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GRAFTING THE APPLE.

INTRODUCTION.

Perhaps no horticultural question has at different times excited more discussion and brought to light a greater variance of opinion than that of the propagation of the apple.

A half century ago, when the majority of the apple trees of the eastern states were of seedling varieties and useful only for cider, it was an easy matter if a choice variety was found, to disseminate this in the neighborhood by means of scions top grafted on such vigorous and thrifty seedlings as one might have at hand, or a layered branch might give a young tree free from all possible suspicion because of being on its own roots. Had an order for a carload of trees of a particular age and variety been placed, it is doubtful if one nursery in the United States could have filled it. Orchards by the square mile, solely for the production of fruit, were not then dreamed of, and until there was a reasonable certainty of such orchards being planted no nurseryman would think of stocking up with any one variety to an extent that would hazard his whole year's profits.

The needs of the market orchardist compelled the nurseryman to resort to more expeditious methods of propagation than had

prevailed heretofore, and grafting upon cut pieces of apple seedling roots came to be the common method.

From its inception the practice of root grafting has met with opposition as being against nature, and the claim has been freely made that with the natural crown of the seedling tree destroyed, no tree could be produced by grafting which would have the same vigor and endurance. These objectors seem to forget that though the embryo of the seed and the wood bud are wholly distinct in origin, the one being produced by sexual propagation in the plant, and the other asexually, yet they have much in common, and that after its productionthe embryonic bud may be regarded as simply a bud peculiarly equipped for maintaining an existence independently of the parent plant which produced it, differing from the ordinary bud in usually being able to maintain its vitality for a longer time when separated from the parent, in being better provided with stored nourishment, or plant food, for use until it can begin to elaborate for itself, and in possessing in a stronger degree the inherent tendency to equip itself with roots.

A fuller evidence of this independence of character in the seed bud may be stated in the fact that in many species of plants a much wider variation from the parent type appears in the plant produced from seed than is found in the plants produced from the wood bud.

A hundred trees secured from a hundred seeds of the Ben Davis apple will each show all the characters of *Pyrus Malus*, the genus and species from which the Ben Davis is derived. Many of them will show some of the characters of Ben Davis in form of tree, twig, and leaf, and possibly in fruit, yet not one will be a true Ben Davis tree. What can we say about the unseparated buds on the twigs of the true Ben Davis? Will each one of these produce a branch with all of the Ben Davis characters? Almost to a certainty. If we take a hundred buds of Ben Davis, and by grafting, budding or layering we equip them with roots, can we with reasonable certainty expect them to produce Ben Davis trees? With a reasonable certainty we can, and yet not absolutely. One of them may produce a tree quite as distinct from the true Ben Davis as any seedling from the Ben Davis might be. The Gano apple is an apparent instance of this very kind of bud departure from the Ben Davis. The wood bud, then, is variable, though only in rare instances. It has stored nourishment at its command, available for either stem or root growth, as demonstrated in the rooting of every cutting. It has no root when separated from the parent plant, but neither has the seed-bud. It has, in a less degree than the seed-bud, we admit, but still in a marked degree, when given proper conditions as to the temperature and moisture, the ability to equip itself with roots and so become an independent plant.

Nature produces myriads of plants by this process of bud

propagation. It is one of her ways of working as truly as by means of the seed, and our artificial methods are merely copied from nature's hints.

Why should it be argued then, that the natural crown of the seedling tree is the seat of any greater vitality than any other portion of the stem, or that we are to get a more vigorous and enduring tree by making a graft above this than below it?

Another class of objectors have claimed that it was the process of grafting that was opposed to nature, and that to layer a branch was the only true way to secure an enduring tree of a given variety.

Two objections to grafting have been used; one that there must always remain an ununited wood surface of the size of the stock and scion at the time of grafting, and that this is apt to become the seat of decay, thus shortening the life of the tree. Comparing this with layering on the one hand, we shall find that the cut ends of the layered branch present fully as much wood surface that must be closed over by the growing sprout before healing is wholly effected; and comparing on the other hand with budding, which has its warm adherents, we shall find that the cut surface of the headed-back stock presents about the same area to be inclosed by the growing bud sprout as does the graft.

In neither case is the dead wood surface greater than that to be inclosed in the removal by pruning of a comparatively small branch; and yet we never hesitate at doing this, and with none but large branches do we have any trouble.

The second objection offered is that in grafting on seedling stocks having the wide range of characters possessed by seedlings, no two trees will be just alike as far as root influences go. This objection seems to be a wholly valid one and worthy of very serious consideration.

In the Station grounds we have several times set small blocks of apple stocks of the grade usually used for grafting and these obtained from a firm using only French Crab seeds. The trees in growth have shown every degree of vigor as well as the widest variations in character. Some make clean trunks with long straight limbs and smooth bark; others show the spiney short branches and close habit of growth which more commonly characterize a seedling tree. While all are apparantly hardy here, as far as resisting the severity of the winter, in their immunity from disease there is a good deal of difference. Twig blight is far more prevalent among them than it is in nursery rows of the standard varieties.

As to their ability to endure severe winters I will quote Professor N. E. Hansen of the South Dakota Agriculture College who says: *"There is a difference in hardiness of the apple seedlings used in nursery grafting. Those grown from imported French Crab seeds

*U. S. Experiment Station, S. Dakota, Bulletin No. 30, Page 9.

are too tender for use in the Northwest Those from seeds of Duchess or other hardy varieties would generally give hardy seedlings but are not obtainable in quantity. The best seeds obtainable in a commercial way are those saved from cider mills in sections where only northern varieties are grown At present this seed comes mostly from large seedling cider apple orchards in Vermont."

As the most of the nurserymen in this part of the country prefer the French seed, or at least take no pains to secure American seed of hardy trees, there can be little in a lot of the average apple stocks to recommend them to furnish the trunk and roots upon which the tops of the commercial or family varieties are to be grown.

It looks reasonable, then, that all of those methods by which the tree is grafted or budded sufficiently above the natural crown to insure no self-rooting of the scion, will give trees as variable in their characters as the influence of the stock can make them Uniformly hardy trees, as produced by such means, can only be looked for if uniformly hardy stocks are used, and the same may be said regarding any other quality that it is claimed can be procured in the tree by grafting or budding above the crown.

The objection to grafting based on the variable character of the stocks seems to be sustained unless we can graft in a way to secure uniformity of root.

STATION EXPERIMENTS IN GRAFTING.

This department has carried on a series of experiments since I889, to try to determine the relative value of various lengths of stock and scion, and of various positions of the graft on the stock. Repeated trials have been made to avoid giving place to conclusions based on one year's results.

The common run of No 1, apple roots have been used, obtained from a firm using the imported French Crab.

Experiment No. 1, 1889.

