa, where the French stocks winterkill. It can be rootgrafted or budded, one advantage of budding being the absence of any roots from the scion, it being found that the roots of the P. baccata are hardier than even the roots of the hardy Russian apples. It has somewhat of a dwarfing effect with the accompanying characteristic of early fruitfulness.

Pyrus rivularis. In the 1906 Report of the Alaska Experiment Station the use of a native crab apple, P. rivularis, is recommended as a stock for propagating trees for Alaska. Crown or collar grafting seems preferable, although topworked trees do fairly well. Apples can also be propagated on pear and on hawthorn as well as on our native wild apples.

PEAR.

French Pear. Seedlings of wild forms of the common pear are used as stocks. These pears are used in France in the production of perry and the seeds separated from the pomace. The seeds are sometimes imported but more often the seedlings themselves are purchased from France. Budding is the usual mode of propagating.

Quince. Pears are dwarfed by budding on Angiers quince stocks obtained by mound layering. The following varieties are said to do well upon quince; Buerre Hardy, Williams Bon Chretien, Duchess d'Angouleme. When the variety desired will not readily unite with the quince recourse is had to double-working. The quince is first budded with a variety of pear which readily unites with it and after a year's growth the pear is again budded to the desired variety. The Clapps Favorite, Duchess de Bordeaux, Jargonelle, Marie Louise, Passe Crassane, Thompsons, Souvenir du Congres, Triomphe de Vienne, are said to do better when double-worked.

Apple. The pear is frequently topgrafted on the apple. The resulting fruits are usually large, but the union as a rule is short-lived. Seckel is probably the variety most used.

Hawthorn. Frequent references are made in horticultural literature to the use of the thorn as a stock, both the European thorn, Crataegus oxyxantha, and the American species being used. This union seems more stable than the one on apple, one writer recording a tree(*) grafted

*Country Gent. 1868, p.376, XXXII.

in 1808, 50 feet high with a trunk measuring 5 feet 9 inches in circumference, and bearing 30 bushels of pears annually.

Other Stocks. The pear is sometimes grown on the mountain ash, one writer reporting that in France the Virgalieus is so grown, to the improvement of its quality. Mr. S. M. Emery(*) reports that the wild crab of Minnesota was tried as a pear stock but that, though it worked fine at first, the top outgrew the stock and the tree broke over.

QUINCE.

Angiers Quince. The quince is usually propagated on the Angiers quince, as a rule by budding, sometimes by rootgrafting.

Hawthorn. The quince is not infrequently worked on the thorn. Mr. Woodbridge Strong(**) says that the quince does much better on English hawthorn, Crataegus oxycantha, than on its own roots, although there is but little less susceptibility to borers. Upon the American thorns there seems to be almost complete immunity from borers; the bushes are vigorous, productive, and the fruit ripens uniformly earlier.

In this connection it is interesting to notice that another writer suggests that when the reciprocal graft is made, the quince root dwarfs the thorn and if the thorn is an ornamental one like the double-flowered scarlet thorn the dwarfing makes it a handsome ornamental shrub.

*Mont.Exp.Sta.Bul.16 p.84.
**Country Gent.LV (1890)p.228.

PEACH.

Peach. The peach is usually propagated on peach seedlings during August or September of the first season's growth. Budding is the method employed and the stocks are grown preferably from "Tennessee pits", the pits gathered from wild peaches in the mountains of Tennessee.

Plum. On heavy soil peach trees are sometimes budded on plum stocks.

Sand Cherry. Prof. N. E. Hansen(*) says that the sand cherry should make an excellent dwarfing stock for peach, especially upon rather light soil. He says the peach bears early and is prolific on sand cherry and that the size is not decreased. This latter fact is important as Mr. H. Somers Rivers of England says(**) "It is curious that apples on Paradise, pears on quince, and cherries on Mahaleb give excellent and large fruits, but when it comes to a dwarfing stock for plums and peaches, the stock which reduces the size of the tree also affects the fruit and makes it much smaller."

The New Jersey Experiment Station(***) also tested sand cherry and Americana plum as stocks for peach and found them apparently immune to borers. The trees were dwarfed and rendered earlier in coming into bearing. These might be advantageous to city planting although the trees would be more expensive. There are also accounts of peaches propagated on whitethorn, C. oxycantha.

---

*Bul. 87, So. Dak. Ex. Sta.
**Gard. Chron, 1910,p.325-371-445.
***Rept.1907,p.129.

PLUM.

With plums the question of stocks is a confusing one. There is such a difference in habit of growth between the European, American and Japanese plums as well as between the different races of European and of American plums that there is no best stock for all conditions. Probably the work done by Prof. Waugh, as reported in the Vermont Experiment Station reports 1900-1905 and the Massachusetts report 1909 is the most extensive experiment along this line. His conclusions were as follows:

Horse Plum. Sturdy and uniform in growth, much used as a stock for Domesticas and Damsons and at present regarded by many nurserymen as the best for these groups.

St. Julien, Dwarfish, hardy and uniform. It has been extensively tested for Domesticas and Damsons but is too slow growing for American nursery purposes.

Myrobolan is extensively used for propagating. It is most used for Domesticas, Damsons and many native varieties and seems suited to all or nearly all of these. It lacks hardiness in the north and in Canada.

Marianna is an offshoot from the Myrobolan and is used extensively because it is readily grown from cuttings. It has been used especially in the south for Japanese, Hortulanas, Chicasaws and Waylands. It has the same defects as the Myrobolan except that it is not quite so dwarf and hence not quite so liable to be overgrown.

Japanese. Have not been very fully tested but would probably prove valuable for Japanese varieties.

Americana and Nigra. These stocks are growing in favor in the northwest and are adapted to varieties of Americana, Nigra and Miner but do not take the Domesticas well.

Wayland. Favored by Mr.J. W. Kerr for native sorts.

Chickasaw. Used in the south for Chickasaw and Hortulana, but sprout badly.

Sand Plum. In the experimental stage.

Sand Cherry. Is expected to make a hardy, early dwarf of native varieties for the northwest.

Choke Cherry. Never proven satisfactory.

Black Cherry. Unpromising.

Peach. Unites well with most classes, especially the freer growing ones, as Japanese. "In the case of plums propagated on peach roots, grafting is much better than budding, which is an empiricism of some interest."

Mr.J. W. Kerr, the veteran plum grower, says that where the peach is hardy it is a good plum stock for plums to be rootgrafted upon. The best general purpose plum stock in his mind, combining the most good qualities and uniting readily with the different types, is the Wayland.

CHERRY

Our cultivated cherries are usually divided into two groups or species; the Hearts and Biggareaus, comprising the sweet cherries, belonging to Prunus Avium, and the Dukes and sour cherries belonging to P. cerasus. The sweet cherries are usually propagated on the Mazzard stock, a variety of P. avium and hence closely related, while the Dukes and sour cherries are propagated on this stock and on other stocks as well.

Mazzard P. Avium. This is a wild red cherry of Europe from which is supposed to have sprung our sweet varieties. It is a strong-growing, vigorous stock but has the weakness of being somewhat susceptible to winter freezing, especially in a dry climate like that of Iowa and Nebraska and northward. It may be budded or grafted, but for cold climates grafting with a long scion, enabling the scion to root above the graft, is recommended.

Morello P. Cerasus. This is a rather dwarf-growing stock, dwarfing the variety propagated upon it, with the accompanying effect of early fruiting. The Morello is a very hardy stock which may be grafted or budded, but has the objectionable habit of throwing up a good many sprouts from the roots.

Mahaleb P. mahaleb. This stock is a native of southern Europe and is used extensively in propagating cherries, especially the sour varieties. It is always budded as it does not succeed when rootgrafted. It is hardier than the Mazzard but not so hardy as the Morello. There is some objection to its use, especially in the propagation of sweet cherries, as it is undoubtedly a better stock for sour cherries, especially the varieties like Early Richmond and Montmorency which have colorless juice, than it is for sweet cherries. Prof. J. L. Budd tells(*) of

*Iowa Ex.Sta.Bul.10,pt.3.

budding 30,000 Mahaleb stocks to Early Richmond, Kentish, Montmorency and English Morello. The next season they made a fine growth. They were banked during the winter to prevent winter injury. The next season the first three varieties made good growth but the Morellos died at the ends and the foliage was sickly. An examination showed that 90% of the roots were dead, due to the fact that the union was so poor as to starve the roots while the roots of the three palejuiced sorts were sound, for the reason that the union was more nearly perfect. Other tests with other varieties showed that, for Iowa at least, the Mahaleb was a poor stock except for the palejuiced sour cherries.

P.Pennsylvanica. This is the native wild red cherry and has been used experimentally to some extent as a stock. While successful experimentally it has never been given a trial commercially.

Sand Cherry P. Pumilla. While it is difficult to make tame cherries unite on the sand cherry stock the union has been effected.

APRICOT.

Prof.Bailey(*) gives as his opinion that "Apricot is the ideal stock for apricot upon soils which are well suited to it, those which are deep and loose and rich and well-drained. There are comparatively few lands of this character, however, and it is probably much safer to rely upon other stocks, particularly as

*Bul.71, Cornell Ex.Sta.

our winters are so long and the ground becomes saturated with water. For the stiffer lands, plum stocks will usually be found to be safer and I am inclined to favor topworked stock - that is plum trees topbudded or topgrafted in the orchard - rather than the nursery budded trees. On all the lighter and drier soils - and these will probably comprise the greater part of lands devoted to the apricot - the peach nursery-budded will probably be found to be the best. In order to prevent the unions of nursery budded trees from breaking, the trees should be set low, so that, if possible, the union is below the ground; and this is especially important with the peach stock in order to escape injury from the borer."

Limitations of Grafting.

The laws determining whether two plants can be united by grafting or not have never been fully worked out. To do this would require, for one thing, a careful separation of tradition and legend from actual authenticated fact, a work requiring no little judgment. For instance, I have been told by a farmer that he could graft the apple on the hickory, two widely different families, a statement I did not believe worthy of credence, and yet Prof. Van Deman tells us(*) of a man in Pennsylvania who sent him positive evidence that he had grafted a gooseberry on an apple tree, apparently just as impossible a feat.

Botanical Relationship. Lindley(**) says: "It is not,

*Ohio Hort. Soc. Rept. 1890, p. 28.
**Theory of Horticulture, p. 216.

however, to be supposed that these operations can be performed indifferently, between any two ~~genesies~~ species, although such was so formerly a belief that it was asserted that roses became black when grafted on black currants and oranges crimson when worked on pomegranate. In point of fact the operations are successful in those cases only where the stock and the scion are very nearly allied; and the degree of success is in proportion to the degree of affinity. Thus varieties of the same species unite the most freely, then species of the same genera, then genera of the same natural order; beyond which the power does not extend unless in case of parasites like the mistletoe, which grow indifferently upon totally different plants. For instance, pears work freely upon pears, very well upon quinces, less willingly upon apples or thorns and not al all upon plums or cherries."

While in a general way this idea of Lindley, that the closeness of relationship determined whether plants would intergraft or not, is true, we must remember that this division into orders, families, genera and species is but a human attempt to express the relationships as we see them and that no two botanists will exactly agree upon the matter. The sour cherry will not grow upon the black cherry P. serotina, though both belong to the same genus, while the pear grows upon hawthorn and mountain ash, both different genera.

