THE RELATIONSHIP

OF

COMPACT SUBSOIL TO ROOT

DISTRIBUTION OF PEACH TREES

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By

HERMAN ADOLPH HINRICHS

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APPROVED BY:

Frank B. Cross
In Charge of Thesis

[illegible]
Member of the Thesis Committee

Frank B. Cross
Head of Department of Horticulture

D. C. McIntosh
Dean of Graduate School

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INTRODUCTION

The problem has arisen time after time as to the possibilities of modification of the soil or subsoil to produce a more vigorous tree growth and increase fruit production on the undesirable soils. Most soils, where trees usually do poorly, have a hard pan, that is a hard compressed layer of soil which prevents the development of roots. These hard pans, preventing the movement of water and development of roots to lower depths, are of a clay type. The clay soils are very hard to alter and almost an impossible problem.

The subsoil on the experimental farm near Perkins is very compact, but it has a considerable amount of sand in it. By working the subsoil in your hand, it becomes very friable. The hard pan is about two feet thick--a layer of soil from 12 to 36 inches in thickness which begins 12 inches below the surface. The fourth foot of soil is very loose and sandy. Root development in this type of soil is shallow and the trees are subject to drouth damage. Also after a rainy season young trees may blow over from high winds. The roots are too shallow and cannot hold the tree up under strong winds. Plum trees upon plum root stocks are more subject to blowing over than other fruit trees. This occurrence was noticed in the orchard at Perkins because these root stocks did not develop as large a root system and were more shallow.

Since the roots do not penetrate this substrata (hard pan) and it contains large quantities of sand, it may be possible to modify this soil so the roots could penetrate to the lower depths. By digging large holes and dynamiting the compressed area as a means of loosening the soil, the root development and top growth could be influenced greatly. Movement of water is more rapid after soil has been loosened.

REVIEW OF LITERATURE

Root development in relation to the soil profile has been investigated extensively. All investigators find root development and distribution to be mainly determined by aeration and water supply; however, the nitrogen supply may affect the root development. Schusters and Stephenson (38) working with walnuts found that porosity and aeration of the soil played the most important role in nut production in Oregon. They found that 10 to 12 per cent of air space under field moisture capacity was favorable for root development while five to six per cent and over 25 per cent was unfavorable. The top soil can be aerated by drying and cracking, but the deep soils are aerated principally by the pore spaces which are too large to hold water against gravity. Deep rooted plants used as cover crops are good aerators.

Porosity is a measurement of the looseness of a soil. The lower the porosity, the more compact the soil. A. T. Sweet (44) found a very definite relationship between subsoil conditions and the growth of the apple tree. The roots penetrating deeper in more open subsoil result in developing a larger tree, increasing production, and lengthening the tree's life. The roots of a twenty-year old apple tree had extended well over 5,000 cubic feet of open subsoil while in a tight subsoil the area was less than one-half of the open subsoil. Toretensson and Eriksson (47) found the average porosity of a loose soil to be 29.3 per cent while a compact soil was 11.4 per cent. This is not in agreement with Baver's (4) report which says an average soil has about 50% pore space.

The soil profiles that have a uniform color from a dark brown to a lighter shade of brown with little or no mottling are the most productive. These soils are loose and well aerated. A mottling or grayish color indicates poor aeration and oxidation. Heinicke and Boynton (26) concluded that an improvement of aeration of soil by mechanical means resulted in great response of the tree in total leaf area, shoot and trunk growth. Oskamp and Batjer (34-35) and others (6-9-30-31-32-33-45 and 46) in surveying the soils in relation to fruit growing in New York found the best orchards were located on soils of uniform color that were well drained. The soils that were mottled were the poorest yielders. The soils that have rapid percolation show good drainage and proper aeration. Roots of trees in such soils will extend over a much larger area to secure its water supply, and the trees will not be as subject to drouths.

The seasonal fluctuations of soil moisture will affect the yield of an orchard, but Boynton and Savage (10) found that a well drained soil with roots penetrating to four feet in depth will seldom limit production because of water shortage in New York. In a deep soil the roots will penetrate deep enough to secure enough water to overcome almost all of the drouth effects. The root systems that are shallow are the ones which will be affected most by drouths.

The texture of the soil has some influence on tree growth but it is more or less correlated with the water holding capacity and the extent that the roots can penetrate through the soil. Sandy or gravelly sandy soils are well drained, but may not hold enough water to be productive and they are subject to drouths. A clay soil is fine in texture and restricts the movement of water, air and plant roots. A soil between these two extremes would be the ideal type of soil for tree growth. Sandy loams, loams or silt loams that are deep are the best soils. Soils of this nature are friable, loose, and well drained.

Chadwick, Bushey and Plitcher (15) reported on the root distribution of moline elms and concluded that the texture of the soil had a direct bearing on the distribution of the roots. In a clay soil, root systems were very sparely branched and there were few fibrous roots. The top growth also was smaller in the clay soil. The sandy soil developed better top and root systems but there was very little branching of the roots. The loam produced the best trees. These trees had the largest root systems with the longest laterals and the most extensive development of fibrous roots.

Veatch and Partridge (48) working with fruit trees on the soil complexes, found that the dryness and the compactness of the soil interfered greatly in the development of the tree and the distribution of roots in the soil. The roots were found in all soil reactions from pH of 4.5 to 7.5.

Anderson and Cheyney (2) modified the texture of the soil by using soils made up of particles of different size secured by screening a sand dune. Growing seedling of pines, spruces, and balsam in each type of soil they found, the length of the tap root was increased from the finer to the coarser soils regardless of the amount of moisture used, and the lateral development of the roots was not affected by the texture of the soil but by the amount of moisture present.

Peach roots develop very extensively in good soil. Havis (24), studying the root system of 12 year old Elberta peach trees found that 60 per cent of all the roots were in the first foot of soil. The roots were found to be extending out as far as 18 feet and 4 inches from the trunk of the tree. He used a trench method in studying the root development. A vertical trench extending radially from the trunk of the tree to the outer extremities of the roots, $2\frac{1}{2}$' wide and as deep as required, was made for the purpose of ascertaining root distribution.

Cowart (21) used June Elberta peach trees on a sandy loam soil with a compact subsoil finding the root development to be three feet in depth and six feet in spread in one year of growth. At the end of the second year's growth the development had extended to $4\frac{1}{2}$ feet in depth with a spread of 12 feet. The root to top ratio was closer together at the end of the second year. It was 41.6 per cent for the first year and 25 per cent for the second year.