One hundred selected No 1 apple-roots were taken to be grafted with Ben Davis scions Cutting off the tops below the crown, one hundred grafts were made on the upper three inch cut; another hundred were made on the second cut; and another on the third or tip. The scions for all these were six inch and of as nearly uniform size and quality as could readily be secured. In the spring these three lots of grafts were set a foot apart in parallel rows in as nearly uniform ground as could be found.

RESULTS: First cut and second cut gave about uniform results as to the number of successful grafts and growth About eighty per cent of each lot grew, and at one and two years old little if any difference could be detected between the two lots.

Of the third or tip cut only sixty per cent grew. During the first season a marked difference was to be seen between these trees and the two first lots, growth being on the average a third less in height and more weak and slender. During the second season this difference was much less marked, though they had not attained the average size of the others when dug in the spring of 1890. Tabular measurements of these lots were not kept, but only general notes on the growth.

Experiment No. 2, 1889.

One hundred strong whips of Ben Davis wood were cut to two feet and grafted on selected stocks, using first three inch cut below crown. These were stored with much care to prevent injury to graft and planted in spring by the side of the three lots of Exp. No. 1. Forming a top of four or five of the vigorous upper shoots as they grew, the other buds were kept off. This in many cases gave a top too heavy for the trunk and necessitated summer pruning to keep them from lopping. At two years old these trees were estimated as being one-half larger and stronger than the lots One and Two with six inch scions.

It is not, however, believed that this method would be commercially profitable on account of the expense and difficulty of obtaining a good supply of the long scions.

A More Extensive Trial.

In the winter of 1893 an extensive series of grafts was prepared, designed to test the comparative value of various lengths of stock and scion and to answer, if possible, the following questions:

First. To what extent is the growth of the tree influenced by the length of the scion used?

Second. To what extent is the growth of the tree influenced by the length of the stock used?

Third. To what extent is the growth of the tree influenced by the grafting of the stock above or below the natural crown?

Conditions of Experiment.

In order to secure uniformity of results and to confine the differences secured as closely as possible to the points involved, the stocks used were all of No. 1 seedlings regraded, making as even a lot as could be selected.

The scions also were made of as even a grade as was practicable, though there was some difficulty in securing the longer lengths. As a further check upon the results the series of grafts were repeated in four varieties of apple, Winesap, Missouri Pippin, Ben Davis and Maiden's Blush. In answering question No. 1 three lengths of scions were run through the entire series, indicated by

the roman numerals: I being twenty-four inch; II, twelve inch; and III, six inch.

In answering question No. 2 the graded stocks were used of the entire length, and in five inch, two and a half inch, and one and one-fourth inch lengths, indicated by the letters "A," "B," "C" and "E."

To meet the conditions for answering the third question, each series of lengths of stocks, "A," B," and "C," was repeated. One lot was grafted an inch above the crown, these being indicated by the use of the single letter "A," "B," or "C." The other lot was grafted below the crown, but the top cut always used, and indicated by the double letters "AA," BB," or "CC."

Under letter "D" was run a series with stocks of two and a half inch lengths but small in size, and under "E" root pieces one and a quarter inch long were used. The entire series and their values will be made more plain in Table A.

The grafts were all made from Jan. 28th to Feb. 20th, the ordinary whip graft being used and the joints wrapped with waxed paper.

In Plate 1 are shown several styles of grafts. Fig. 1 shows an average "whole root," or entire first class apple seedling, as received from growers. Fig. 2 shows a "whole" apple root grafted "above the crown" with a six inch scion, or such a graft as is indicated by "A III" in our schedule.

Fig. 3 shows a whole stock shortened to eight inches and grafted "above crown." This will be referred to in another series. Fig. 4 shows a five inch stock, first cut "*below crown*," with a six inch scion. This graft is indicated by "A III" in our tables.

Fig. 5 shows a two and a half inch stock, top cut of standard size, and is lettered "CC III."

These grafts were all stored in a cool cellar and in spring set in nursery rows four feet apart and a foot apart in the rows.

As nearly as could be managed, they were all set at a uniform depth, bringing the graft or union three inches below the surface of the ground. This is the depth that experience has shown to be the best for the ordinary nursery graft with six inch scion and three inch stock, and this was adopted as the standard depth for all.

The planting of the "A" and "AA" lots was a very difficult task for many of them were a foot long below the union and required a trench fifteen inches deep to let them into the ground.

Table A.

Series Number.	Designation of Graft.	Description of Graft.
1	A I	Whole root cut above crown, 24 inch scion.
2	A II	" " " " " 12 " "
3	A III	" " " " " 6 " "
4	AA I	" " " below " 24 " "
5	AA II	" " " " " 12 " "
6	AA III	" " " " " 6 " "
7	B I	5-inch stock " above " 24 " "
8	B II	" " " " " 12 " "
9	B III	" " " " " 6 " "
10	BB I	" " " below " 24 " "
11	BB II	" " " " " 12 " "
12	BB III	" " " " " 6 " "
13	C I	2½-inch " " above " 24 " "
14	C II	" " " " " 12 " "
15	C III	" " " " " 6 " "
16	CC I	" " " below " 24 " "
17	CC II	" " " " " 12 " "
18	CC III	" " " " " 6 " "
19	D I	" " piece root (small) 24 " "
20	D II	" " " " " 12 " "
21	D III	" " " " " 6 " "
22	E I	1¼-inch " " " (standard size) 24 " "
23	E II	" " " " " 12 " "
24	E III	" " " " " 6 " "

Results of Experiments of 1893.

The spring was very unfavorable to this work and the percentage of loss great. An advantage which the long root grafts possessed over those on short pieces was soon apparent and continued to show strongly during the whole season.

The loss in whole root grafts was least and the rate steadily increased as the pieces diminished in length. This ratio of loss is not constant or uniform in any one variety, as can be seen in Table B in columns headed "Number of trees," but a summing up of the number of trees of all varieties and lengths of scion under "A" or whole root above crown, "B," "C," "D" and "E" shows as follows:

Kind of graft.	Number made, all varieties.	Per cent of live trees at 1 year.
"A"	1100	84.6
"AA"	1200	78.9
"B"	1100	53 8
"BB"	1200	43.6
"C"	1000	13.4
"CC"	1200	20.4
"D"	1200	11.0
"E"	1200	6.0

It is not claimed that so high a per cent of loss in the shorter piece root grafts is necessary in a nursery business. Our cellars were too warm, and situated, as they were, in connection with recitation and work rooms, very difficult to keep cool. The grafts were started too much when put out, and with the student labor available only in the afternoons, work could not be rushed as fast as desirable when the ground was in condition to work. I state the facts as they occur regarding the grafts, only pointing out the

significance of securing under adverse conditions so much higher per cent of growth in the longer roots.