<u>Structure.</u> One other factor affecting the union is

mentioned by E. Leroux in Journal of Society of Natural Horticulture, France(*) in which he summarizes his work on the influence of the hardness of the wood in grafting cider apples. His conclusions are: "(1) In the culture of cider apples varieties with tender wood can be most successfully grafted on stocks having tender wood, or varieties with hard wood on stocks having hard wood; (2) success follows only rarely when a variety with tender wood is grafted on a stock having hard wood; (3) success seldom or never follows when a variety with hard wood is grafted on a stock with tender wood. These principles are believed to apply to other orchard fruits as well as the apple." This should help us to understand why the pear does better on thorn and quince than on apple.

Loudon(**) after speaking of the need of relationship between stock and scion, as quoted above from Lindley, says that no plant can be successfully grafted upon another stock which does not thrive at the same temperature; the period of growth should be the same, evergreens seldom succeed for any length of time on deciduous plants; there should be somewhere near the same vigor, as in cases in which the scion was much the weaker it would be unable to use the flood of sap furnished it while in case the scion were much the more vigorous the stock would be unable to furnish it sufficient sap; there should be similar density; softwoods do not unite readily with hard

*Ex.Sta.Rec.XIV,p.146.
**Loudons Horticulturist,p.282.

woods, nor ligneous with herbaceous, nor annuals with perennials; there should be analogy in sap as a plant with milky sap will not associate long with one with watery sap, thus the Norway maple, Acer platanoides, the only maple with a milky sap, does not do well when grafted with other maples.

Some Special Grafting Problems.

1. The Kieffer as a Stock for Topworking. The heavy plantings of Kieffer when this variety was new, (amounting in some cases to overplanting) together with the fact that the Kieffer is a vigorous grower, has suggested topworking this variety with the European varieties, in the one case to substitute crops of Bartlett, Howell and Seckel for crops of Kieffer, and in the other to secure a good vigorous stock for the slower growing European varieties. While horticultural writers seem pretty well decided on the question of advisability of the Kieffer as a stock, some in favor and some against, there is in horticultural literature a dearth of evidence supporting either contention and giving rise to the suspicion that these views were general deductions based on little or no investigation. On this account a search was made to find orchards so treated.

Two authorities whose opinion is worthy of consideration may be quoted as recommending the Keiffer as a stock. Mr. [illegible] Willard of Geneva, N.Y. in answer to a question regarding its value said: (*) "We [illegible] that we

*Mich. Hort. Soc. Rept. 1893, p473.

don't want anything better". Mr Powell says:(*)" I have grafted the Kieffer pear and had the best Anjous and Boscs I have ever grown". Other writers could be quoted who say that the union is poor and that the trees are short lived.

The New York Experiment Station (**) gives a tabulated report of replies to inquiries sent to growers in different portions of the United States. Unfortunately the writers do not agree, eight recommending Kieffer as a stock and eleven refusing to recommend. The number of trees grafted is not given in any case but there is reason to suppose from the answers that in some cases the number was quite small, making the observations less valuable. In studying this problem it seemed to the writer to be important to get observations on as many grafted trees as possible and so more or less complete information through correspondence, interview and observation was gathered on nearly thirty orchards containing upwards of 5000 bearing topworked Kieffers. The number of such trees in each orchard varies from a couple of dozen up to 500,740, and in one case 1000 trees.

In analyzing the observations it is well to separate the problem into its several factors.

(a) Will the Kieffer readily unite with other pears? Yes. Men report 90%, 95% and even more of a perfect stand of scions. Mr. Murphy reported that the second year he received enough pears from 7000 Bartlett scions on Kieffer

(*) Western N.Y.Hort Soc.Rept.1911, p.199.
(**) Bul 332.

to pay for the grafting.

(b) Is the union strong? Yes, as strong as any graft. The best unions for looks and strength seem to be on the trees not over 6 or 8 years of age. I saw grafts made 4 years in which only a single scion lived but the Kieffer stub threw out so much of new tissue along the wound on the other side that the stubs were healed as well as though both scions had lived. In sectioning grafts I found that the scion frequently filled the cleft with new wood making the strongest possible kind of a union. One man wrote that when the limbs broke from wind or weight of fruit they always broke a foot or so above the graft. Another man told me of sawing out the grafts and splitting them and said " The union is fine, almost impossible to break it."

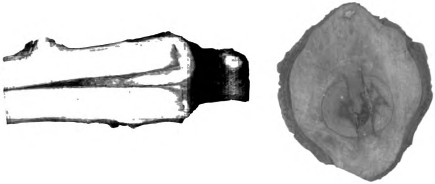
(c) Is the union sightly? Usually so, The younger the tree the less chance of an unsightly callous or knot. Mr. Hutchins reported such a knot on a Kieffer worked to Bosc but said that later it disappeared. The 740 Kieffer trees in the orchard of Mr Heinze which were grafted to Bosc and Howell at 7 years of age, after 7 years growth are about as smooth as ungrafted trees while on the 20 year old trees of Mr.Holmes grafted when they were 2 or 3 it is frequently impossible to tell just where the graft took place.

(d) Does the grafting make a vigorous lasting tree? The oldest trees examined were the twenty year old trees of Mr. Holmes which have been worked 18 years. These are as healthy and vigorous as could be desired. Mr. Fury writes that his 180 fifteen year old trees, worked 11 years seem stunted and poor. The trees in the orchards of Mr. Heinze, Murphy Bros., and Dr. Kales, 740, 500, and 250 trees respectively and topworked 9, 7 and 8 years are as vigorous thrifty trees as a man could ask for and give every promise of long life and productiveness.

Having answered the question regarding the union the next question refers to the advisability of using the Kieffer as a stock.

(e) Is the grafted tree more subject or less subject to blight? The Kieffer seems very erratic in the matter of blight. Once it was believed to be immune and frequently it seems little affected but when it starts to blight there seems to be no way of checking the disease. The past season has been a bad one for this malady and this fact must be kept in mind in interpreting observations. The sentiment seems to be that there is more danger of blight in the grafted tree. When it attacks the grafted tree it spreads more quickly and is more destructive. Especially is this true in grafting older trees. Of course the period of especial danger is the first few years after grafting and when this coincides with a blight epidemic there is a probability of serious loss.

(f) What is the effect on the fruit? Where there is any change noticed the size and appearance of the fruit is improved. One grower thought the fruit inferior while Many of them said that there was a distinct gain in size. If the shape varies at all it is only slightly. Three different growers report that the fruit is two weeks later



Section of Bartlett on Kieffer grafted four years.

Twenty-year old Bartletts topworked on Kieffer at two or three years of age. Almost impossible to find the point of union.

2. Different Methods of Propagation.

Grafting vs. Budding. Of course there are numerous occasions when one or the other of these methods of "inoculation", to use an old term, is much more successful than the other, and in these cases expediency determines the method to adopt. Thus peaches and cherries are usually propagated by budding, while in topworking old apple trees grafting is the only method employed. There are those, however, who argue that there is an intrinsic difference in the trees themselves, independent of the ease of propagation. The arguments for and against this contention were quite well stated at a meeting of the Utah State Horticultural Society(*), Prof. W. H. Homer arguing against the grafted trees while Mr. J. Edward Taylor, State Horticultural Inspector, and others defended grafting. The arguments against grafted trees were:

1. The grafted trees rooted above the graft and thus instead of being entirely on the uniform French crab stock they came to be on various stocks of various degrees of excellence.

2. Prof. Homer had 1500 budded Spitzenbergs and 500 grafted Spitzenbergs all four years old, and the grafted trees were decidedly inferior.

3. He advanced the idea(not argument) that the only excuse for nurserymen persisting in root grafting was the fact that it gave winter work for their employees.

The arguments brought up in defense of grafting were:

*Rept 1912 p.66 and 107.

1. Most of the orchards we have, which are giving us such fine apples today, are grafted. It was admitted that there was more opportunity for root gall infection in grafting, but this should be detected before leaving the nursery.

2. Mr. Holingren, 4 years ago, bought 2000 trees both budded and grafted and today no one can tell which are budded and which grafted.

3. In experiments of the Kansas Experiment Station(*) there was no difference in growth seen.

4. The tap root on a budded tree is longer than on a graft, but the grafted stock root system is usually stockier and the total is about the same.

5. The budded tree is nothing but a piece root graft as the seedlings are usually cut back before planting, if they were not most of the small roots would be below the tree digger and would be lost.

6. The rooting of grafted trees above the graft is less objectionable than the sprouting of budded trees below the bud.

7. In inspecting trees Mr. Taylor finds poor roots on buds and on grafts as well as good roots on both and hence he favors selection according to root development rather than according to mode of propagation.

There are cases, as in growing apple trees in the northwest, when the French crab stock is less hardy than the scion, in which grafting is decidedly superior to budding, but the question in the main is a nurseryman's question

---

*Bulletin 106.

and as long as he delivers to the fruit grower a well rooted tree on the proper stock the question of mode of propagation need not be asked.

2. Root- vs. Top-Grafting. There are many times when topworking is necessary, due to a change of plan, but there are many people who believe it advisable, especially in the case of apples, to set trees with the plan of top-working them soon after setting to the desired variety. There are arguments in favor of this plan and conditions under which it is undeniably an advantage. Sometimes an orchard is planted just as a new variety is passing through the testing period, and by planting a hardy variety for topworking it is possible to have one or two years' growth on the orchard and at the same time observe the behavior of the new variety for another season or two before deciding whether or not to put it in the orchard. It is also customary to topwork varieties which have some weakness in root or stem. The King and Grimes Golden are subject to collar rot and by topgrafting this danger is avoided, although there are cases on record of the collar rot or something very similar occurring in the top of the tree, at the union of stock and scion.

Besides these cases, which are very patent, there is a belief held by many men that there is a definite advantage in topworking all the apple trees they plant, holding that the trees so managed will be more vigorous, hardy and productive. Their arguments are, as stated by one of them: (*)

*G. Harold Powell, Dela. Ex. Sta., Bul. 48.

"1. It provides a healthy, strong trunk for all varieties, corrects the poor growth of some, overcomes the tenderness of others in the far north, and sometimes makes a stronger system of roots.

2. It gives the grower a chance to select the buds or scions from trees of steady productiveness, hardy foliage and highly colored fruit.

3. It is said to hasten fruitfulness."

The arguments against topworking are the increased expense and the danger of misshapen trees if the work is not followed up.

One theory is that in root grafting the root system is affected by the scion used producing as many varying root systems as varieties of scions used while in trees which are topgrafted at planting or later, if worked on a stock having a good root system, a more uniform root system is secured and hence a better orchard. Mr. W. W. Farnsworth of Waterville, Ohio, who has used Spy and Ben Davis for stocks, topworking the year the trees were set, held this theory for a number of years and nearly all his orchards have been thus grown. At present he believes that the scion has as much influence on the roots of the topworked tree as on the roots of the root-grafted tree and hence he has abandoned the plan of topworking. An excellent refutation of the claim that topworking increases vigor is seen in adjacent mature trees of Sutton's Beauty in Mr. Farnsworth's orchard. Some are topworked on Stark and some are on their own

Pear grafted on an apple tree.

Twenty-year old Baldwin trees topworked on Duchess in the nursery. Note the difference in enlargement at point of union.

roots, but between the two there is no choice so far as vigor is concerned. It is evident that to secure any increase of vigor or improved root system topgrafting must not be done until the trees are 3 or 4 years old or older.

In the northwest there seems to be a very general belief that topgrafting such varieties as ordinarily will not stand the severe winters upon stocks which are hardy will render it possible for the horticulturists of that section to raise varieties otherwise impossible. One writer(*) tells of 20 Virginia crab trees topworked to Wealthy, most of which survived and bore well for 30 years or long after an adjoining row of Wealthy on their own roots had died. Mr. A. G. Hanford of Waukesha, Wis.(**) gives the following statement along this line:

"Baldwin rootgrafted, tender in nursery, bark splits and top kills back; worked high seems hardy.