Partridge and Veatch (37) found that almost all of the roots of apple trees in a good soil were in the upper $1\frac{1}{2}$ to 2 feet of soil which is in the A horizon. The densest root development is from six to eight inches below the surface or in the area that contains the most organic matter. The roots may penetrate as deep as twenty feet. They concluded that some soils which have hard pans or poor drainage may be reclaimed by deep tillage, dynamiting, or by drainage.

Clark (18) working in shallow phased soil in western Oklahoma and under semi arid moisture conditions found approximately 97 per cent of tree roots in the upper 24 inches and the remaining three per cent in the next foot of soil. His study was on apple and apricot roots. The root zone was definitely limited to the zone of weathering.

In a comparison of nitrates and of sulphate of ammonia, Batjer and Sudds (3) reported that nitrates produced the most extensive roots. The sulphate lowered the pH 2.3, but at the 16 to 20 inch level the difference was only 0.41.

The root system can be modified by changing the soil environment. Yocum (53) reported that intercropping caused a vertical development of roots while mulch resulted in a lateral development. When these two conditions or modifications are removed, the development of the roots is nearly normal. Intercropping with corn removes the surface moisture and causes the roots to go down for water. A heavy mulch prevents the loss of moisture at the surface and causes heavy lateral development of roots in the soil just underneath the mulch. The exhaustion of subsoil moisture is the chief factor in determining the life of the orchard.

Beckenback and Gourly (5) using different cultural practices found the root development to be the same for all treatments used in a good soil on 10, 32, and 40 year old apple trees. Trees mulched for 35 years had a very heavy mat of roots in or just below the mulch.

Dynamiting to improve and loosen the soil has been studied to some extent; however, the results have been more or less unsuccessful. The dynamite forms a cavity from the blast which will restrict the movement of water and roots around it. If the subsoil is wet or a clay type, the cavities develop more easily and the walls are more compact. A sandy soil remains more loose and does not pack as easily as clay soil in dynamiting. Call and Throckmorton (12) showed the shape and the extent of the jug or cavity formation made by the blast. The soil was so compressed in the wall of the cavity that a hollow or jug shaped mass of soil could be removed leaving a definite outline of the cavity formed. One-third to one-half of a stick of dynamite would form the cavity upon blasting.

Card (13) using apples, peaches, plums and cherries in dynamited subsoil found no beneficial effect from the treatment. The death rate of the trees was higher in dynamited soil than in the ordinary planting. Thirty per cent of trees were killed or damaged heavily in dynamited soil while only 8 per cent were killed in the ordinary planting. The charge was placed from 30 to 36 inches in depth using a stick of 20 per cent dynamite. The soil was well shattered and loosened to 36 inches with the lines of breakage in all directions. The root system of peach trees developed deeper with larger roots, but only a few fibrous roots were found in this treatment. Apples responded to the treatment less effectively than peaches. Farley (23), working much earlier, came to about the same conclusion. The two years' study he made on peach trees was in favor of dynamiting but the experiment was discontinued before positive results were available.

Stewart (41) used dynamite to loosen a hard pan in a silt loam soil for Baldwin tree planting, and also around trees that were twenty-five years old. He found slightly superior growth in trees of dynamite soil but thought it due to normal variations.

Chilcott and Cole (17) working with wheat and corn reported that subsoiling, deep tilling and dynamiting was not effective in increasing yields. Dynamite was placed three feet deep and twenty feet apart in all directions over the field.

Sudds (42), working on deep cultural practice in West Virginia, stated that no significant difference could be found. A shale was present in soil about 18 inches deep. Two sticks of 20 per cent dynamite were used in each hole 36 inches deep and six holes were placed around the tree on a nine foot radius. The treatment was on Rome Beauty and Stayman Winesap planted 25' x 30' in the hexagonal system. In 1930, the moisture was low and no significant odds were obtained on the circumference on total growth but in 1931, which was a wet season, the Rome trees had odds of 54 to 1 in favor of the dynamite. Delicious planted in 1931 show no effect on the yield from this treatment.

Yeager and Latimer (51) reported the vigor of the tree is closely correlated to the trunk diameter and the trunk diameter is correlated with the production of the tree.

The digging of large holes for planting fruit trees according to Card's (13) findings was beneficial to cherries and plums but apples did as well with the ordinary method of planting. Morse (28), also working with fruit trees, could find no benefit from the large hole treatment.

The large holes may stimulate the root development to such an extent that the soil will be depleted more rapidly of its nutrients. Thus the tops would not grow as fast as the ordinary planting trees in the second and third years. Smith and Romberg (39) used indolebutyric acid to stimulate root development of pecan trees. They found with an overtreatment the root development was too great in the immediate area to supply enough nutrients to the top growth. The top growth was smaller on high application of indolebutyric acid. The root system being very extensive in small areas deplets the soil to such an extent that the top cannot get enough nutrients to increase its development.

ORCHARD LOCATION AND MANAGEMENT

The orchard in which work herein reported was done is a part of the Oklahoma Experimental Station farm near Perkins, Oklahoma. It is about three and one-half miles north of the Cimarron River and the soil is sandy. Farther from the river, the soil changes to a very red and heavy clay. The soil on the farm works very easily and it develops a fine tilth if cultivated when moisture condition is favorable but if worked when too wet, it becomes cloddy and rough. There is enough clay present to puddle the soil if it is worked too wet. After the first rain and working at the proper moisture content, the soil will return to a condition of good tilth.

The orchard is underlaid with a hard pan that is about two to two and one-half feet thick. It is compact enough to restrict the movement of water and the development of roots. After passing through the compressed layer of soil, a very sandy strata is found. The sand at the lower depth gives excellent drainage but the layer just above (the hard pan layer) holds the water back.

The orchard site is terraced and slopes to the south. The peach trees are planted 25 x 25 feet with the treatments running north and south between east and west terraces. There are four or five trees in each row and every fourth row has the same treatment.

The orchard was in clean cultivation from the time trees were planted (February 18, 1939) until hairy vetch was planted in September. The hairy vetch was seeded at the rate of 12 pounds per acre with 100 pounds of super phosphate. The vetch was planted with a two row corn or cotton planter using furrow opener attachment so the seed would be placed in moist soil. The vetch was double rowed between the trees leaving enough room on each side of the tree rows for early cultivation in the spring. Plate 1 shows the one year's growth of the peach trees in each treatment with the cover crop growing in rows between the trees. After the vetch had made seed, it was disk harrowed and then cultivated until fall. The next year the same plan of modified cultivation and cover cropping was used. However, little or no seeding of vetch was needed because a sufficient stand had germinated from the volunteer seed.