It was found necessary to transplant these grafts to another part of the grounds in the following spring and though they were dug with as much care as possible the root systems were of necessity somewhat disturbed. They remained in this situation two years, during both of which heavy rains, caused the adjacent creek to overflow, thoroughly irrigating the ground. This, though a damage to some of the trees, caused a good growth on the whole.

Late in the fall of 1895 after growth had stopped, measurements were taken of the height of each tree and diameter of trunk at twelve inches from ground. These are exhibited in Table B, and in the two right band columns are shown the averages for the four varieties.

Table B.

Averages from measurements taken in spring of 1896 of trees from grafts set spring of 1895 and transplanted spring of 1891.

Series Number.	Designation of Graft.....	Number of trees from 100 grafts.				Average diameter in in. at 1 ft. from ground.				Average height in feet.				Average diameter of the four varieties.	Average heights of the four varieties.
		Winesap.	Ben Davis.	Mo. Pippin.	Malden's Blush.	Winesap.	Ben Davis.	Mo. Pippin.	Malden's Blush.	Winesap.	Ben Davis.	Mo. Pippin.	Malden's Blush.		
1	A I...	48	66	.....	69	.716	.739	.....	.795	6.3	6.32	.....	6 87	752	6 52
2	A II..	61	61	68	24	.637	.657	.725	.672	6.35	6 14	6.78	5.68	.674	6 35
3	A III	72	72	75	75	.710	.630	774	.818	6.50	6.02	6.66	7.18	.734	6 59
4	AA I...	49	54	77	79	.826	.678	.695	.730	6.82	6.12	6.20	6 99	.726	6 51
5	AA II..	51	77	49	78	.688	.641	.702	737	5.85	6.08	6.38	6.62	783	6 25
6	AA III	62	59	70	56	.758	.612	.681	.633	6.56	6 03	6.42	6 08	675	6 29
7	B I ..	16	41	.....	48	.648	.767	.....	.765	5 66	6.50	.....	6 34	.815	6 30
8	B II..	6	36	43	63	.663	.630	.782	.845	5.75	6.34	6.57	7 08	.611	6 70
9	B III	38	47	7	39	.530	.650	.803	.765	5 27	6.31	6.43	6.75	.657	6 14
10	BB I	2	13	16	8	.750	.625	.649	.437	6.75	6.23	5 87	4.06	662	5.91
11	BB II..	8	41	53	58	.733	664	.778	.735	6.31	6 51	6 29	6 91	.631	6 55
12	BB III	47	49	16	48	.760	.602	.710	.775	6 63	6 12	6.47	6 99	.711	6 53
13	C I...	7	15	.....	.....	.767	.633	.....	.....	6.00	6.03	.....	.....	.675	6.02
14	C II..	8	4	18	17	.578	.469	.666	.543	5 31	5.25	6.30	5.09	.587	5 60
15	C III	.....	10	7	.....	.....	.537	.590	.....	.....	5.75	5.78	.....	.558	5.76
16	CC I...	21	8	13	21	.565	.656	.702	.711	5.00	6.50	6 19	6 79	.653	6.03
17	CC II..	2	.....	15	29	.250	.....	.733	.620	2.00	.....	6.76	6 62	.641	6 46
18	CC III	17	3	7	18	.632	.750	.269	.610	6.14	6.66	6.36	6 61	.635	6 39
19	D I...	.....	7	2	7	.....	.785	.750	.607	.....	7.14	5.75	6.51	.702	6 68
20	D II..	3	8	6	3	.500	.640	.375	.583	6 16	7 18	4.08	6.17	.531	5 54
21	D III	.....	1	.....	1	.....	.625	.....	.500	.....	6.00	.....	6.00	.562	6 00
22	E I...	2	10	11	10	.500	.750	.715	.625	5.75	6 35	5.23	6.29	.685	6.08
23	E II	.....	.....	8	.....	.....	.....	.695	.....	.....	.....	5.90	.....	.695	5.90
24	E III	.....	.....	.....	1	.....	.....	.....	.500	.....	.....	.....	5.50	.500	5.50

A careful study of these measurements will reveal the fact that while the variations are considerable, and on the whole the growth is slightly heavier on the trees with longer stocks, this difference is slight as compared with the difference in the stocks used. For instance the average diameter of 183 trees in "A I," having the whole root grafted above the crown, is .752 of an inch, while the average of 33 trees in lot "E I," grafted with only an inch and a quarter stock, is .685 of an inch, a difference of less than .07 of an

inch. The average difference in height is less than 6 inches. Taking all of lot "A," or above the crown, the average diameter for 691 trees is .72 of an inch.

All of lots "AA," or below crown, average .728 of an inch.

Lots "B" average .694 of an inch, while lots "BB" average .681 of an inch

Lots "C" average .607 and lots "CC" .643 inch.

Here we can detect a slight decline in growth as the length of stock shortens but no constant difference between those grafted above or below the crown.

Looking down the columns we detect a tendency, not clearly defined, to show the best growth in connection with the longest scion.

Footing up and striking averages of all these trees, we have the following:

I,	or	24	inch	scions,	average	.701	inch	in	diameter.
II,	or	12	"	"	"	.656	"	"	"
III,	or	6	"	"	"	.629	"	"	"

A variation of *.08* of an inch in such averages is all that we can find for either of the lots showing variation in stock or scion, which leads us to conclude that we may draw from this experiment the following answers:

To question No. 1: The growth of these trees at three years old is found to be influenced by varying the length of scion from six inches to two feet, about eleven per cent in favor of the longest scions.

To question No. 2: There is about the same variation, eleven per cent, due to difference in length of stock from $1^1/_4$ inch to whole root, and in favor of the whole root.

To question No. 3: There are no constant differences in favor of grafting either above or below the crown.

Table C.

Number.	Symbol.	Number of trees at 3 years from 100 grafts made.			Average in inches of diameters 1 foot from ground.			Average of heights in feet.			Averages of the three varieties.	
		Ben Davis.	Winesap.	Mo. Pippin.	Ben Davis.	Winesap.	Mo. Pippin	Ben Davis.	Winesap.	Mo. Pippin.	Diameters	Heights.
1	A I	43	81	70	.612	.565	.573	5.08	5.13	5.04	.578	5 08
2	A II	77	62	66	.522	474	.486	5 01	4.64	5.20	495	4.95
3	A III	42	66	28	.431	.458	.402	4.56	4.42	4 39	.405	4 6•
4	AA I	60	53	62	552	.554	.619	4.76	5.14	5.84	.572	5.31
5	AA II	47	49	60	.433	421	587	4.23	4.13	5 66	.425	4 76
6	AA III	24	77	50	493	.419	380	4.02	4.05	4.36	.493	4.15
7	B I	50	58	.....	.525	.479	.....	4.31	4.55	.....	.500	4 43
8	B II	23	43	.....	.277	.379	.....	3.21	3 92	.....	343	3.66
9	B III	11	35	.....	.238	369	.....	3 04	3.84	.....	.273	3 62
10	BB I	21	63	31	.327	.455	.454	3.26	4.48	4 75	433	4 36
11	BB II	11	40	21	.233	.415	.381	3.04	4.23	4 50	384	4 12
12	BB III	13	20	18	.288	.231	.312	2.95	2.55	3.44	.274	3 55

GENERAL AVERAGES OF TREES. For the different stocks and scions.