Esopus Spitzenberg same as Baldwin.

Roxbury Russet tender if rootworked, stockworked is more hardy.

Rhode Island Greening. Almost worthless when rootworked except on sandy or light land with porous subsoil. Stockworked it is hardy and productive.

Swaar. Hardy when rootworked.

Yellow Bellflower. Hardy worked either way.

Northern Spy. Hardy worked either way."

Peter M. Gideon claimed(***) that the crab and hardy

*Minnesota Horticulturist, 1909,p.423.
**Country Gent. VII(1856),p.238.
***Country Gent. XLIII(1878),p.231.

hybrids make a brief vigorous growth and as they naturally ripen their wood early in the fall the tendency is for them to force the top to ripen early enough to avoid winter injury. While this may be true, I believe that frequently winterkilling takes place in the trunk and roots and the fact that the trunk and roots were of a hardy variety would seem a logical explanation. Most of us no doubt have seen winterkilled trees expand their buds and sometimes open their leaves only to die because the dead trunk or roots could not supply the buds with food. A clue may be given to the reason for topgrafting in the northwest in the statement of one writer that grafting on the limbs was preferable to body grafting. This would indicate that winterkilling took place in the body or forks and hence the real reason for the topgrafting was to replace these susceptible parts rather than to cause the early ripening of the top as Mr. Gideon suggested.

Writers do not all agree on this subject. For instance, Mr. Macoun in the Report of the Canada Experimental Farms, 1904, page 109, says that "During the past six years 90 varieties of apples have been topgrafted on hardy stocks with the object of determining whether varieties which would not succeed when grown in the ordinary way would prove satisfactory when topgrafted on trees having hardy trunks. Last winter killed practically all that have proven tender when tried as standard trees. The dividing line between stock and.

scion was very marked in all cases examined. A Northern Spy which had been topgrafted on a Duchess for 13 years was killed completely back to the stock, which was as healthy as ever. A Wealthy tree was topgrafted half to Milwaukee and half to Martha. The Martha was all killed but the Milwaukee not only lived but bore fruit. Topgrafting will bring a tree into bearing sooner and will permit of growing varieties which sunscald on the trunk or are weak in the trunk in other respects but if the grafts are made any hardier it is not enough to enable them to withstand very severe winters."

Seven years later Prof. Macoun is quoted by Mr. Kains(*) as saying: "We have done more or less top-grafting here for the past 17 years. I have been interested in it merely from the standpoint of increasing the hardiness of trees which, grown as standard trees was not satisfactory. After trying a great many varieties, about 90, I found that the stock did not make the graft sufficiently hardy to withstand severe winters, so I have come to the conclusion that, as far as increasing hardiness is concerned, while topgrafting may make some difference,there is not enough to warrant this method. "

Thus authorities disagree and the problem must receive further study. Is it possible that in northern Illinois, Iowa, Wisconsin, Minnesota, Dakota and Nebraska, where the air is dry and the snow not deep, winterkilling may take a different turn from the winterkilling in Ontario, where the air contains more moisture

*Western N.Y.Hort.Soc.Rept.1911 p.31.

and the snows afford greater protection for the roots and trunks? We do not as yet know enough about the phenomena we call winterkilling and the opportunities for observation and study come so irregularly that this problem is difficult of solution.

Topworking is of undoubted value in the case of varieties having a weakness of root, like the Mann, or stem like the King and Grimes, or in case of a peculiarly trying climate as the northwest, or in special cases as the changing of undesirable varieties into desirable;

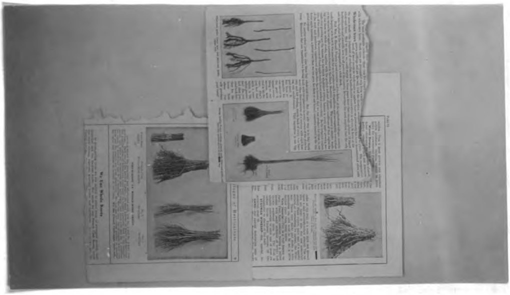
Mann Trees.

it also in some cases hastens fruitfulness by the shock which the act of grafting, with its accompanying pruning brings to the tree, but that the benefits derived from topgrafting as a general policy are sufficient to pay for the increased labor and cost has not yet been conclusively proven.

<u>Whole Root vs. Piece Root Grafting</u>. While it is purely a nurseryman's problem, the fact that certain nurserymen use the claim of whole-rooted trees to induce the fruit grower to buy from them, claiming that such trees are vastly superior to piece-root trees, makes it important that the matter be straightened out and that everyone familiarize himself with the true facts in the case. It is a common sight to see in the front pages of a nursery catalog a picture of a bunch of whole-root grafts such as "we" use and beside it a much smaller bunch labelled "piece-root grafts", the implication being that the value of the trees produced by these two methods varies in exactly the same proportion as the size of the grafts portrayed. There are three arguments offered when this stand is attacked; that piece-root grafting is a cheap makeshift, that the piece-root trees are not so vigorous and lasting, and that the collar is the only natural (and hence the only proper) place for stem and root to unite.

Probably the most extensive experiments carried on to test this problem out was the work reported in Bulletins 65 and 106 of the Kansas Experiment Station. In carrying on their tests during the years 1889 to 1895 over 13,500 grafts were made and grown in the nursery row for a year or more. These were made with 24-inch scions, 12-inch scions and 6-inch scions; with whole roots, whole roots trimmed to eight inches, 5-inch stocks, $2\frac{1}{2}$-inch stocks, $1\frac{1}{4}$-inch stocks; with stocks grafted an

inch above the collar and others an inch below the collar. The conclusions reached as a result of all this work are:



"Whole Root."

"First. That whole root grafted apple trees are of no greater value to the buyer than trees grafted on piece roots 5, 4 or 2½ inches in length.

"Second. That grafting above the crown of the seedling stock secures in a tree no valuable quality which is not secured by grafting below the crown.

"Third. That the use of whole roots or long pieces may offer some slight advantages to the nurseryman, but that these will not compensate for the extra labor and expense.

"Fourth. That the greatest uniformity in growth is secured by use of grafts that secure an early rooting of the scion above the union."

Some of these trees were planted in the Station orchard and ten years later they were measured(*). The piece root trees averaged 11 inches taller than the whole root but were 3/10 of an inch smaller in diameter; neither difference being worth notice.

Besides their own experiments the Kansas Experiment Station(**) gives the results of a test made by Judge F. Wellhouse, President of the Kansas Horticultural Society. In 1876 he made 30,000 grafts,principally Winesap, Ben Davis and Missouri Pippin. The scions were all cut about 6 inches long. Six hundred grafts of each of the above three varieties were made on whole roots - year-old seedlings 3/8 of an inch in diameter and about a foot long -, 600 of each were grafted 2 inches above the root-crown and 600 of each 4 inches above, the roots being cut off 4 inches below the crown; 600 of each were put on piece roots 4 inches long, 600 of each on piece roots 3 inches long, 600 of each on piece roots 2 inches long and 600 of each on pieces 1 inch long. The roots which were grafted above the crown were set so the graft was at the surface of the ground and then a furrow thrown up against them. After two seasons growth the trees were dug,showing the following number of first class trees(out of 600):

---

*Kan.Bul.106.
**Bulletin 65.

	Winesap	Ben Davis	Mo.Pippin
On whole roots	515	523	496
Grafted 4 inches above crown	411	442	381
" 4 " below "	435	486	403
On 4-inch roots	516	520	503
On 3 " "	513	514	494
On 2 " "	520	519	502
On 1 " "	342	360	321

He found that in all cases the old root grew but little; even in the whole rooted trees the tap root was often smaller than some of the side roots. The 2-inch roots gave the best rooted lot of trees and in his opinion this is about the right length roots to use. The first six or eight years after the trees were set in the orchard the whole root trees threw up more watersprouts than the piece root trees. Finally Judge Wellhouse says, "These whole root trees have been growing nineteen years in the orchard and two years in the nursery side by side with 2-inch piece root trees, and if, in all that time, the whole root trees have grown more vigorously, borne more fruit, or shown more signs of longevity, I have not been able to see it."

The Illinois Experiment Station(*) also experimented extensively to test the value of whole root and piece root trees. Of course, the term whole root can not mean the entire root system as the roots are broken in digging, but is applied to the collar and 5 or 6 inches below it. Two thousand root grafts were prepared in the

*Bul.21,p.81.

following ways.

"Roots 10 inches long with the scion set 2 inches above the collar, on the collar and 2 inches below.

Roots cut in 2 pieces each 5 inches long, being careful to put the scion in the collar of the upper cut.

Roots cut as above but side branches left on.

Roots cut into three pieces each 4 inches long, being careful to put the scion in the collar of the upper cut.

Also 2-inch and 1-inch lengths.

The conclusions of one year's work are:

The whole root has no advantage over the piece root of the same size (length and thickness).

Roots with the small side branches left gave better results than roots of the same size with rootlets cut away.

Roots 5 inches long gave better results than roots 4 inches, 2 inches or 1 inch long.

Roots 5 inches long untrimmed gave nearly as good results as roots 10 inches. "

The U. S Department of Agriculture in 1897 sent out a number of varieties of Hungarian apples propagated in sets on whole root, top half and bottom half. The Alabama Experiment Station(*) reported on the growth of the trees received by them after two years' growth, the Oregon Experiment Station(**) after four years' growth, and the Pennsylvania Experiment Station(***) after 11 years' growth, and all report that the difference between the different lots is too small to consider.

*Ala.Ex.Sta.,Bul.98,p.287. **Ore.Ex.Sta.Rept.1901,p.38.
***Penn.Ex.Sta.Rept.1908,p.198.

Thus we have a record of experiments carried on by careful investigators in which over 48,000 grafts were made and grown under experimental conditions and all are agreed that there was no advantage of the whole root over a reasonable sized piece root stock. Were this evidence not sufficient to prove that a reasonable amount of root, whether next the collar or not, is all that is necessary for a stock in root grafting, it would be possible to offer in addition evidence from practical fruit growers and nurserymen to the same effect. (*)

One sectional objection to whole root grafting comes from the Plains states of the Northwest. The seedling roots used in propagation are not so hardy as the roots from the hardy varieties grown there. Piece root grafts, especially when planted deeply, frequently root from the scion and are able to survive even after the seedling root is killed, while a whole root tree has its seedling roots nearer the surface, is less apt to root from the scion and in case of winter-killing of the seedling roots the tree necessarily dies.

Scions from Bearing Trees. There are three problems involved under this head: first, is there danger of producing barren trees by continually propagating from immature nursery stock? Second, is there more danger, or less, of spreading mistakes and disease by budding or grafting from nursery stock than from bearing trees? Third, will propagation from a tree of known

*Country Gent. VII(1856), p. 412 and 1859, p. 110.

superior merit produce a strain of pedigreed trees? Upon none of these questions have we sufficient evidence to give a positive answer.