SOIL TREATMENTS

Fair Beauty and Sun Glo peach varieties were planted for this project. The trees of each variety were divided into three uniform groups, one of which was planted in each of the following methods as to modification of subsoil: large holes, dynamited holes and holes of ordinary size.

In December of 1938, 45 large holes 5' x 5' x 4' deep were dug at each place where a tree was to be set. Abnormally light rainfall for several years previous to this time resulted in a subsoil dry and difficult to dig. The soil between 10 to 45 inches from the surface had to be loosened with a pick. It was so hard that a shovel could not penetrate it. Holes were made through this compressed area to a loose sandy soil encountered at four feet. A team and fresno were used to fill the holes with top soil and the soil removed from the holes was leveled over the surface between the hole locations.

The total cost for digging the 45 large holes amounted to $53.75, at a rate of twenty cents per hour. This amounted to $1.20 per hole. The expense would be additional to what it takes to set the trees out by the ordinary method.

The second method of treatment consisted in exploding a charge of dynamite in the compacted layer or subsoil.

On January 18, 1939, four sticks of 60 per cent dynamite were placed in the soil at a depth of five feet, where trees were to be planted. The dynamite was bottomed at five feet and packed back to within three feet of the surface. The charge shattered and loosened the subsoil without blowing out at the surface. This loosened the compressed area but a definite cavity was formed from each blast. The cavity extended to within two feet of the surface being three feet in length and 18 to 24 inches across the middle. These cavities were filled in with soil at planting time.

There were 44 holes blasted for tree setting. The total cost for dynamiting amounted to $40.50 with an average cost of 90 cents per tree over the ordinary planting method.

The third treatment consisted of planting a tree by the ordinary method without having the subsoil disturbed. This method consists of digging a hole large enough to accommodate the root to the proper depth.

Plate 1. Young peach orchard with hairy vetch planted as cover crop between trees.

The average hole was made about 18 inches deep and 20 inches in width. Forty-six trees were planted in this manner.

February 18, 1939, the Fair Beauty Peach trees were sorted as nearly as possible into three groups of uniform size and planted in one-half of the orchard. The trees were placed in blocks of 12 trees each--three rows and four trees to the row. The first row was large hole planting, the second was dynamited and the third was the ordinary planting.

The Sun Glo was planted April 15, 1939, in the other half of the orchard. The trees again were sorted to a uniform size. The trees coming in very late from a northern nursery had started growth. Each tree was given water to insure its survival.

METHOD OF STUDY

Top Growth Measurements

Trunk diameter measurements were taken as an index of growth in each treatment. The trees were measured 10 inches above the soil line before growth had started in the springs of 1940 and 1941. Twig growth was also measured in the spring of 1940 as another method of comparing growth. The second year twig growth was not measured because of the time and the inaccuracy of measuring the total growth for the year. The trunk and twig growth measurements were taken for both varieties.

Removal of Tree Roots and Measurements

The entire root system of a Fair Beauty Peach tree was removed from the soil in each treatment and weighed and photographed. The roots were removed from the soil on April 1, 1940. A deep trench was dug just beyond the outer extremities of the tree roots working toward the tree from this trench, soil was carefully removed until large quantities of roots were encountered. Plate 2A and 2B show a trench made around a tree which had been planted in a large hole and in an ordinary hole. Data were taken upon the distribution of roots as to location, depth, and distance from the trunk of the tree. The final removal of the soil from the roots was obtained by washing with water. Nozzles from a 300 gallon orchard sprayer operating at 300# pressure were used to wash the soil away from the roots. In Plate 3 the process of washing the soil away is shown. Plate 4 shows the roots produced by a tree planted in the dynamited hole just before removal. After the tree was removed, the root system was rearranged on a wire screen in some relative position as it was found in the soil and photographed. The weights of roots and of tops were recorded.

After the second year of growth, roots of other trees in the same blocks had data taken in the same manner, but the trench had to be started much farther away from the trunk of the tree. Again the Fair Beauty trees were used for the study. They were removed from the soil April 19, 1941.

MOISTURE

Moisture determinations were made on September 30, 1939, and April 20, 1940, on soil in which Fair Beauty trees were growing. A soil sampling tube was used to secure the samples of soil at the different depths. The sampling in September, 1939, was taken at a distance of two feet from the trunk of the tree on the southeast side while in April, 1940, it was taken two feet from the southwest side of the tree.

Starting in September, 1940, a Portable A.C. bridge operating at high frequency as described by Bouyoucous (7) was used to determine the per cent moisture in place. Porous blocks were placed at 12, 24, 36 and 48 inches below the surface in each of the subsoil treatments of the Fair Beauty trees. The amount of moisture in each block will affect the electrical resistance which if read in ohms, can be converted into the per cent moisture present. The block is porous enough so the water will move freely and very rapidly to and from until an equilibrium is reached with the soil.

Temperature and moisture curves were constructed in order to convert the electrical resistance reading into moisture percentage. As the temperature increased, the resistance in ohms decreased. Several blocks with a wide range of moisture from low to high were sealed moisture tight. When the reading of the blocks becomes constant at a constant temperature, the curve can be constructed by taking readings upon varying the temperature. Figure 1* shows the effect of temperature on the electrical resistance. All readings were corrected to 70 degrees F. As readings are made in the field, the temperature of the soil is taken for each depth in order

* Dr. H. B. Cordner, working with fall Irish potatoes and taking moisture readings with the Portable A.C. Bridge, helped to construct the temperature curve.