Designations	Stocks.				Scions.		
	Whole root above crown "A."	Whole root below crown "AA."	5-in. stock above crown "B."	5-in. stock below crown "BB."	24-inch scion "I."	12-inch scion "II."	6-inch scion "III."
Diameters	.492 inch.	.466 inch.	.372 inch.	.363 inch.	.520 inch.	.411 inch.	.388 inch.
Heights	4.88 feet	4.74 feet.	3.90 feet.	4.01 feet.	4.79 feet.	4 37 feet.	3 98 feet.

Experiments in 1894.

For the year 1894 we have the records of a series of grafts in the styles "A," or whole root grafted above crown; "AA," the same below crown; "B," five inch stock above crown; and "BB," same below crown. One hundred of each were made in scions six, twelve and twenty-four inches in length, giving a series of twelve styles of graft. These repeated in Winesap, Ben Davis and Missouri Pippin give 3600 grafts.

They were made in the same manner and about the same time as those of the previous year, only being wrapped with waxed muslin instead of waxed paper,

Results of 1894.

Table C shows the series, with record of three lots of Winesap missing. Measurements were taken at two years old, of diameter at one foot above ground and height of tree as in previous lots. A careful study of these as condensed in the columns headed "Averages of the three varieties" shows most remarkably the decline in diameter and in height corresponding to the decrease in length of scion. In the column of diameters there is not an exception in the twelve lots, to the rule that, with a given stock, the two foot scion

gives the strongest growth, the twelve inch the next, and the six inch scion the least.

In the column of heights the same rule holds with a single exception, that in lots on stock "B." The presence of blight in the nursery, necessitating an occasional pruning back, might be a possible explanation for this.

Through an oversight, measurements of these trees at three years old were only taken in the "A" lots, or whole root above crown. These show that the variation due to the length of scion is very much less than at two years, as shown in Table C.

AVERAGE DIAMETER OF TREES OF THREE VARIETIES.

188 trees in I, or twenty-four inch scion, .788 inch.
193 " " II, " veive " " .741 "
127 " " III. " six " " .737 "

Severe blighting of tops late in the summer caused too much of an error in average height to make the figures of value.

From these figures at three years old and those obtained from the 1893 grafts at three years, we cannot avoid the inference that the differences due either to length of stock or scion are more apparent in the first and second years of the tree than in the third.

Grafts Made in 1895.

In a series of grafts made in this season we introduced what the nurseries advocating whole-root grafting generally claim to use as a stock—the seedling grafted above the crown and the root cut to eight inches long. This is the graft illustrated in Fig. 3, Pl. 1. That this will make as good a tree as the actual whole-root stock, which it is safe to say is only used in experimental trials, one would readily believe on reflection and the man who has the grafts to set will be very ready to adopt this conclusion, for the last four or six inches in the bottom of a fifteen inch trench becomes a matter of some seriousness in setting even a few hundred grafts.

Table D.

Ben Davis trees from grafts set spring of 1895 and transplanted spring of 1896.

AVERAGES FROM MEASUREMENTS TAKEN SPRING OF 1897.

Designation of graft.	Number of trees.	Diameter at 1 foot in inches.	Height in feet.	Designation of graft.	Number of trees.	Diameter at 1 foot in inches.	Heigh in feet
AA II	67	.647	5.19	B II	48	.690	5.56
AA III	38	.609	4.90	B III	34	.584	4.69
A+II	49	.716	5.52	BB II	57	.736	5.76
A+III	45	.646	4.60	BB III	23	.521	4.24
AA+II	71	.801	5.99	C II	41	.616	4.83
AA+III	37	.672	5.16	C III	14	.475	4.00
				CC II	25	.605	5.24
				CC III	6	.396	3.91

In Table D are shown the grafts made and the measurements at two years old. No constant differences in favor of any particular

length or style of stock can be traced out from this list but the fact is plain that with a given stock the twelve inch scion, II, invariably gives a better growth than the six inch, both in diameter and in height. The eight inch stocks give slightly better results in this case than either the whole or the five inch.

Again we find no constant difference in growth between those grafted above and those grafted below the crown.

Root Characters.

It is in a critical examination of the roots of the different lots of grafts that we get the real clue as to the value of different lengths of stocks. In digging the trees of different lots and at different ages it soon became apparent that certain characteristics ran through them all. A description of a tree root is difficult to make in words that will bring to the mind of the reader the true character.

In order to preserve fully the record of the root growth a typical tree was selected from each of many lots and photographed.

The series is not complete for all varieties and styles of graft, but enough have been preserved to show the tendency very clearly.

In all, fifty negatives were taken, showing nearly a hundred and fifty different trees. While these photographs constitute a part of the office records of experiments, only a few of them can be given in this Bulletin, owing to the expense of engraving and printing. Enough have been selected to fully illustrate each series, and show just where the root growth is made.

In Plate II, very much reduced, are shown on the left four styles of stock, the numbers referring to the left hand column in Table "A," from which we see that we have whole root stocks grafted above and below crown and five inch stocks in the same. All of these are the scion series 11, or twelve inch.

These trees, even at three years old, show where the graft was made by a dim scar on the bark, and at one year this union can sometimes be shown in a photograph not too much reduced, so that in putting them up against a background for photographing they are all placed with this union on the tape-line which is seen stretched across the board. The depth at which they grew cannot be very clearly made out in the pictures but the union is usually three or four inches below the soil surface. With this understanding we are ready to study the pictures.

Note that in each tree in Nos. 2 and 5 the *whole-root* as it was grafted shows clearly in the center with no side roots and no added growth to speak of. A comparison with the whole root stock shown in Plate 1, Fig. 1, will make this clear.

The fine and fibrous roots which support the tree are produced from just below the union of the stock and scion.

In Figs. 8 and II of Plate II, the five inch piece roots show

some growth from the lower end, much more than the long roots do, but here as in the first two we see that the real growth has, been made from near the union. In the right hand column of this plate the trees were photographed at three years old and the series, those of Tables A and B, had been transplanted at one year. Though an effort was made to preserve all of the long roots, this. could not always be accomplished and the cut ends were in good condition to throw out shoots. They did this to some extent, but, as in the one year series, the strong roots are all found near the union of stock and scion. In a few of these three year trees we find quite strong roots from above the graft, especially if the graft- had been planted a little too deep or soil had been washed in around it.