Regarding the first question we have the testimony of Alexander Hamilton of Bangor, Mich., an experienced and careful nurseryman who said: (*) "I have budded from the Hills Chilli for 35 years, and I can show you trees today two years old from that stock that are just as full as they can hang, and I have Elbertas from my original stock that I never went back to the original tree for, and I do not think it affects the bearing quality one single bit, and my experience along that line holds me out in saying that it does not. I believe you can bud it for a hundred years and it will continue, if it is a Chilli or a Lewis seedling it will come into bearing at once. Last fall nearly every variety was filled with hundreds and hundreds of fruit buds in the nursery and on varieties we have had in the nursery for twenty years." Of course you may say that in budding from nursery trees of peach you are budding from bearing trees. I know of no test or proof either for or against this claim as regards apples or pears. The fact that most nurserymen propagate from the nursery row and that, so far as we can determine from literature, old varieties behave very much as they were wont to do years ago, seems to throw the burden of proof upon those who object to cutting buds and scions

---

*Mich.Hort.Soc.Rept.,1900,p.22.

from nursery trees.

The next proposition, the introduction and perpetuation of mistakes and diseases into nursery stock, is one open to debate. The nurseryman will tell you that his men can recognize the different varieties by their appearance and mode of growth and that any deviation is rogued out, that in the cutting of buds and scions in the orchard there is the same danger of a stray tree escaping the memory of the orchardist, and that his nursery is free from disease, but the cutting of buds and scions outside (necessarily, to secure the varieties, in a number of different orchards) would mean the possible introduction of yellows, little peach, scale and other troubles. On the other hand, the orchardist can show that a few mistakes in propagation from nursery trees have the power of unlimited multiplication in a few seasons. As this, when divested of the other two phases of sterility and pedigreed trees, is a question purely of nursery management, it may be passed without further comment.

The third question is that of pedigreed trees or propagation from trees of known worth. In this we must carefully distinguish between pedigreed and bud varieties. In the case of bud variations or sports such as the two red Twenty-Ounce, Hitchings and Collamer, and the two red Gravensteins, it is a well known fact that trees propagated from the sports will perpetuate the variation, but whether the little variations in size, shape, color and productiveness which lead a man to go to

a particular tree to secure apples for exhibition or scions for propagation can be transmitted by grafting or not has not been demonstrated by any series of experiments. Prof. Shamel in his work with citrus fruits has shown that there is great difference in the quality and amount of fruit produced by different trees of the same variety and that these characteristics are correlated with certain tree characteristics. The next thing to do is to prove whether these characteristics are transmissible or not.

3. Reciprocal Influence of Stock and Scion. The mutual effect of stock and scion is by far the most important problem connected with graftage and the one concerning which the most has been written and the most intense feeling aroused. There are all grades and shades of opinion from those who are ready to accept any story of change even to the old Roman legend of black roses being produced by grafting the rose on the black currant, down through those who admit some change, to those who claim like Baltet, the eminent French horticulturist, that "grafting is a form of federative union wherein the interested parties retain their antonomy." (*)

To understand the true relation existing between stock and scion and the influence that each holds in the life of the other, we must approach the subject without prejudice and, after tabulating the facts, attempt to ascertain the laws and principles governing the phenomena. No one who has ever seen a dwarf tree can deny that there is some influence between stock and scion. The best

*Gard.Chron.XXI(1897)p.207.

article written on the mutual influence of stock and scion is probably the one by A. A. Crozier in the Report of the Michigan Horticultural Society for 1891, pages 105 to 148. In this Mr. Crozier cites nearly 300 references, tabulating them according to the effect produced. These effects as given by him are as follows:

Change in habit.

1. Dwarfing. He quotes A. S. Fuller as drawing a sharp distinction between dwarfing and stunting. Dwarfed trees are apt to be more vigorous the first year or two than standard trees.

2. Increased vigor. A scion may add vigor to a stock or a stock may add vigor to a scion.

3. Fruitfulness, or its lack, is usually associated with the two above effects.

4. Form. He quotes A. S. Fuller as saying that if two buds of the same variety of cherry be placed on Mazzard and Mahaleb the tree on Mazzard will tend to become pyramidal while the one on Mahaleb will be more spreading.

5. Character of the roots. The scion, especially in root grafting, exercises an influence over the roots of the stock, so that in digging nursery trees diggers notice a difference between the root systems of one variety and that of another variety. This difference is, however, not marked enough to enable anyone to identify a variety from the roots alone. Probably the

most self-evident example of this influence is the Mann apple. It is seldom that we see a dozen or more full-grown Mann trees in an orchard that one or more of the trees are not recumbent, due to a weak root system.

Earliness. Upon this the reports are conflicting, some reporting a difference and some not. In general the difference is more apt to appear in fruiting time than in budding or blooming. Some grape grafts are cited to show that an early stock tends to make the graft bud earlier while an early scion has not the same effect on the stock. In general where there is a difference in ripening the stock tends to cause the period of ripening of the scion to approach the time of ripening of its own fruit.

Character of the Fruit.

1. "Ennobling and Degeneration." There was an old belief that grafting on superior stocks improved the quality of fruits and that repeated ennobling continued to increase the excellence; while the continual use of inferior stocks caused the quality to deteriorate or degenerate.

2. Flavor. Numerous references are given to show the increase or decrease of acidity due to working on sweet or sour stocks, as well as some telling of other changes in flavor.

Color. Under this head citations are given of changes of color of stem, blossom and fruit.

Disease. Cases are cited showing the transfer of disease from stock to scion and scion to stock.

Variegation. When certain variegated-leaved plants are intergrafted with green-leaved, the green-leaved portion, whether stock or scion, is very apt to take on the variegation.

Hardiness. Knight, Fuller and Hovey are quoted as believing that the stock gave little if any increased hardiness to the scion, but a list of references are also given showing apparent increase of hardiness.

Adaptation to Soil. The change of stocks with the change of soil conditions is discussed, the point also being brought out that whether a stock bore a graft or not sometimes affected its behavior in a given soil.

Split Grafts and Graft Hybrids are also discussed.

The conclusions at which he arrives are clear and are worth consideration at this time.

"In the foregoing pages there is abundant evidence that the stock and graft influence each others growth in many ways. Seldom, however, is it shown that the recorded observations were based on direct experiments undertaken for the particular purpose of determining the modifying influence of the stock or graft. Certain of the statements made are contradictory; and if we would come to any conclusion in the matter, some of the testimony must be rejected. In at least a few cases the changes said to have been observed were evidently imaginary or due to other causes than grafting. As these cases appear to form but a small proportion of the whole, and as it is of some interest to know what beliefs are held, I have not excluded testimony simply because it seemed unreasonable to me. There is need of careful and extended experiments to fully settle many of the points involved, and the writer hopes to contribute something to this end in the future. A careful study of existing evidence seems to justify the following conclusions:

"1. Size and Vigor. The stock and graft each imparts to the other something of its own degree of vigor or lack of vigor. This influence is greater the first year or two than afterward. If the difference in vigor is great, both stock and graft may ultimately perish. The dwarfing which in certain cases results from grafting does not always arise from a diminished food supply, but often indirectly from earlier and more abundant fruitfulness.

"2. Form. The alterations in the forms of trees, as the result of grafting, arise mainly from increased or diminished vigor. This probably applies also to alterations in the form of the roots, vigorous roots having larger, longer and fewer branches than feeble ones. Many of the observed changes, however, in the form of the roots of grafted trees, are probably due to the trees having rooted from the graft. The observed changes in the form of the fruit of the graft, causing it to resemble that of the stock, are as yet too few to be considered other than accidental.

"Fruitfulness. The most important of all the results of grafting is increased fruitfulness. This is being brought about(a) by the mere process of grafting, which

operates in the same manner as a ligature, or the removal of a ring of bark; (b) by diminished vigor through defective nourishment from a feebler stock; (c) by increased vigor imparted by vigorous stocks to varieties which are naturally toofeeble to bear heavily.

"4. Precocity. Earlier, as well as more abundant fruiting, is induced by the act of grafting; also by diminished vigor due to dwarf or feeble stocks. The precocity of trees on dwarf stocks is not, however, always directly due to diminished vigor, but largely to the habit of early bearing imparted to the graft by the stock in a manner not fully understood. Probably the diminished supply of sap derived from dwarf or feeble stocks, and its consequent richer character, is an important factor in inducing the earlier and more abundant fruitfulness.

"5. Season of Growth and Maturity. The stock and the graft each modifies the period of vegetation of the other when their normal times of beginning and closing their season's growth are different. Thus a late variety grafted upon an early stock begins and ends its season's growth earlier than it otherwise would. This alteration in habit appears in some cases to affect the time of ripening the fruit.

"6. Hardiness. There is some evidence that hardy stocks increase the hardiness of the grafts. This, however, does not appear to be by the transfer of any inherent hardiness peculiar to the variety, but to result from the increased or diminished vigor in certain cases or an earlier maturity in varieties which, upon their own roots, are inclined to grow too late in the season. The advantage usually sought in hardy stocks is to furnish hardy stems able to resist injury to the bark by sunscald, etc., and to supply roots of uniform hardiness in place of those of ordinary seedlings which are frequently less hardy than those of most cultivated varieties. Conversely, a hardy graft has been known to increase the hardiness of the stock, but known examples of this are rare and usually no such influence can be observed.

"7. Adaptation to Soil. 'Favored by the influence of the stock, many species are able to thrive in unfavorable soils, and often in those in which they could not live if upon their own roots.' There is in this fact no evidence that the character of either stock or graft is modified. In some cases, however, the demands of a vigorous or fruitful graft may render the roots of the stock more exacting as to soil, so that they require one which is more fertile or of more definite character in which to maintain in health the grafted tree than would be required for a tree of the same kind as the stock growing in its natural state.

"8. Color. An alteration in color as the result of grafting, may occur, (a) by the direct transfer of coloring matter, as in the case of the white and yellow carrots; (b) by earlier or later maturity, earlier maturity inducing more heightened color; (c) by the restoration of normal nutrition to a 'variegated' stock or scion; (d) by the transfer

to a healthy stock of the disease known as variegation. There is little evidence that the characteristic color of fruits is modified by grafting.

"9. Flavor. The testimony is abundant that fruits may acquire the flavor of the fruit of the stocks on which they are grafted; this has been especially noticed in the case of sour apples grafted upon sweet varieties. Other modifications in the flavor and texture of the fruit have been noticed, which do not cause them to resemble the fruits of the stock. The operation of grafting itself often causes the fruit to be larger and more succulent, and to ripen earlier; this latter change, when it causes more perfect ripening, improves the flavor. We can say that certain stocks improve the flavor of fruit borne by the graft, while others deteriorate it, and that it is probable that stocks bearing highly flavored fruit intensify the flavor of the fruit borne by the graft, while stocks bearing fruit which are sweet or mild in quality diminish it; but notwithstanding the abundant testimony to this end, direct and careful experiments are needed.

"10. Disease. The evidence is conclusive that certain diseases may be conveyed from stock to graft, and viceversa. This applies not only to diseases caused by parasitic fungi but also to the peculiar form of malnutrition known as variegation. It will be observed that nearly all the best established changes which are noted are due to altered nutrition, and though they sometimes cause the stock and graft each to acquire some of the features of the other,

these alterations extend mainly to such points as vigor, color, and period of vegetation, and in no case can they be considered to be of the nature of hybridism."

Another though shorter summary of the effect of grafting is given in the Country Gemtleman for May 18, 1899(*). A large number of instances of the effect of stock on scion are given in two papers presented before the Massachusetts Horticultural Society and in the accompanying discussion as given in the reports for 1875(**), 1879(***) and 1880(#). The effort of Josiah W. Talbot(##) to explain the phenomenon led him to assert that as the wood of the scion governed the fruit(a pear graft produces pears, even on quince) then the only way that the sap elaborated in the leaves of the stock could affect the fruit of the scion was to change the nature of the wood.