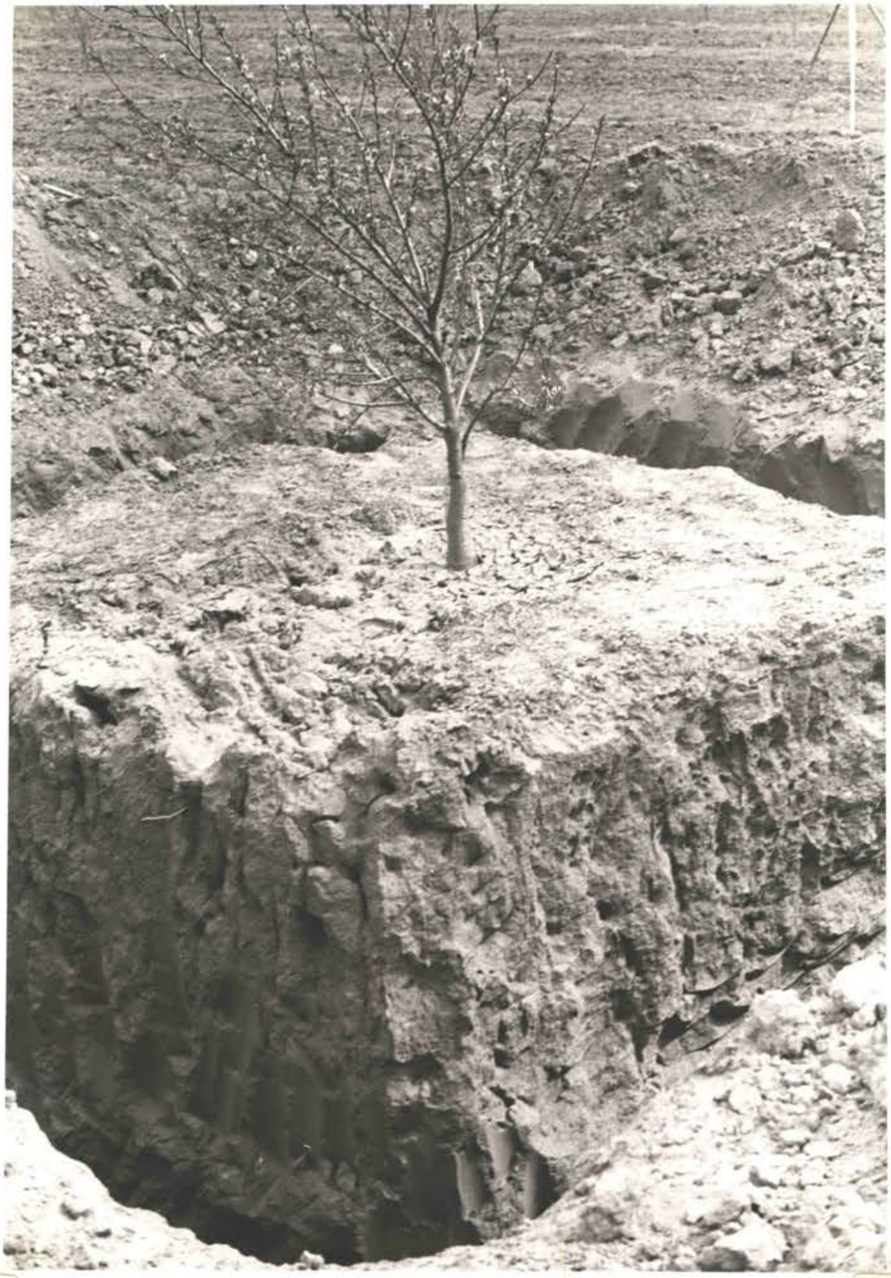

Plate 2-A. Tree planted in large hole: After one year of growth, showing trench dug preparatory to removal of soil from roots.

Plate 2-B. Tree planted in ordinary sized hole; after one year of growth showing trench dug preparatory to removal of soil from roots. Compare the size of ball with 2-A.

Plate 3. Washing the roots of a one year old peach tree from the soil with water from a large sprayer.

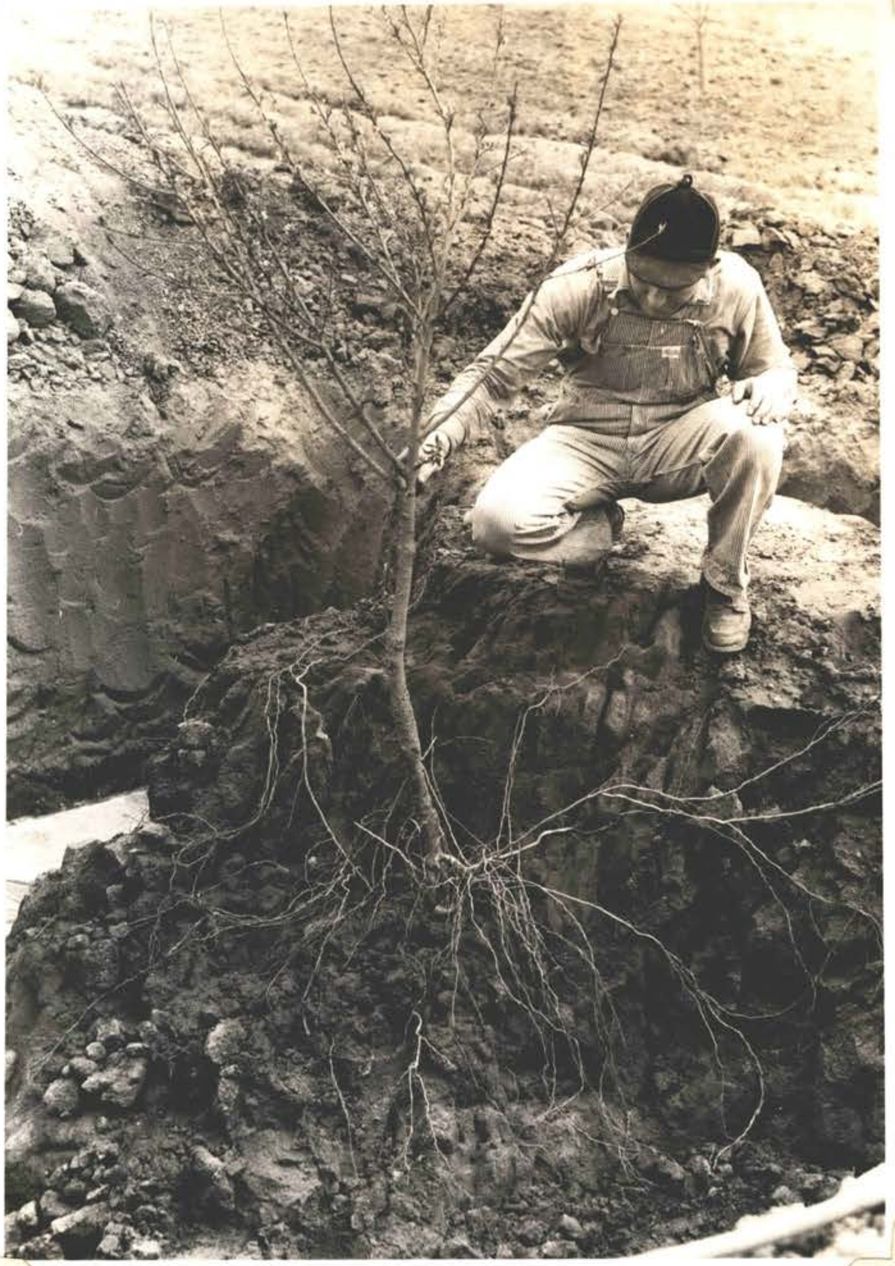

Plate 4. A one year old peach tree from dynamite hole showing the roots partly exposed by washing.

to make the proper correction.