In Plate III is shown a full page reproduction from a photograph of a tree of this type. In the washing of the soil a row of Ben Davis had for several rods been covered from four to six inches, deeper than they mere set. This occurred during the first summer. The tape-line in the background shows the point where the graft. was made and the whitened portion in the middle of the picture below this, painted to distinguish it from the rest of the roots, is, the *whole root stock above the crown* on which the scion was grafted.

Just below this point of union are seen the small side roots. corresponding to those produced on the year old trees shown, in Plate II.

They have made but little growth since the second rooting of the tree, due to the deeper covering, and the long whole tap root has made scarcely any.

Where is the true crown of this tree now? Clearly at a point just opposite the lower corner of the label card. Does anyone believe that this is any less the true crown of that tree than if the tree were grown from seed, or that we might not cut off that tap root at the tape-line and have left just as valuable a Ben Davis tree to plant as could be secured by any process?

Let us study the grafts still further. In Plate IV are shown. two year old trees in grafts 2 and 5 as in Plate II. The larger, size of these enables us to see clearly the manner of rooting. Strong roots from near the union and little growth from the lower portion of the stock tap-root we find to be the rule again, with some roots above the union.

Plate V, showing Nos. 7 and 11 of Table A, shows us that the five inch pieces of stock have rooted more freely from the ends and we have from these styles really more deeply rooted trees than are seen in the other.

In Plate VI me show the use of eight inch stocks grafted above and below crown. and the same story is repeated, though in these one year trees more rooting has been done toward the

lower end of the stock than in the whole-root trees.

If we turn to Plate VII, however, we have very clear photographs of two Ben Davis trees at two years old which show that the lower roots made but little further growth while the strong growth of the second year was almost wholly from the upper portion of the stock.

These few photographs submitted serve to make clear facts apparent through all the list, and the trees selected have, been those most typical of the lot they were taken from. They fairly represent, then, the root growth on about 4500 trees of four varieties as grown in our soil and under our conditions.

Conclusions from Root Photographs.

Tile facts which they portray are these: First, that the main root growth from all lengths of stock is made, in the first year, at and just below the union of the stock and scion; second, that the growth at this point becomes more pronounced in the second and third year's growth of the tree; third, that growth from the lower portion of the stock is very slight during the first year and becomes of less importance during the second and third; fourth, that this lower growth is greatest on the shorter piece roots and least on the whole root; and fifth that where the graft is buried deeply a new system of side roots will take the lead at about the usual depth below the surface of the soil, to the more or less complete dwarfing of the lower and earlier root systems.

Theory of Root Growth.

The fact of so strong a root growth at and just below the union is in part explained, no doubt, by the obstruction offered to the free flow of sap by the whip graft. The transfer of sap is at first only through the callus, and later through the new wood growth, but the process can hardly be a free one till well into the summer. The effect must be about the same as cutting a tongue on a layered branch.

But this root growth must be further explained by its relation to the soil surface.

The depths at which our grafts have been set brings the union -at about the depth at which side roots are most apt to form, and this circumstance, together with the obstruction afforded, make the union the most favorable spot for root production; but when we remember that deeply set grafts will root somewhat above this the first year, and very strongly the second and third, we must infer that the position of the main roots of the tree bears a stronger relation to the soil surface than to any stock influence. The first few inches below the surface of the soil is evidently nature's place for sending out the main roots of the apple as well

as of many other trees. The apple in particular is provided with few roots other than these at any age. Undisturbed seedling trees may be a little more slow to establish this habit than transplanted or grafted trees, but they will do it without fail, and the tap root will be found to have served only a temporary purpose.

Any theory of propagation that attaches great importance to the use of a long tap-rooted stock for the apple seems to find support only in the effect it is to have on the tree for the first year or two and not on any permanent character that it is to give to that tree.

How Does the Stock Effect Longevity?

The claim has often been made that the use of whole root stocks with the natural seedling crown preserved is the only way to insure a grafted apple tree of vigor and longevity. In support or refutation of this nothing can be offered in notes from nursery rows. Only parallel rows of the two kinds of grafts in the same soil and of the same varieties standing the test of years could contribute the answer to the question raised here.

Fortunately we have in Kansas one such orchard of au age to begin to be of value as evidence in the case, and the data regarding it are fully preserved.

Having heard that veteran orchardist, Judge F. Wellhouse, of Leavenworth county, now president of the Kansas State Horticultural Society, speak of a series of experiments begun by him in 1876, in whole and piece-root grafting of the apple, I wrote asking him for particulars as to the present condition of the trees then grafted. I was gratified to learn that he had preserved very full notes of the experiment and under date of March 27th he gives me the following account, with permission to use it in this Bulletin:

Statement of Judge Wellhouse.

"In February 1876 we put up 30,000 grafts, principally Winesap, Ben Davis. and Missouri Pippin. Of these me grafted 600 Winesap, 600 Ben Davis, and 600 Mo. Pippin on whole roots. These roots were of one years growth from seed and were of the usual size—about ⅜ of an inch in diameter and of full length, about, one foot.

We then grafted 600 of each variety two inches above the root crown and 600 of each four inches above, and cut off all the roots four inches below the crown.

Next we put up 600 of each on piece roots four inches long. 600 of each variety on three inch roots. 600 of each on two inch roots, and 600 of each on one inch roots. These roots were all cut off below the crown, and were cut, into pieces of the desired length and all used that, were large enough to receive a graft.

The scions were all out about six inches long. All these grafts were, planted in nursery about 15th of April.

The whole roots were very hard to plant. We had to dig holes with

spade, and a man and boy would put in 400 to 500 a day.

All the balance were planted the usual way.

The roots that were grafted above the crown were set so that the conjunction was above the ground, and immediately after setting we threw up a furrow on each side so as to cover the junction, and this earth was kept there during the summer or until scions and roots were well knit together.

All these trees received the usual care and cultivation in the nursery for two seasons, and in the spring of 1878 they were all taken up and planted in our Miami orchard.

In taking them up we first run the tree digger under, cutting off a11 ten inches deep and twenty inches wide. Then, as they were pulled up and earth shaken off, they were handed to me. I gave the roots careful examination and sorted them into two grades, and the following are the number of first grade of each kind, 600 of each lot being planted in nursery.