Singularly enough about the only experiment undertaken with the purpose of studying the influence of stock upon scion has given a negative result. Prof. A. G. Gulley(###) took trees grown from root grafts of Sweet Bough and Jersey Black, selecting the latter because it was an exact opposite of the former, being a very late, small, dark red apple of just fair quality. On these he topworked Red Astrachan and Red Canada, the latter because it is supposed to be variable under different circumstances and on different stocks, and the former on account of its

*Page 388. ** Page 82. ***Page 7. #Page 93.
##Mass.Hort.Soc.Rept.,1879,p.7.
Mich.Hort.Soc.Rept.,1905.p,158.

difference from the latter. When they fruited there was no observable difference in the product. The Astrachans, which might have been expected to be sweeter on the sweet stock and later on the late stock showed no change in flavor, season, size, shape, or color, nor did the Red Canadas. Why these results were not obtained will be discussed later.

That changes do occur as the result of grafting we are forced to admit, but there are certain limitations to these changes. In the first place the change is temporary, lasting only as long as the union of stock and scion endures (except in the case of variegation and hybridization as we will see later). Were this not so, such varieties as the Baldwin and Greening would be so changed by being repeatedly grafted on so many different stocks that they would be lost in a maze of apples of all sizes, shapes and colors, and all Baldwins or Greenings. Just before its death, Prof. Gulley secured scions from the original Rhode Island Greening tree, which had a written record of 160 years of bearing, and grafted them beside scions from New York grown trees(without doubt many "graft-generations" from the original). In a recent letter he says: "I have fully demonstrated that the many generations of grafting the Greening have had no result."

Another point is that different varieties seem to show different degrees of susceptibility to this influence. The Canada Red, which showed no change for Prof. Gulley, is frequently mentioned as being susceptible, but the most frequent reference is to the Porter, the acidity of which seems to vary with the acidity of the stock.

A third factor which will be discussed later is the quantity of stock.

That there is a reason and a law governing this matter no rational person doubts and a study of the histology of the graft should assist us to understand the problem and discover the answer.

If we could section a graft so as to see just how healing and growth take place it would be of great assistance, but as Prof Waugh (*) found it is impossible to secure a section showing cell development. Let us therefore, without the aid of the section, study a graft union, for instance, pear on quince. The two pieces are so applied that their cambium layers are pressed together. We know that the cells of wood and bark can never change their form until destroyed by decay. The cells of the cambium, however, under the influences of growth do change and their numbers increase. The cells do not fuse together; so far as we know it has never been proven that a cell of stock and one of scion ever fused together, but the pear cells divide each becoming two pear cells, and the quince cells similarly each becoming two quince cells. By this cell growth a new layer of wood is formed between last year's wood and the bark, but the cells composing this layer are either pear cells or quince cells. Though as the cells elongate they may dovetail together and under the microscope appear continuous, yet the fact remains that there is an invisible

(*).Mass.Ex.Sta.Tech.Bul.,2.

boundary line between the two kinds of wood. The cell, however, is not the life of the tree but is rather the house in which this life, the protoplasm, resides. Here I wish to quote from Prof. T. J. Burrill:(*) "No true liquid lives. Propoplasm, however soft, is never soluble in the living state. Hence it can not be carried living through plant tissues with ascending or descending sap. It can, to a limited extent, get from cell to cell by migratory powers peculiar to itself. This is why when two varieties are grafted each preserves its own peculiarities." Thus in grafting there is no fusing of the two natures, no commingling of the protoplasm of stock and scion, any more than in two ropes neatly spliced there is any union of the hemp and sisal of which the two ropes are made. Each rope is distinct though the union may be so neatly made as to be almost invisible.

Difficulties of Interpretation.

There are a number of factors which have made for confusion and controversy in this problem of stock and scion and in order to be able to offer a solution of this problem we must have a clear idea of these factors which come in and obscure the vision.

Mystery. There is a disposition among many people to surround anything which they cannot understand with still more mystery and each of nature's miracles but affords an opportunity for charlatans to delude and the credulous to weave a network of fable, legend or tradition about it and in studying this problem we must make allowance in some

*Mass.Hort.Soc.Rept.,1887,p.461.

cases for the obviously imaginary.

2. Ignorance and Carelessness of Observers. Much that is laid to grafting might be explained by other causes were all the data available. Thus in one case described, the fruit from a certain tree always decayed before ripening and accordingly the tree was topworked to English Russet, a long keeping variety. The Russets on the grafted tree partook of the nature of the fruit of the stock and also decayed. The inference was that the stock affected the scion through the graft but, in the light of plant pathology, would it not be possible that a bitter rot canker in the top of the tree might explain the decay of fruit on stock and scion?

Again we have the case of Mr. Benjamin P. Ware(*) who cut with his own hands scions of Sheppards Sweet which he grafted on two trees of his own. The fruit on the larger tree, was true while that on the smaller tree was entirely different. Later he found that the tree from which he cut his grafts bore both kinds, and in fact his own large tree bore both kinds.

3. Effect of Pollen. This may be seen in two ways. The grafting of a limb of another variety into a barren tree might induce it to bear but the fruiting might be due to crosspollination.

Mr. Mehan is quoted(**) as authority for the statement that a bough of a pear tree was unfruitful until it was projected into the bough of a neighboring apple tree; when fruit was produced which in skin, flesh and other

*Mass.Hort.Soc.Rept.1879,p.17.
**Mass.Hort.Soc.Rept.1879,p.7.

respects were apples and had only seeds, carpellary portions, and stalk of the pear. Had the pear limb been grafted on the apple we would have unhesitatingly attributed to the influence of the stock that which was patently the influence of pollen.

4. Difference Between Influence of Stock over Scion and Substitution of Stock for Scion. In the matter of resistance to cold or heat the increased hardiness is often due to the fact that the susceptible portion(roots or body) is replaced by the hardy stock and while the resulting plant is more hardy the resistance of the scion itself may be unchanged. Similarly in selecting a stock congenial to the soil, the relation of scion to soil is unchanged but a more favorable connection secured.

5. Stimulus due to the Operation Itself. The mechanical operation of grafting must be taken into account. Crozier quoted Darwin to the effect that grafting has some such invigorating effect as the changing of seed, while Knight likens the influence of grafting to that of ringing. We all must admit that the pruning incident to grafting as well as the imperfect transfer of food materials while stock and scion are uniting must exert at least a temporary influence to be considered.

6. Bud Variation.is by no means uncommon. There are more varieties in the Apples of New York that are the result of bud variation than the result of definite plant breeding where both parents are known. Should one of these variants happen to be used as a scion the variation

would undoubtedly be attributed to the stock, especially if it was in the direction of the stock.

7. Quantity of Stock. Crozier touched upon an important point when he discussed ~~the~~ this matter, quoting Charles Downing, Burbidge and others to the effect that the quantity of the stock affected the influence of stock over scion. Burbidge says: "Do we not rob the stock of a deal of its power to ameliorate the scion when we denude it of all its own leaves?" while Charles Downing says: "There is no doubt that in large trees topgrafted the stock has more or less influence, but when grafted or budded on small stocks near the ground the influence, if any, would be little."

Herbs are so much more easily worked with than woody plants, and seem so much more sensitive to influences that those who are studying the effects of grafting finds herbaceous grafting affords a superior opportunity for study. M. Daniel, who has done considerable work in herbaceous grafting, found, as we saw on page 31, that in grafting beans the graft having all the top of the stock removed resembled closely the ungrafted plant of the same species as the scion, while the graft in which some of the leaves of the stock were left(a mixed graft) developed a plant intermediate in character between the stock and scion. A clue to the reason may be found in the following experment. M. Ch. Laurent(*) made the reciprocal grafts both plain and mixed of tomato and nightshade. When the nightshade was used as the stock none of the atropin(poisonous alkaloid of the nightshade) passed from the nightshade to

*Gard.Chron.42(1907)p.414 and Bul.Agr.Intell.&Pl.Dis.Nov.1912.

the tomato but when the tomato was used as the stock the atropin passed from the nightshade to the tomato, being found in the stem, leaves and fruit. In some of the mixed grafts of tomato on nightshade the fruits contained the alkaloid. In other words, the finished product(in this case atropin) for which the roots supplied the crude sap, is the product of the foliage. The leafless stock cannot formulate these products for distribution in the scion, the leafy scion can formulate them and transmit them to the stock, and if both bear foliage an opportunity is offered for an interchange of elaborated sap. May not the negative results of Prof. Gulley's experiment with Red Astrachan and Red Canada have been due to the fact that none of the foliage of the stock was allowed to remain? Thus you see the importance of knowing whether a graft is a mixed graft or not, a fact which few observers are careful to record.

Conclusions.

1. Variegation. Having discovered the various limiting factors which must be kept in mind while we are reviewing the evidence submitted, let us first take up the phenomenon in which the evidence is least contradictory. It has been found that when certain green-leaved and variegated-leaved plants are intergrafted, regardless of which is the scion, the green-leaved portion tends to change its nature and become variegated. The most frequently quoted example is the grafting of Abutilon Thompsoni upon a green-leaved Abutilon. One small graft seems enough to transform the

entire plant. It is usually conceded that variegation is a disease, perhaps enzymatic, in which case budding or grafting would be in the nature of inoculation.

3. Graft Hybrids and Chimeras. Certain phenomena have been observed from time to time which have been so analogous in their results to the results obtained in hybridization by cross-fertilization that they have been termed "graft hybrids". The oldest of these and one which has been so much quoted as to become a classic is the case of the Cytisus Adami. In 1826 a French gardener named Adam budded the lilac flowered Cytisus purpureus on the yellow flowered laburnum, Lāburnum vulgare. As a result branches arose some showing the characteristic foliage and lilac flowers of the Cytisus and some the characteristic foliage and yellow flowers of Laburnum, while other branches showed all gradations and combinations between. Upon these intermediate forms the foliage and form of the blossom clusters were more or less intermediate while the same cluster held some blossoms entirely lilac, some entirely yellow, and those in which one or more petals were one color and the remainder the other. Moreover, plants propagated from this form retained the habit and the variety became known as a graft hybrid and named Cytisus Adami. Another famous case was the graft hybrids of Brouvaux between the white thorn, Crataegus monogyna, and the medlar, Mespilus germanica. Two types were represented by two branches which grew side by side from the point of union of medlar

and thorn. One of these types known as Crataego-mespilus Dardari approaches the medlar more closely; the other, Crataego-mespilus J.d'Asnieres is more like the thorn. The supposition was that these shoots each arose from a bud which was the direct outcome of the fusion of two cells, one from each member of the graft union and hence that it was a graft hybrid, just as the union of pollen cell and ovule cell forms a seed hybrid. Further study has changed this view and given us further information in the matter, at the same time giving us an illustration of the way in which different experimenters working along different lines may each contribute to the solution of a given problem. In 1907 Hans Winkler published a report of grafting invrstigation carried on by him with nightshade and tomato. He had grafted nightshade on tomato and after growth had been resumed a transverse cut was made in such a way as to sever both stock and scion in the hope of obtaining an adventitious growth from the cut surface along the line of growth of stock and scion. Such shoots appeared and in one case the shoot contained tissues of both stock and scion but it was not a hybrid because one side of the shoot was tomato and the other nightshade, the boundary being so sharply marked that some leaves were part one and part the other. Winkler called this production a <u>chimera.</u> A year later he announced the production of a true graft hybrid, the first ever produced under exact experimental control, and named it Solanum tubingense after the university town where it was produced. In 1909 he announced the discovery of four more graft hybrids (some of which appeared several times in the cultures), two favoring one parent and two the other. While his results were accepted his conclusions were not. One reason was that the seedlings always reverted to the nearer parent and that, while they could be hybridized sexually with the nearer parent, the resulting generation was always pure tomato or pure nightshade.