The per cent moisture for each electrical resistance at 70 degrees F. is shown in Figure 2. Each soil varies in electrical resistance for the same amount of water present. A sandy soil has less water present at the same resistance than a heavy soil. Blocks were placed in the soil from each level and sealed. The moisture in the soil was varied from high to low. When the reading or resistance becomes stable, they are placed in 70 degrees F. chamber and readings made. From these readings the curve was constructed for each soil level studied. The per cent moisture curves were similar to the ones Bouyoucous (7) reported but the curve broke more sharply at 800 to 1,000 ohm than his.

Precipitation was recorded after each rain. Thus by using the conductive bridge the movement of moisture downward could be traced.

AERATION AND POROSITY

Porosity indicates to some extent the looseness of the soil and is thus closely related to and associated with aeration. Pore space was determined from the real and the apparent specific gravity. Specific gravity was determined by the use of a pycnometer and apparent specific gravity by a comparison of the volume and weight of the soil. An undisturbed block of soil was obtained to get the volume. The air space is calculated from the pore space with the known amount of water present in the soil. The air space is that portion of the pore space not filled with water.

SOIL PROFILE

The description of the soil profile as found in the orchard where the peach trees are growing show it not to be the ideal type. The top five inches is in the A1 horizon being dark brown in color. This is the soil that is turned by plowing and it contains the largest amount of organic matter. The A^2 horizon extends from five to nine inches and it is a little lighter in color lacking some of the organic matter of A^1. B^1 horizon extends from nine to twenty-eight inches, being brown in color with mottling of light brown. This is a compressed area that contains some clay. The B^2 horizon extends from 28 to 40 inches, being of a light brown color. This is the most compressed area. There is a sufficient quantity of clay present to make the soil sticky. C^1 horizon extends from 40 to 46 inches, being yellowish brown with an intermixture of reddish brown and grayish spots. The C^2 horizon is below 46 inches, being very sandy and a yellowish brown color much lighter than C^1. It shows mottling of brownish red and some grayish spots.

The mottling of grayish spots in the soil shows it may be less productive according to Oskamp and Batjer (34) findings in the New York soil. The mottling is probably due to poor aeration.

RESULTS

Modification of the subsoil had a marked influence on root development and top growth of peach trees. The more loose and better drained soils developed much better root systems. The trees planted in large holes had the greatest root and top development. The roots were more branched and more extensive than with the other treatments. After one year of growth in the large holes, the roots had a maximum spread of 12 feet and reached a maximum depth of 7.5 feet. This signifies deep penetration and wide extension of the roots during the first years in a soil with good aeration and plenty of moisture. Plate 5 shows the vertical development of the roots in large holes; while Plate 6 shows the horizontal development. The roots extend far beyond the ends of branches of the tree in one year's growth. Plate 7 compares the roots to top in spread.

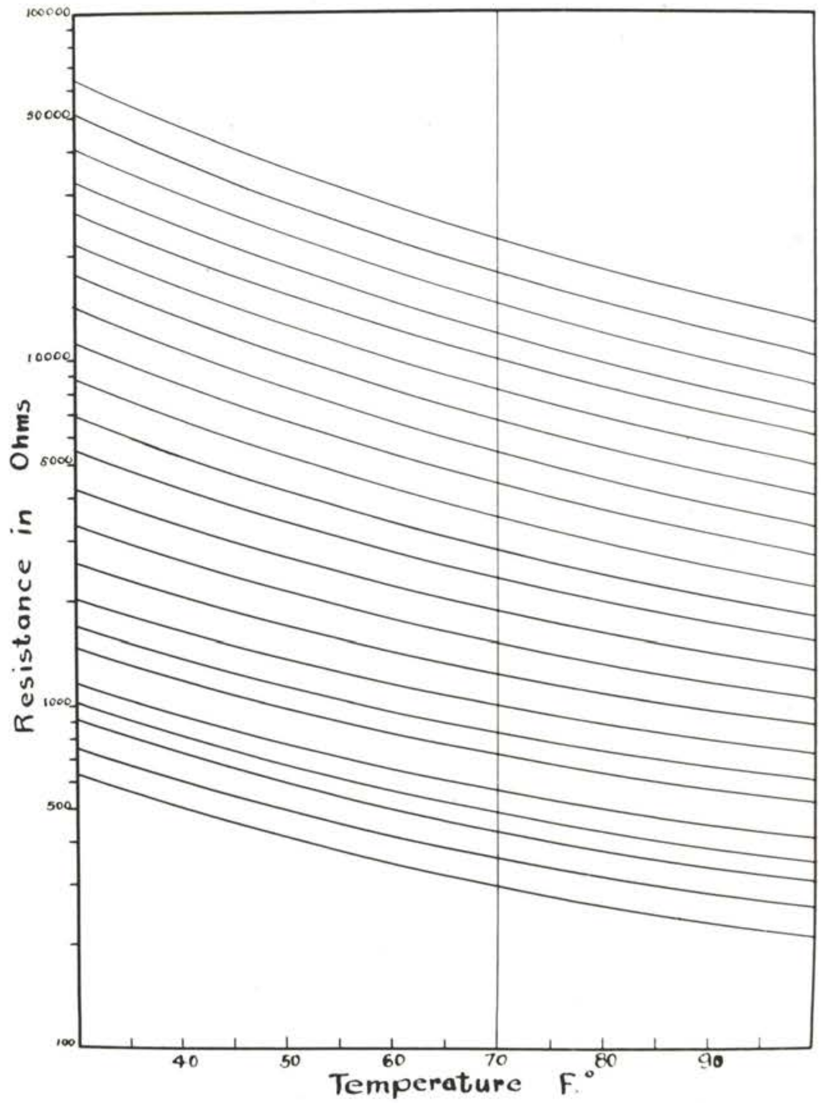

Figure 1. The influence of temperature on the electrical resistance in ohms.