On	whole-roots				Winesap	515	Ben	Davis	523	Mo.	Pippin	496
Grafted	4	inch	above	crown	"	411	"	"	442	"	"	381
"	2	"	"	"	"	435	"	"	486	"	"	403
On	4	"	piece	roots	"	516	"	"	520	"	"	503
"	3	"	"	"	"	513	"	"	514	"	"	474
"	2	"	"	"	"	520	"	"	519	"	"	502
"	1	"	"	"	"	342	"	"	369	"	"	321

On examination of the whole root trees I was disappointed. I expected to find a large tap-root and a lot of small side roots. but, instead I found the original or tap roots had made in most cases but, little growth, and in many trees the side roots mere larger and longer than the tap root, and not one of these trees had rooted above the graft.

Of those grafted above the crown, both two and four inches. the roots were irregular, showing clearly that the scion had but little control over shaping the roots.

This irregularity was in evidence to some extent in the whole root trees, but not nearly so much.

On the piece root trees with four inch roots the roots were in good shape, but not one of them was rooted above the graft.

Those on three inch roots mere all right, and a few were sooted above the junction.

The two inch roots were also in good shape and nearly all were rooted above the graft, and the roots on this lot of trees were more satisfactory than any of the others.

The one inch roots were all right, and all of them mere rooted above the graft and made good trees.

One peculiarity I found in the roots of these trees from the whole roots down to the one inch roofs, and that was that the original root made but little and in some cases no growth after being set, in nursery; and that the sustenance of the tree had to depend on new roots thrown out. I have often noticed this since then.

The above experiment satisfied me that a two inch root was about the right length and we have used that length ever since and by using long cions and putting them well into the ground when set, in the nursery me have in nearly every case secured good roots above the graft.

When we planted the orchard we kept enough of the whole root trees to set six rows across the orchard, two of Winesap, two of Ben Davis and two of Mo. Pippin. These rows, as we11 as all the other rows in the orchard, mere 32 feet apart, the trees in the row being 12 feet apart, and contained a little over 200 trees to the row of 160 rods in length.

This orchard was planted the latter part of March and as we had a

good growing season me secured a good stand, not losing over one per cent, and I could see no difference between the whole root and piece root grafts.

The ground in this orchard was cultivated in corn for five years, then seeded in clover, and has not been cultivated since.

During the first six or eight years the whole root trees threw up from the roots more water-sprouts than the piece root trees, but in every other respect I could see no difference.

These whole root trees have been growing nineteen years in the orchard and two years in the nursery side by side with two inch piece root trees, and if, in all that time, the whole root trees save grown more vigorously, borne more fruit, or shown more signs of longevity, I have not been able to see it.

Two years ago every alternate tree was cut out."

The figures given by Judge Wellhouse on the number of first class trees obtained from the different styles of graft are of much interest, showing that while the whole root grafts gave a high number of excellent trees there were no more of them than of the four inch piece roots, and not as many as on two inch pieces. The two lots grafted above the crown furnish a lower number of trees than any except the one inch piece roots.

The fact of the whole roots failing to produce any side roots of importance or to make further growth is exactly in harmony with what is shown in our photographs.

Too high a value cannot be attached to the fact of there being a lot of whole root trees nineteen years old where they can be exactly compared with trees on two inch piece roots grafted and set at the same time. While the time of the severest test, when the orchard begins to fail, has not arrived, their uniformity of growth and vigor so far leaves little room for hope that there will appear any important difference later.

I take great pleasure in being able to put these important facts on record, feeling sure that the final outcome will be watched with much interest.

An experimental orchard was set in our grounds in 1890, designed to test the values of these different grafts, but from the small number of trees of each of many varieties, and the diverse sources from which it was later learned that the dealer had obtained many of them, comparisons as to behavior of whole and piece root stocks can have but slight value.

Summary.

In answer to Question No 1, we may conclude that there is a uniform difference in growth in favor of the longer scions used. This may be due to the greater leaf surface that the graft is able to present early in its growth. It is not believed that this increased growth is sufficient to pay for the expense and trouble

of making twenty-four inch scions and it is doubtful if it will pay for twelve inch.

To Question No. 2, the answer is clear that growth is somewhat greater with whole root stocks than with piece root during the first and second years, but that in the third year this difference largely disappears and that this difference is not great enough to warrant the extra labor and expense of handling the whole root grafts. Our experiments would point to the five inch piece root as giving rather the best results in proportion to expense, while Judge Wellhouse secured most satisfactory trees from the two inch piece root grafts.

In answer to Question No. 3, no difference can be shown between grafts an inch above the crown and an inch below, when both are set with the union three or four inches below soil surface. Grafting three or four inches above the crown may prove a positive detriment to the quality of the tree secured, as shown by the experiments of Judge Wellhouse.

Conclusions.

First. That whole root grafted apple trees are of no greater value to the buyer than trees grafted on piece roots of 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.

Ewing Herbert, Printer, Hiawatha, Ks

PLATE I.

PLATE II.