Here the work of another man, studying another problem, entered the field. "Erwin Baur found(*) from a careful study of geraniums with white margined leaves that the green cells and colorless cells each are descended from others of their kind, the peripheral portions(comprising two or three rows) being colorless and the internal portions green, the limits between them being sharp. Since the sexual cells are from the peripheral white portion the seedlings are pure white. White branches give only white forms vegetatively and green branches only green forms. If a pure white and a pure green form are hybridized sexually there result, besides pure white and pure green offspring, green-white mosaics. If inthe latter the growing point is situated on the line between the white and green portions there results a chimera such as Winkler obtained so frequently in Solanum. Since in cross section the two components appear as sectors Baur has given to such forms the name of sectorial chimeras. For the condition that Baur finds in an ordinary pelargonium with

*Henry C.Cowles Bot.Gaz.Feb.1911,Vol.51,p.148.

white margined leaves he gives the name periclinal chimeras, one of the components investing the other. He holds that these so-called graft hybrids of Winkler are periclinal chimeras." He found that the Crataego-mespilus hybrids were also periclinal chimeras, one being a Crataegus body with a Mespilus epidermis of two layers and the other the reverse. Similarly the Cytisus Adami is a body of Cytisus and epidermis of Laburnum, and the seedlings are always Laburnum because the sex cells arise from the hypodermal layer. Winkler applied the test to his so-called graft hybrids and found four out of the five evident periclinal chimeras but the fifth may be a true graft hybrid.

One interesting fact in this connection is that fifteen years before another writer, McFarlane, spoke of these plants as resembling one plant wrapped about another, but he lacked the evidence to prove the reality of his statement.

In a recent number of the Journal of Heridity (*) is a reference to a statement made by M.Lucien Daniel before the French Academy of Science that in anatomical examination of grafts of Helianthus on Helianthus and cactus on cactus he found internal adventitious roots from the scion penetrating the stock, in some cases even to the soil, so as to give the scion complete independence of the stock. He believes this the probable explanation of some cases of graft hybridization.

3. Nutrition. After disposing of the cases of variegation, graft hybrids and chimeras, and after making allow-

*Vol.V No.1,p.5.

ance for ignorance and carelessness of observation, for insufficiency of data, for the effect of pollen, and even the act of grafting itself, and for bud variation, I believe we can be safe in saying that most, if not all the other changes attributed to grafting are caused by a modification of the quantity and quality of crude sap furnished to the scion by the stock or of elaborated sap returned to the stock from the scion or(in the case of mixed grafts) to an interchange of elaborated sap. To demonstrate this fully would require a vast amount of careful scientific work but to demonstrate its reasonableness a review of Crozier's list of changes should suffice.

Change of Habit

Dwarfing. All dwarfing stocks have a relatively small feeding area; dwarfs as a rule are particular about the soil they occupy, so that probably both quantity and quality of sap is modified.

Increased Vigor. A vigorous stock or scion furnishes more crude or elaborated sap to the less vigorous portion.

Fruitfulness depends largely upon the two above. To this is added the stimulus due to the operation of grafting itself.

Form. It is concieveable that the form might be affected by the quantity of quality of the sap.

Character of Roots. In piece root grafted trees the scion is apt to root above the graft and it is claimed that budded trees show less of this root effect than grafted trees.

Earliness In grafted grapes it has been found that an early stock will advance a late scion while an early scion has little effect on a late stock. Whether this is caused by sap pressure or not I am unable to say. Some other phases, such as the period of ripening, are not so readily explained, although it may be possible to account for them along the line of nutrition.

Character of Fruit.

"Ennobling" is hardly accepted at the present time.

Flavor. If alkaloids can be transferred between stock and scion it is reasonable to assume that fruit sugars and acids may.

Color. In some of the references given there was a direct transfer of soluble coloring matérials. In other cases color is affected by time of ripening, amount of foliage, etc., making color secondary to vigor.

Disease. The transmission of disease is more in the nature of inoculation or infection than physiological change.

Variegation has been discussed.

Adaptation to Soil in almost every case is a case of substitution rather than influence of stock over scion.

Graft Hybrids have been considered.

Summary.

1. Grafting is an ancient art handed down to us from the Romans or Phoenicians who were familiar with top-grafting though they probably knew nothing of root-grafting.

2. Root-grafting was first practiced about 1800, being the invention of Thos. Knight.

3. The uses of grafting by the horticulturist are manifold and to this art is largely due the production of so much fruit of superior quality that we have today.

4. By means of grafting man is able to in many ways adapt a plant to meet conditions or to meet his desires.

5. There are numberless forms of grafting, many of them adapted to special uses or simply minor modifications of standard types.

6. The more important forms of grafting are the cleft, kerf, crown, saddle, side, bridge and whip graft.

7. The cleft graft is the one most commonly used in topworking.

8. The kerf and crown graft are used where the limb is too large for cleft grafting and have the advantage over cleft grafting of not splitting the heart wood.

9. The whip graft is used in topworking where stock and and scion are of nearly equal size and is almost

the only union used in root grafting.

10. The standard American grafting wax is composed of 4# resin, 2# beeswax, and 1# tallow melted together, thoroughly mixed, poured into a pail of cold water and pulled like candy until smooth.

11. If there is any difference in the vigor of stock and scion, the scion should be the more vigorous.

12. Some of the requisits for a successful graft union are:

Botanical relationship.

Similar wood density
Similar season of growth
Similar optimum temperature
Similar vigor
Similar sap

13. The Kieffer unites readily with the European varieties of pear, making a strong union and usually a sightly one. The grafted tree is often vigorous giving promise of long years of usefulness. The grafting may induce blight but probably no more than any grafting. Fruit on these topworked trees are of superior size and appearance. Whether the flavor is affected or not is a debatable question.

14. Except for special conditions, such as are found in the plains states of the northwest, the planter has nothing to choose between a budded and a grafted tree of equally good appearance.

15. Piece root grafted trees, where sufficient root has been used to produce a good top, are in every way

as good as a whole root tree and in some respects are superior. This has been proven by experiments involving over 48,000 trees.

16. That there is an influence between stock and scion is demonstrated by every dwarf tree.

17. The changes produced include size and form of the tree, productiveness, time of blooming and ripening, color, size and flavor of the fruit, disease, variegation and graft hybridization.

18. The recorded observations of these changes are imperfect and incomplete.

19. Some things which we have ascribed to the influence of stock over scion or scion over stock should be attributed to other causes.

20. The principal way in which a hardy stock increases the hardiness of a variety is by replacing the susceptible portion of the tree (root, stem or forks) with the more resistant species or variety.

21. Variegation is usually considered to be a disease.

22. Most of the cases of so called graft hybridization have proven on later investigation to be chimeras.

23. The changes which are not due to the two causes given above (variegation and graft hybrids or chimeras) are probably due to changes in the quantity or quality of sap transferred between the two members.

REFERENCES

To give a list of all the references to grafting would require almost a complete list of the horticultural books and magazines as almost every one of them contains more or less extended references to grafting. Much of this of course is simply reprint. The following are given because they are devoted entirely to this subject, because they are especially good or the writings of a horticultural authority, or are the record of experiments or observations. These latter are of especial value. An unsupported statement may simply be the author's finespun theory or a quotation from some other theorist, while an actual observation, especially when taken in connection with other similar observations, should, when rightly interpreted, give the truth.

<u>General</u>

Grafting and Budding — Charles Baltet
Translation of "L'Art de Greffer"

Grafting — Trans. from French of D'Albrecht
Gard. Chron. 1851.

Grafting, Its Consequences and Effects — Dr. Masters
Gard. Chron. 1872, p. 215, 322, 361.

The Pleasant Art of Grafting — C. S. Crandall
Mich. Hort. Soc. 1886, p. 205.

Influence of Grafting on the Seed — A. J. Downing
Fruits and Fruit Trees of America, p. 4.

Is Graftage a Devitalizing Process? — L. H. Bailey
Mich. Hort. Soc., 1891, p. 148.

Effects and Limitations of Grafting — D. B. Miller
Indiana Hort. Soc., 1898, p. 182.

Grafting — Jackson Dawson
Mass. Hort. Soc., 1895, p. 115.

The Graft Union — F. A. Waugh
Mass. Ex.Sta., Tech. Bul.2.

Natural Grafts.

Natural Grafting
EX. Sta. Rec. XVII, p.371.

Natural Graft
Gard.Chron.1895,Vol.XVIII,3d Ser.,p.770.

Natural Graft
Mich.Hort.Soc., 1880, p.113.

Natural Grafting of Rhubarb Leaves
Gard.Chron.1893,Vol.XIII,3d Ser.,p.392.

Purposes.

Use for Grafting — R. E. Smith
Utah Hort. Soc.,1912,p.18.

Grafting to Evade Borers — Woodbridge Strong
Country Gent. Mar.20,1890.

The Grafting of Beets
Ex.Sta.Rec.XI,p.334.

Plum on Peach
Mich.Hort.Soc.,1896,p.48.

Grafting - "X" -
Gard.Chron., 1879,p.365.

Purpose of Grafting — U.P.Hedrick
N.Y.Ex.Sta., Bul.350.

Use of Grafting — T.A.Knight
Knight's Horticultural Papers,1841
pp.223-272

Methods.

Root Grafting — John Lindley
Theory of Horticulture, p.225.

Root Grafting — B.O.Curtis
Ill.Hort.Soc.,Vol.III.
New Ser.(1869),p.238.

Root Grafting the Apple
Country Gent., XIII,p.302.

Root Grafting Stone Fruits — Hort.Dept.
Country.Gent.,XLI(1876) p.54.

Root Grafting F.K.Phoenix
Downings Horticulturist, I(1846) p.280.

Autumn Grafting and Spring Budding Robt.Nelson
Downings Horticulturist I(1847) p.515.

Bud Grafting instead of Budding Roses "F.M."
Gard.Chron.XL,3d.Ser.(1906)p.367.

Grafting Roses F.R.Mathison
Am.Florist,XIV,p.1229

Grafted Roses Robt.Craig
Am.Gardening XX(1899),p.61.

The Double Grafting of Pears A.W.
The Garden, XLIX(1896) p.73.

Methods of Herbaceous Grafting L.H.Bailey
Cornell Ex.Sta. Bul.25,p.174.

Grape Grafting
Country Gent. XXXVIII,p.879.

Grape Grafting E.G.Lodeman
Cornell Ex.Sta.,Bul.77.

Herbaceous Grafting(of Grapes) T.Gr.
Am.Gardening XVI(1895) p.178.

Grafting the Grapevine Geo.W.Campbell
Country Gent. XVII(1861) p.222.

Grape Grafting N.B.White
Am.Gardening XXIV(1903) p.703.

Bench Grafting Resistant Vines
Calif.Ex.Sta. Bul.127.

New Methods of Grafting and Budding Vines E.H.Twight
Calif.Ex.Sta., Bul.146.

Random Notes on Grafting A.Fahnestock
Downings Horticulturist III,p.330.

On Propagation of Woody Plants Through Grafting Under Glass Protectors
Ex.Sta.Rec.V,p.1017.

Methods and Results of Hybridizing Fruits Theo.Williams
Am.Breeders.Assn.1906,p.186.

Grafting on-Cuttings
Gard.Chron.,1889,p.631.

A Method of Grafting Martin Ernst
Country Gent.,LXV(1900)p.304.