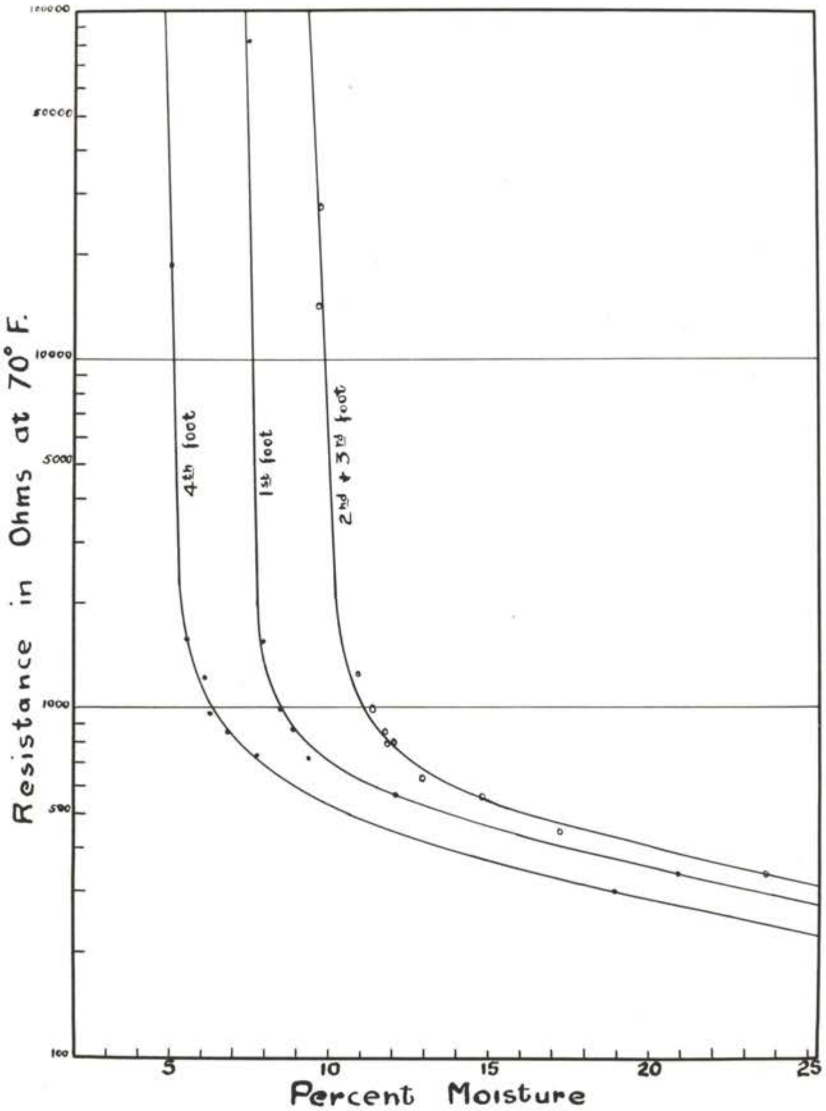

Figure 2. The percent of moisture for each electrical resistance in ohms at 70°F. from each soil level in the orchard.

Root development was less in dynamited soil than that found in the large holes and they were not branched as well, but were somewhat better than the ordinary planting. The maximum spread and depth was eight feet and four inches and five feet respectively. The roots that penetrated to the lower depths went through the area of soil where the cavity was formed by dynamite. The plate 8, 9 and 10 show the vertical, horizontal and the root to top growth, for the dynamited treatment.

In the ordinary planting, the root system was quite shallow. The penetration in depth extended to only two feet, thus showing that the hard pan had restricted the roots to the upper horizon. The maximum spread was six feet with very little branching of the roots. The number of fibrous roots was less than in the other treatments. Plates 11, 12 and 13 show the extent of root development in the undisturbed soil. The top growth was very small as compared to the other two treatments.

The root development as found was very similar to the findings of other investigators. Most of the roots were in the upper 12 to 16 inches of the top soil. Roots were encountered near the surface. The cultivation and lack of moisture prevented them from coming up to the surface. In the ordinary planting the roots remained closer to the surface but where the subsoil was altered the root development extended farther down. In the former, a great many roots were found just above the plow line, six to eight inches deep. Otherwise the roots were fairly well distributed through the top 16 inches for the ordinary planting. The top 18 inches would include 90% of the roots from the ordinary planting tree. The roots of trees planted in dynamited holes had developed a little deeper than those of the ordinary planted trees. The large hole planting had the roots developed quite extensively to the third foot at the end of the first year's growth.

Plate 5. The vertical spread of Fair Beauty peach roots from a large hole treatment. One year's growth.