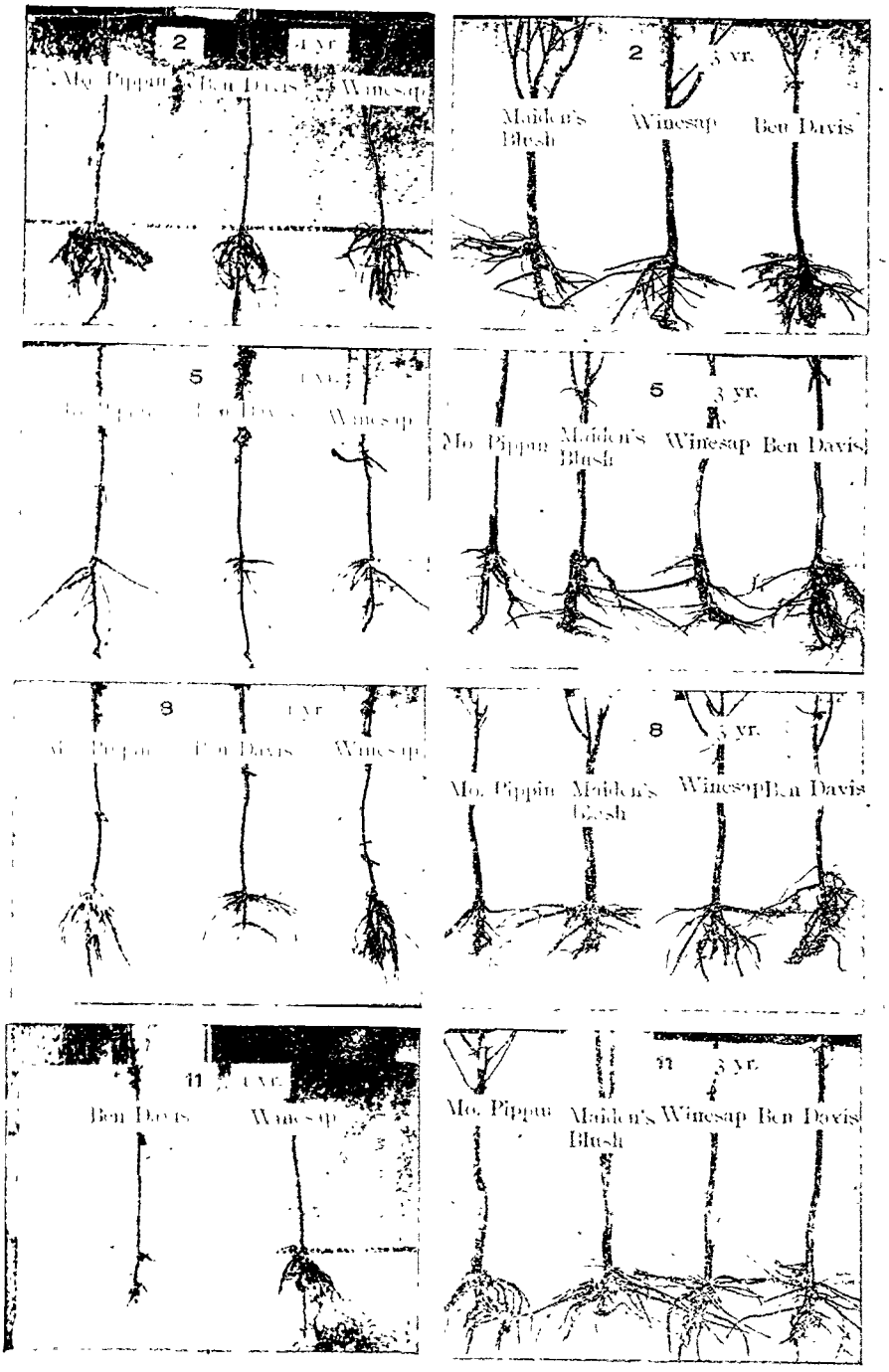


PLATE III.

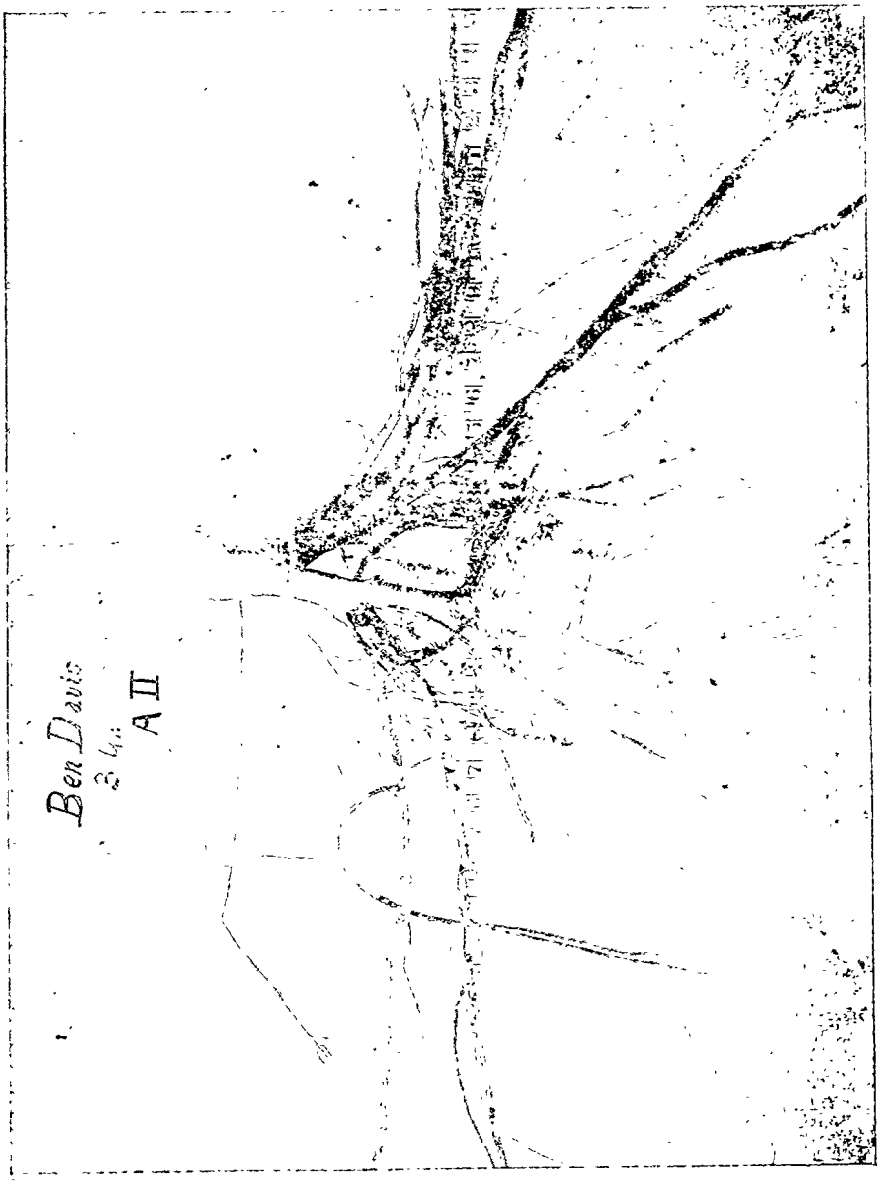


PLATE IV.

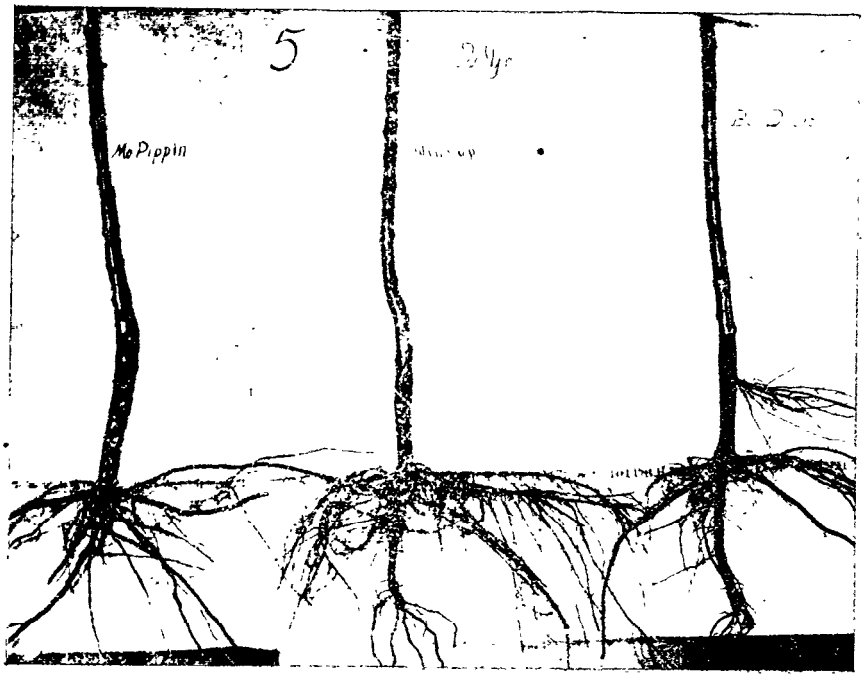


PLATE V.