Bridge Grafting Mice Gnawed Trees
Country Gent., VIII(1857), p.191.

Two Methods of Grafting — F.S.Crandall
Am.Gardening, XI, p.64

Grafting Walnut Trees — T.A.Knight
Knight's Horticultural Papers, p.326.

Nursery Hints West — L.C.Corbett
West Va.Ex.Sta., Bul.54.

Bark Grafting — T.V.Peticolas
Country Gent.III, (1853) p.394.

Side Grafting — F.A.Waugh
Gard.Chron.XXXIII, 3d Ser.(1903)p.407.

Side Graft — Chas.Jones
Gard.Chron.XLI, 3d.Ser.(1907)p.201.

Side Grafting — J.B.Smith
Country Gent.LV(1890) p.348.

Winter Budding — Thos.L.Brunk
Md.Ex.Sta.Rept., 1891.

Recovering Dried Grafts
Rural New Yorker, II, (1851) p.43.

Graft Budding — Dr.H.A.Peck
Downings Horticulturist, III(1848)p.276

New Mode of Grafting — "Sigma"
Country Gent. XI(1858) p.366,

Crown Grafting of Cherries — John Craig
Bul.17, Dept.of Ag., Ottawa, Can.

Grafting Stone Fruits — J.L.Budd
Canadian Hort., XIII(1890) p.165.

<u>Topgrafting</u>

Topworking of Pecans — W.W.Carroll
Southern Orchards & Farms, Jan, 1913.

Topworking the Peach — L.C.Corbett
Am.Gardening XX(1901) p.147.

The Topworking of Orchards — W.W.Munson
Maine Ex.Sta., Buls.122 & 139.

Topgrafting Nursery Apple Trees — C.P.Close
Dela.Ex.Sta., Bul.60.

Topgrafting — Hort. Dept.
Country Gent. LXX(1905) p.1078.

Topgrafting the Apple — C.G.Patten
Iowa Hort.Soc.XXVIII(1893) p.203.

Topgrafting Fruit Trees — O.B.Whipple
Colo. Exp.Sta.Bul.147

Topgrafting Apple Trees — G.H.Powell
Dela. Ex.Sta.Bul. 48
Also U.S.D.A. Year Book,1902,p.245.

Waxes, Tools, Etc.

Grafting Waxes — Hort.Dept.
R.I.Ex.Sta.Rept.,1906,p.161.

Grafting Wax — Geo.O.Green
Country Gent.LXXI(1905) p.202.

Grafting Wax
Downings Horticulturist,III(1849)p.349

Grafting Wax — Dr.Franklin
Ohio Hort.Soc.,1883,p.75.

Grafting Waxes
Gard.Chron.,XXVI,3d.Ser.(1899)p.184.

Potatoes instead of Grafting Wax
Gard.Chron.LI(1912) p.123.

A New Grafting Machine — F.A.Waugh
Vt.Ex.Sta.Rept.,1896,p.122

A New Grafting Tool — Ashael Foote
Downings Horticulturist,II(1847)p.341

A Tool for Transplanting Buds
Gard.Chron.XXVII.3d Ser.(1900)p.252.

Wrapping of Apple Grafts — H.von Schrenk
U.S.Bur.Plant Industry,Bul.100,pt.2.

Rubber-strip for Grafting — R.P.Rodgers
Royal Hort.Soc.London,1901,p.248.

Stocks

Fruit Tree Stocks — H.Somers Rivers
Gard.Chron.XLVIII 3d.Ser(1910)

Russian Stocks for Apples in the Northwest — N.F.Hansen
S.Dak.Ex.Sta.Bul.35
Also Country Gent.1899.

Pyrus Baccata as a Stock for Apples S.A.Bedford
Canada Exp.Farms,Rept.1905,p.346.

Apples on Siberian Crab J.W.G.
Country Gent.,XLIV(1879) p.6.

Pyrus rivulans as a Stock
Alaska Exp.Sta.Rept.,1906.

Stocks M.G.Kains
Western N.Y.Hort.Soc.1911 p.29

Stocks for Root Grafting E.S.Goss
Wis.Ex.Sta.,Bul.77.

Apple on Hawthorne R.T.Hesketh
Gard.Chron. XXXIX,3d Ser.(1906)p.347

Stocks for Apples in Iowa E.R.Heize
Iowa Hort.Soc.,1879,p.57.

Apples on Pear Trees
Gard.Chron.XII,3d.Ser.(1892)p.562

Pyrus baccata N.E.Hansen
Am.Pom.Soc.1899,p.143-151.

Pear on White Thorn "B.T."
Country.Gent.XXIX(1867)p.318

Pear on Hawthorn Hort.Editor
Country Gent.XXXII,1868,p.376

Pear on Thorn M.Quinby
Country Gent.XVI(1860) p.240

Pear on Thorn Mr.Forward
Mich.Hort Soc. 1900,p.23

Pear on Apple S.M.Emery
Montana Ex.Sta.Bul.16,p.84.

Pear on Apple Hort.Editor
Country Gent.LVII(1893) p.228

Pear on Apple "Experimenter"
Am.Gardening,XXII(1901)p.171

Pear on Mountain Ash D.L.Halsey
Country Gent,,XIV(1859) p.174.

Pear on Quince "Experience"
Gard.Chron.XIX,3d Ser.(1896)p.552.

Pear Stocks Thos.L.Brunk
Texas.Ex.Sta.Bul.9.

Quince

Quince on White Thorn — E.A.King
Country Gent.XXXVIII(1873) p.214

Thorn on Quince
Gard.Chron. 1870

Quince on Thorn — Woodbridge Strong
Country Gent.LV(1890)p.228

Peach

Plum Stocks for Peaches
N.J.Ex.Sta.Rept.1907,p.129

Peach on White Thorn — A.S.F.
The Amer.Garden IX(1888)p.41.

Stocks for Peach and Plum — S.C.Mason
Kan.Ex.Sta.Bul.73,p.185

Plum

Stock and Scion — Waugh and Stuart
Vt.Ex.Sta.Rept.XIII(1900),XIV(1901)
XV(1902),XVIII(1905)
and Mass.Ex.Sta.Rept.XXI(1909)

Stocks for American Plums — G.Onderdonk
Bailey in Cornell Ex.Sta.Bul.38.

Plum Stocks — W.N.Fruit Growers Assn.
Country Gent.VIII(1857)p.14.

Stocks for Wild Goose Plum — J.S.Newman
Ala.Ex.Sta.Bul.30,p.15

Stocks for Plum — J.W.Kerr
Country Gent.LXIII(1898) p.288.

Sand Cherry as Stocks — Budd & Hansen
Iowa Ex.Sta.Bul.22,pt.4.

Western Sand Cherry
So.Dak.Ex.Sta.Bul.87.

Cherry

Stocks — E.S.Goff
Wis.Ex.Sta.Bul.77

Cherry Stocks — H.C.Price & E.E. Little
Iowa.Ex.Sta.Bul.73.

Stocks for Cherries — W.G.Waring
Country Gent.XXXIX(187 4) p.598

Cherries on Mahaleb Stock
Country Gent.XXXIII(1869)p.36

Mazzard Stocks for Cherries J.V.Hopper
Country Gent.XXIX(1867) p.334

Limitations of Grafting

Strange Grafts
P.N.Y.IV(1853)p.189

Gooseberry on Yellow-flowered Currant
Horticulturist IV(1850) p.65

Gooseberry on Apple Prof.VanDeman
34th Ohio Hort.Soc.Rept.(1890-1)p.28

Grafting Grain
Downing's Horticulturist III(1849)p.437

Grafting Humbugs
Downing's Horticulturist III(1849)p.437

Grafting F.D.Pershore
Gard.Chron.1850,Nov.30

Grafting Lindley
Theory of Horticulture,p.216-239

Grafting Marshall P.Wilder
Mass.Hort.Soc.1878,p.8-9

Intergrafted Genera
Gard.Chron.XXVI 3d.Ser.p.57

Influence of Hardness of Wood in Grafting Cider Apples
Ex.Sta.Rec.XIV,p.146

Limits of Possibility in Grafting Plants L.Daniel
Ex.Sta.Rec.Xii,p.642

Experiments in Grafting L.H.Bailey
Country Gent.L(1886) p.676

Limitations of Grafting Robt.Manning
Mass.Hort.Soc.Rept. 1879,p.37

Some Special Grafting Problems

Kieffer

Kieffer Grafting Geo.T.Powell
Western N.Y.Hort.Soc.Rept.1911,p.199

Grafting Kieffers — Chas.E.Bassett
Mich.Hort.Soc.Rept.1911,p.131

Grafting Kieffers — Geo.Chatfield
Mich.Hort.Soc.Rept.1911.p.131

Kieffer as Stock — S.D.Willard
Mich.Hort.Soc.Rept.1893,p.473

Kieffer as Stock — J.T.Lovett
21st Ohio Hort.Soc.Rept.(1887-8)p.165

Kieffer as Stock — Isaac Freeman
35th Ohio Hort.Soc.Rept.(1901)p.69

Kieffer as Stock — C.L.Whitney
35th Ohio Hort.Soc.Rept.(1901)p.70

Grafting on Kieffer — Davidson Greenault
Am.Gard.XX(1899)p.219

Oriental Pears and Their Hybrids — John Craig & H.B.Cox
Cornell Ex.Sta.Bul.332

Oriental Pear Stocks — J.H.Haynes
R.N.Y. April 1, 1911

Kieffer as a Stock — S.D.Willard
Country Gent.LXXI(1906) p.472

Grafting on Kieffer — M.L.Bell
Am.Gard.XX(1899)p.129

Grafting vs.Budding

Rooted Graft vs.Budded Trees
Utah Hort.Soc.Rept.1912,p.66 & 107

Root vs.Top-Grafting

Effects of Winter-Killing on Top-Grafted Trees
Canada Exp.Farms Rept.1904,p.109

Hardiness of Stocks — W.F.Macoun
Quoted by M. G. Kains,W.N.Y.Hort.Soc. Rept.1911,p.31

Root vs.Top-Grafting — Peter M. Gideon
Country Gent.XLIII(1878)p.231

Root and Top-Grafting — Hort . Dept.
Country Gent.XLIX(1884) p.976

Root Grafting vs.Stock Grafting — A.G.Hanford
Country Gent.VII(1856) p.238

Top-Grafting — A.J.Phillips
Minn.Horticulturist,1909,p.423

Top Grafted Apples — L.C.Corbett
W.Va.Ex.Sta.Bul.47,p.448
W.Va.Ex.Sta.Rept.1896,p.199

Root Grafting vs.Stock Grafting — A.Babcock
Country Gent.XXXI(1868)p.30 & 150

Whole vs.Piece Roots

Whole and Piece Root Grafting — T.J.Burrill
Ill.Ex.Sta.Bul.21,p.81

Whole vs.Piece Root Grafting — John P.Stewart
Penn.Ex.Sta.Rept.1908,p.198

Whole Root vs.Piece Root Apple Trees — F.S.Earle
Ala.Ex.Sta.Bul.98,p.367

Root Grafting — Suel Foster
Country Gent.XXVIII(1866)p.286

Root Grafting
Oregon Ex.Sta.Rept.1901,p.38

Grafting the Apple — S.C.Mason
Kansas ExpSta.Bul.65

Experimental Apple Orchard — A.Dickens
Kan.Ex.Sta.Bul.106

Whole vs,Piece Root Grafts — Hort.Editor
Country Gent.XIII(1859)p.110

Whole vs.Piece Root Grafts — N.W.Fruit Growers Assn.
Country Gent.VII(1856)p.412

Scions from Bearing Trees.