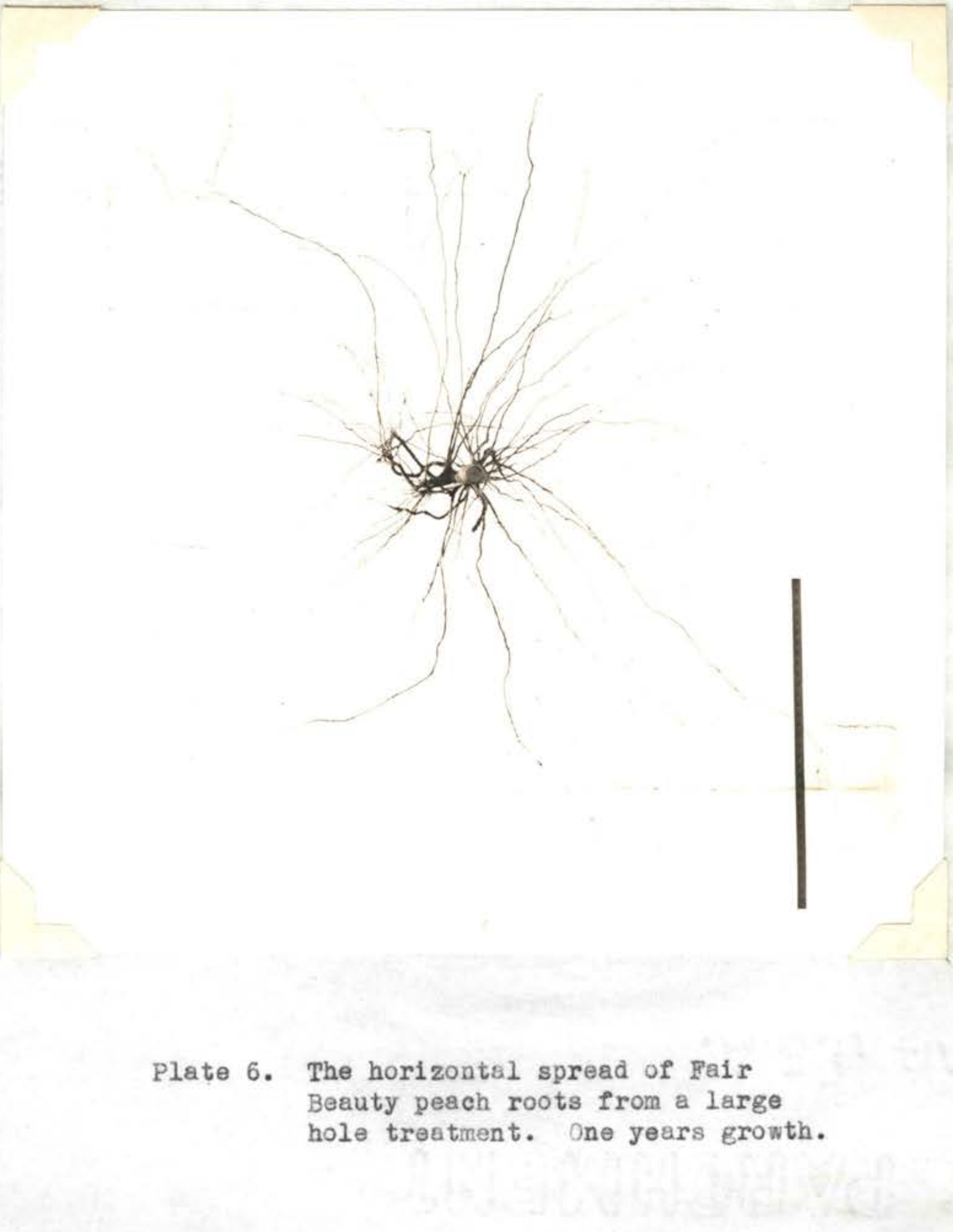

Plate 6. The horizontal spread of Fair Beauty peach roots from a large hole treatment. One years growth.

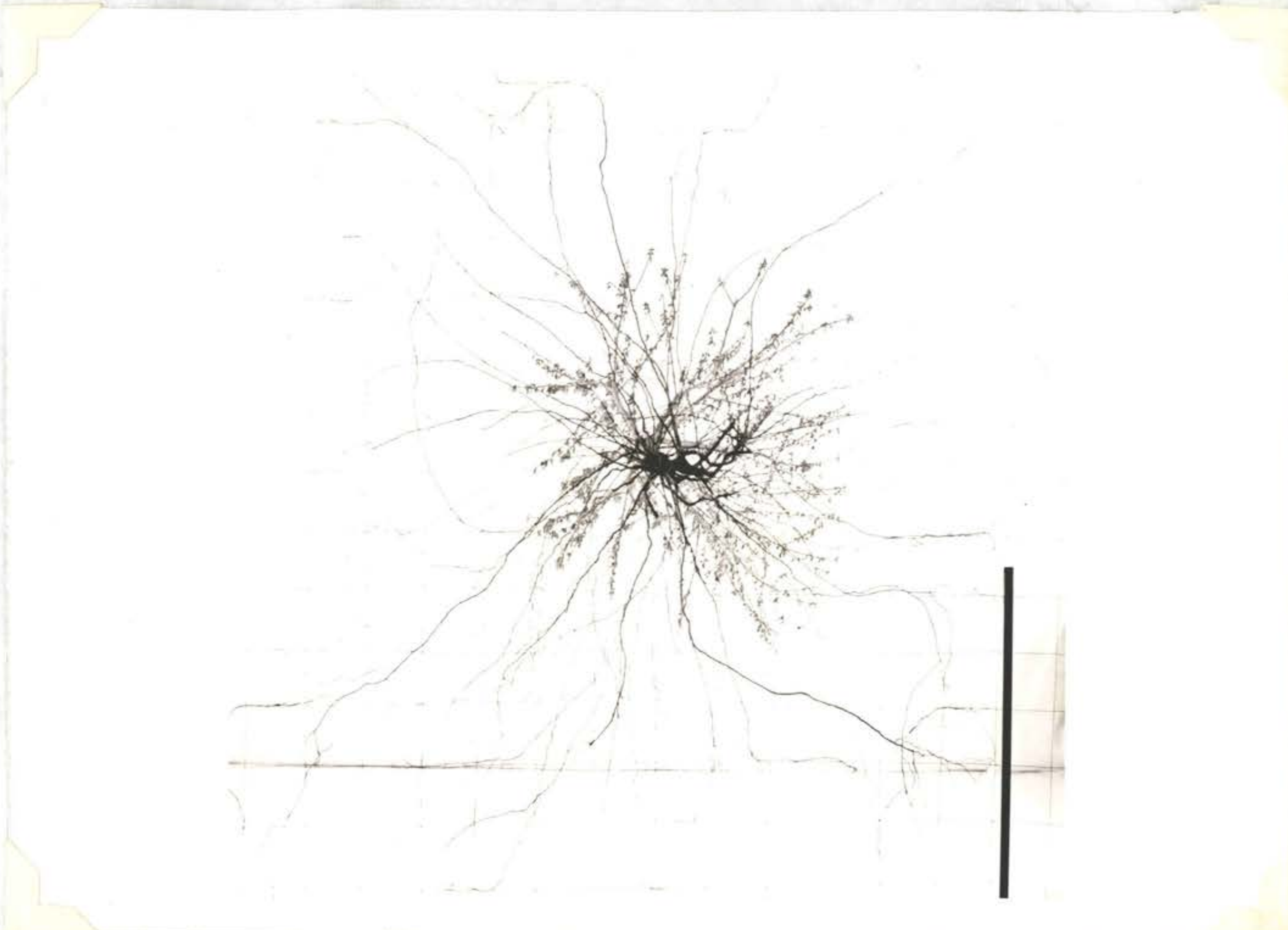

Plate 7. The comparison of the root to the top growth in spread for one year's Fair Beauty peach growth in large hole treatment.