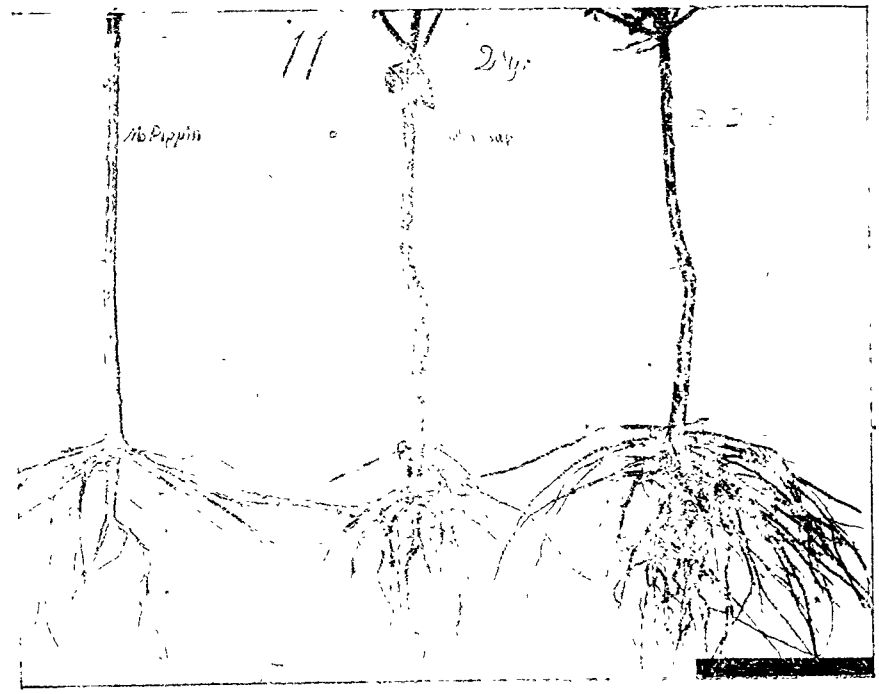
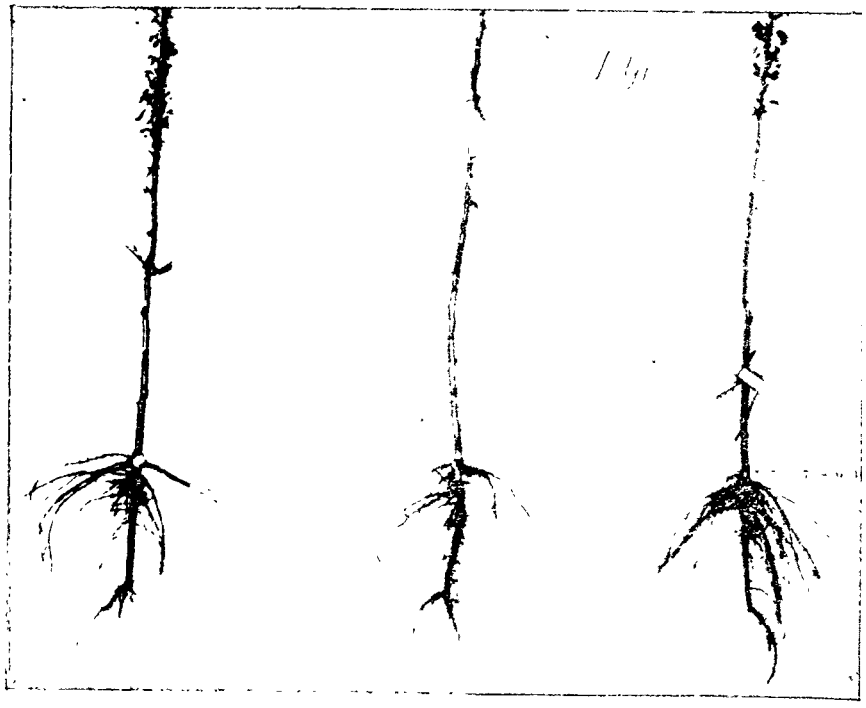


PLATE VI.



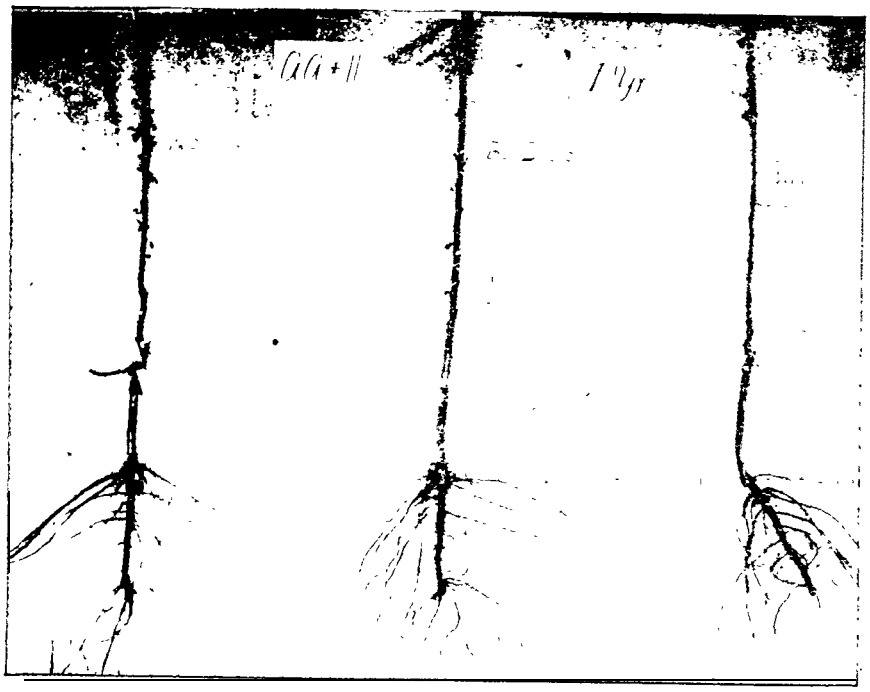


PLATE VII.