Budding fromthe Nursery — A.Hamilton
Mich.Hort.Soc.Rept.1900,p.22

Apple Scions from Bearing Trees for Topworking
R.N.Y.Oct.14,1905

Doubleworking Apples on Vigorous Stocks — F.W.Card
Soc.Hort.Science,1906,p.49

Reciprocal Influence of Stock and Scion

Mutual Influence of Stock and Scion — A. A. Crozier
Mich.Hort.Soc.Rept.1891,p.105-148

The Effect of Grafting — Hort.Dept.
Country Gent.May 18,1899,p.388

Influence of the Stock on the Graft — Josiah W.Talbot
Mass.Hort.Soc.Rept.1879,p.7

Influence of Stock on Scion — Dr.E.L.Sturtevant
Mass.Hort.Soc.Rept.1880,p.93

Natural Sports and Stock and Scion — C.M.Hovey
Mass.Hort.Soc.Rept.1875,p.82

Stock and Scion — B.Hathaway
Mich.Bd.Ag.Rept.1871,p.123

Effect of Stock upon Varieties — A.G.Gulley
Mich,Hort.Soc.Rept.1905,p.159

Stock and Scion — A.C.Hammond
Gard.Chron,1870,p.1057

Influence of Grafting on Posterity of Scion
Ex,Sta.Rec.XVI,p.265

Stock and Scion — A.G.Gulley
Western N.Y.Hort.Soc.Rept.LI(1906)p.14

Case of Grafting Having no Effect on Growth — Robt.Dawes
Gard.Chron.XXXV,3d Ser.(1904)p.316

Influence of Stock on Scion — J.Paelinck
Ex.Sta.Rec.XXVIII,p.541

Stock and Scion — J.P.Kirtland
Horticulturist II,p.544

Grafting of Solanums — E.Griffon
Ex.Sta.Rec.XIX,p.37

Stock and Scion
Mich.Hort.Soc.Rept.1880,p.327

Influence of Scion on Stock — G.W.Trobridge
14th Ohio Hort.Soc.Rept.1881,p.93

Stock and Scion
Amer.Jour.Hort.IX,p.185,215,309

Stock and Scion — W.Paddock
Amer.Gard.XXIII(1902)p.6

Stock and Graft in Apples — J.L.Budd
Amer.Gard.XIII(1892)p.506

Stock and Scion — T.Baines
Gard.Chron.1873,p.472

Stock and Scion — Wm.Burns
Gard.Chron.1880,p.53

Stock and Scion
Gard.Chron.1879,p.596

Stock and Scion
Gard.Chron.XII,3d Ser(1892)p.497

Relations of Stock and Growth J.W.Talbot
Country Gent.XLIV(1879)p.198

Stock and Scion
Gard.Chron.X 3d Ser(1891) p.35

Stock and Scion W.H.Clark
Gard.Chron.XXXVI 3d Ser(1904) p.450

Scion on Stock-Double Grafting Thos.Rivers
Gard.Chron.1869,p.54

Stock and Scion H.E.B.
Country Gent.XLVII,(1882)p.312

Stock and Scion T.H.Hoskins
Country Gent.XLIV(1879)p.224

Stock and Scion Hort.Ed.
Country Gent.XXXIX(1874)p.6

Influence of Stock on Scion J.N.
Country Gent.XXXI(1868)p.168

Influence of Scion on Stock
Country Gent.XXIX(1867)p.398

Stock and Scion Prof.L.H.Pammel
Amer.Gard.XXIII(1902)p.86

Stock and Scion L,Daniel
Ex.Sta.Rec.XV,p.363

Grafting B.P.Ware
Mass.Hort.Soc.Rept.1879,p.17

Stock and Scion
Mass.Hort.Rept.1880,p.108

Physiology of the Graft T.J.Burrill
Mass.Hort.Soc.Rept.1887,p.461

Stock and Scion
Gard.Chron.XXI(1897)p.207

Stock and Scion Prof.Stuart
Vt.Ex.Sta.Rept.1905,p.304

Influence of Scion and Stock A.S.Fuller
Propagation of Plants,p.344

<u>Bud Variation</u>

Sports Physiologically Considered J.W.Talbot
Mass.Hort.Soc.Rept.1883,p.144

Dimorphism J.Paelink
Ex.Sta.Rec.XXVIII,p.541

Bud Variation O.W.Blacknall
Country Gent.LXX(1905) p.179

Bud Variation
Country Gent.XXXVI(1871)p.152

Apple Sport
Gard.Chron.LI(1912)p.25

Natural Sports and Reciprocal Influence of Stock and Scion Chas.M.Hovey
Mass.Hort.Soc.Rept.1875,p.82

Bud Sport David Starr Jordan
Pop.Sci.Mo.LX(1905)N.3,p.201

<u>Roots in Nursery</u> (Effect of Scion)

Apple Trees and Roots W.F.Massey
R.Y.N. Nov.18,1911

Roots in Nursery Josiah W.Talbot
Mass.Hort.Soc.Rept.1879,p.18

Influence of the Graft upon the Roots
Amer.Jour.Hort.III,p.363

Stock and Scion A.A.Bensel
Country Gent.XLVII(1882) p.48

Influence of Scion over Stock Hort.Editor
Country Gent.XXIII(1864)p.366

<u>Herbaceous Grafting</u>

Influence of Grafting on Posterity of Scion
Ex.Sta.Rec.XIV,p.265

Grafting of Muskmelon
Ex.Sta.Rec.XI,p.153

Grafting of Herbaceous Plants
Gard.Chron.XLVI,3d Ser(1909)p.78

Grafted Dahlias
Gard.Chron.XLI,3d Ser.p.254

Cure for Mildew on Cucumbers F.M.
Gard.Chron.XXXVII 3d.Ser.(1905)p.386

Grafting Cucumbers
Gard.Chronicle,1890,p.139

Herbaceous Grafting
Gard.Chron,XVII,3d Ser(1895)p.294

Grafting Embryos
Gard.Chron.1855,p.627,678,692.

Grafting Beets
Gard.Chron.1855,p.20

Grafting of Herbaceous Plants
Ex.Sta.Rec.XX,p.751

Grafting the Chrysanthemum
Gard.Chron.XIV,3d Ser.(1893)p.659

Grafting Chrysanthemums
Gard.Chron.XLIII 3d Ser.(1908)p.10

Carnation on Saponaria — Editor
Gard.Chron.XXXVIII 3d Ser.(1905) p.150

On the Limits of Possibility of Grafting Plants — L. Daniel
Ex.Sta.Rec.XII,p.642

Grafting and Its Results — Editor
Gard.Chron.XXXVIII 3d Ser.(1905)p.248

Experiments in Grafting
Gard.Chron.XXXII 3d Ser(1902) p.399

Herbaceous Grafting Experiments — R.H.Biffen
Annals of Botany XVI(1902) p.174

<u>Potato Grafting</u>

Potato Grafting — Henry Taylor
Gard.Chron.1869,p.220

Grafted Potatoes
Gard.Chron.XXVI,3d Ser.(1899)p.174

Experiments in Grafting Potatoes — E.Laurent
Ex.Sta.Rec.XII,p.942

Potato Grafting
Gard.Chron.XXV 3d.Ser.(1899)p.187

Potato Grafting — Chas.Rintoul
Gard.Chron.(1870)p.1507

Grafting Potatoes
Gard.Chron.1868,p.598

Graft Hybrids

Graft Hybrids
Journ.of Heridity,V No.1,p.25

Graft Hybrids
Gard.Chron.XVII 3d Ser.(1895)p.140

Graft Hybrids
Gard.Chron.XLIX 3d Ser.(1911)p.170

Graft Hybrids — R.P.Gregory
Gard.Chron.L,3d Ser.(1911)p.161,185.

The Existence of Graft Hybrids — W.Koss
Ex.Sta.Rec.XVI,p.1082

Graft Hybrids and Chimeras — H.C.Cowles
Bot.Gazette LI(1911)p.147

Cytisus Adami
Gard.Chron.XXXVI 3d Ser.(1904) p.217

A Graft Hybrid — Herbert L.Jpnes
Gard.Chron.XIII,3d Ser.(1893)p.545

Graft Hybrid — David Starr Jordan
Pop.Sci.Mo.LXVI(1905)No.3,p.201.

Curious Case of Asexual Hybridization
Ex.Sta.Rec.XVI,p.568

Graft Variations
Gard.Chron.XXXVI,3d Ser.(1904)p.225.

Graft Hybrids
Gard.Chron.XLI 3d Ser.(1907)p.140

Curious Effect of Grafting by Approach — A.Nomblot
Ex.Sta.Rec.XVIII,p.637

Graft Hybrids — Dr.Beal
Mich.Hort.Soc.Rept.1880,p.333

Graft Hybrid
Gard.Chron.LIV 3d Ser.(1913)p.188

Experiments of Prof.Daniel

Stock and Scion
Gard.Chron.XXIV,3d Ser.(1898)p.246

Grafting as a Means of Modifying the Habits of Plants
Gard.Chron.XXXIV 3d Ser.(1903)p.290

M.Daniel.
Gard.Chron.XXXVI 3d Ser.(1904) p.464

Mixed Grafting L.Daniel
Ex.Sta.Rec.IX,p.945

The Conditions of Success with Grafts L.Daniel
Ex.Sta.Rec.XII,p.947

M.Daniel's Experiments in Grafting
Gard.Chron.XXXII 3d Ser.(1902)p.469

Effects of Grafting
Gard.Chron.XXXII 3d Ser(1902)p.419

Specific Variations Caused by Grafting Editor
Gard.Chron.XXXII,3d Ser(1902)p.409

Specific Variations in the Graft
Ex.Sta.Rec.XIV,p.654

Mixed Grafting
Gard.Chron.XXIII 3d Ser.(1898) p.84

Variations Produced by Grafting and their Inheritance
Gard.Chron.XXVII 3d Ser.1900,pp.13,35,85,118

Effect of Grafting on Composition

Stock and Scion
Ex.Sta.Rec.XIX p.539

Stock and Scion
Ex.Sta.Rec.XX,p.1311

Grafting and Chemical Variations Ed.Griffon
Bul.Agr.Intell.and Pl.Dis.,Nov.1912.

Stock and Scion Transfer of Alkaloids Editor
Gard.Chron.XL,3d Ser.(1907)p.414

Hybrids in Relation to Grafting and Vines L.Daniel
Ex.Sta.Rec.XVII,p.1070

Influence of Grafting on Quality of Wines
Ex.Sta.Rec.XIX,p.739,
and Ex.Sta.Rec. XX,p.443.

Influence of the Graft on the Quality ~~and~~ of Grapes and Wine and its Employment in the Systematic Amelioration of Sexual Hybrids — Curtel & Jurie
Ex.Sta.Rec.XVII,p.976

Influence of Grafting on Composition of Grapes — G.Curtel
Ex.Sta.Rec.XVI,p.877

Variation in Composition and Comparative Resistence of Grafted and Non-Grafted Plants — C.Laurent
Ex.Sta.Rec.XIX,p.728

Variation in Composition of Certain Food Plants after Grafting — C.Laurent
Ex.Sta.Rec.XIX,p.738

Degeneration of Plants — Horace Piper
U.S.Dept.Ag.Rept.1867,p.315

Effects of Grafting on the Vine
Gard.Chron.XXXVI 3d Ser(1904)p.11

Influence of Grafting on Plants Containing Hydrocyanic Acid. — L.Luiguard
Ex.Sta.Rec.XIX,p.1025