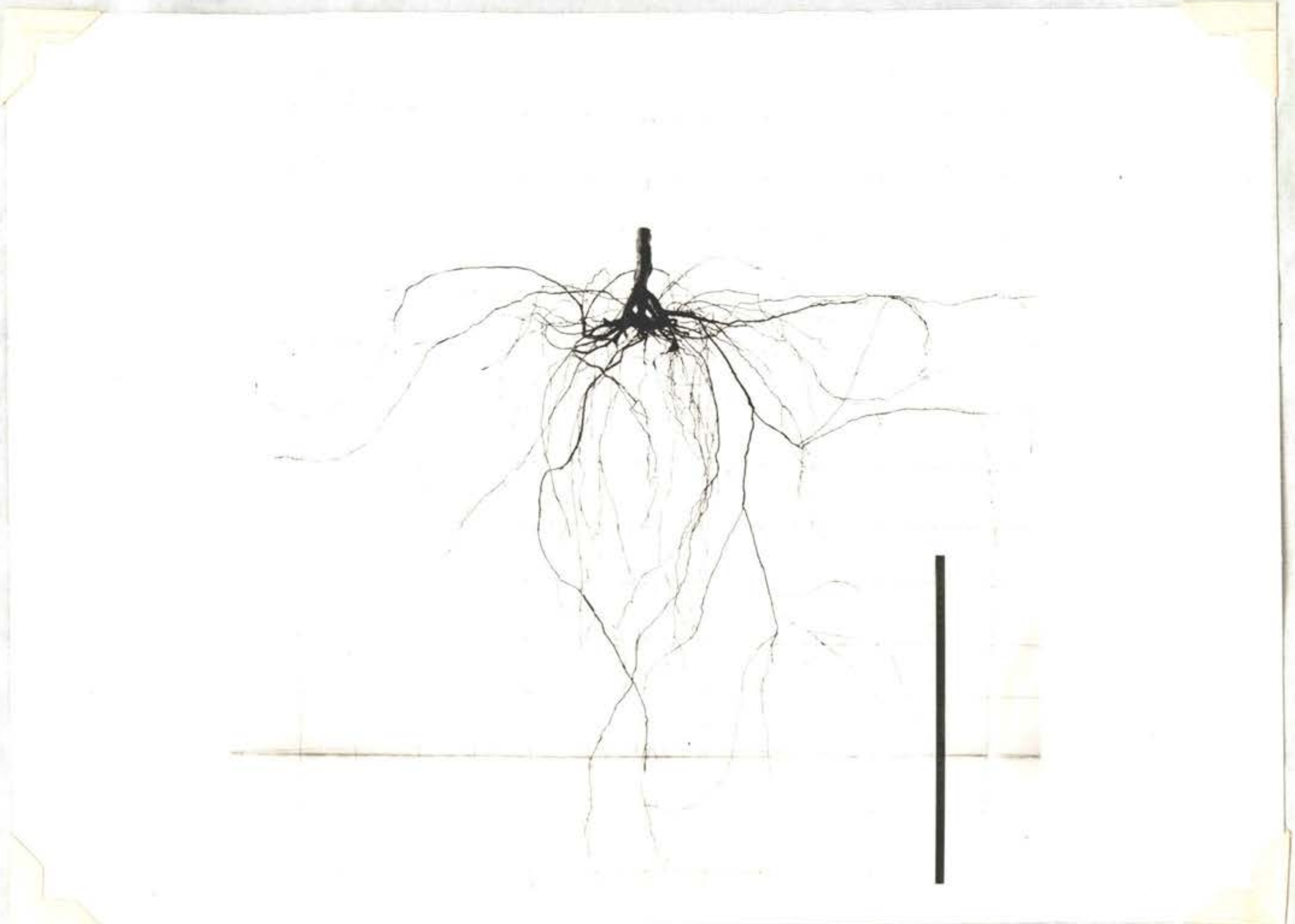

Plate 8. The vertical root spread of a one year's Fair Beauty peach growth in dynamited soil.

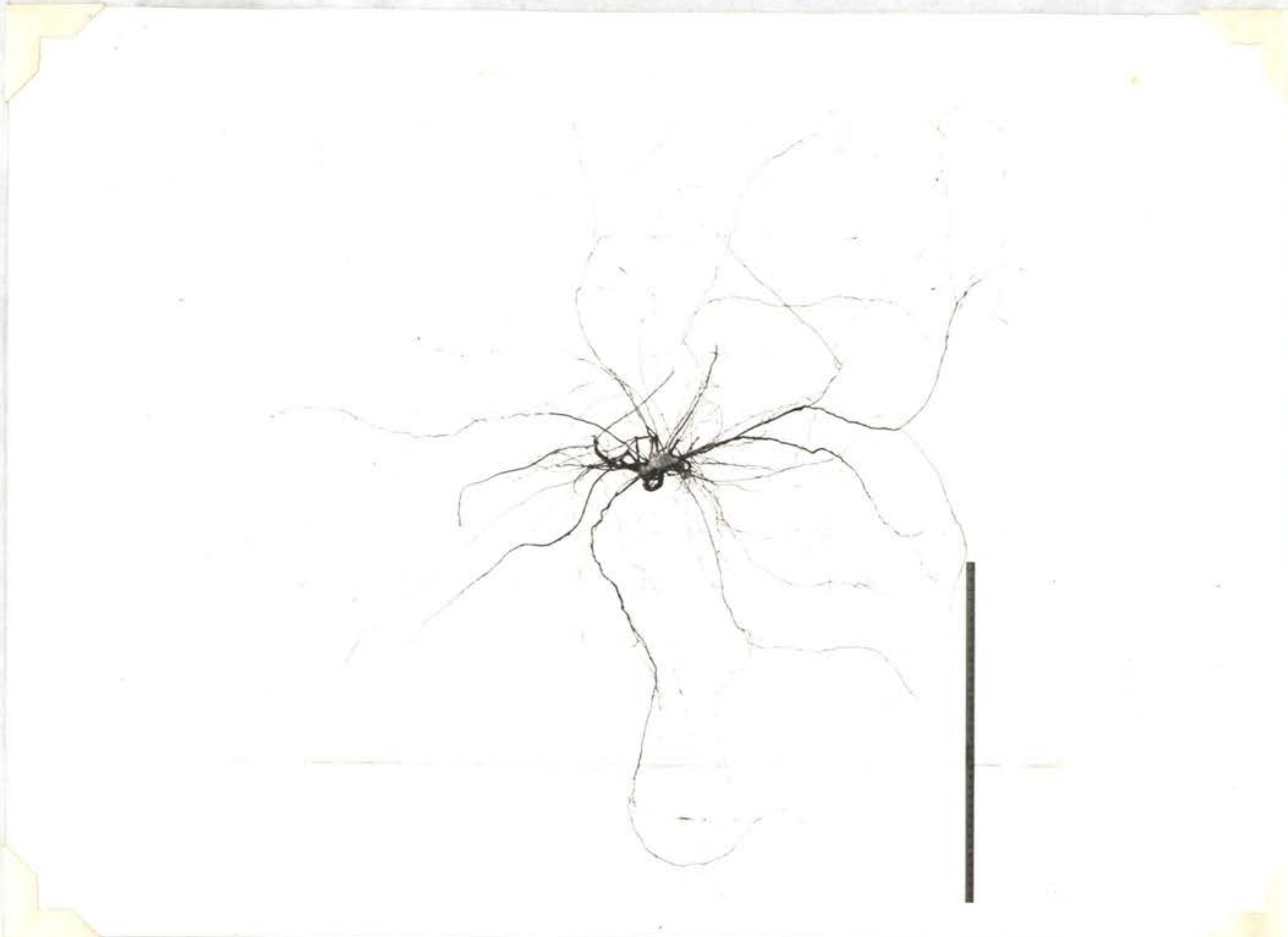

Plate 9. The horizontal root spread of a one year's Fair Beauty peach growth in dynamited soil.

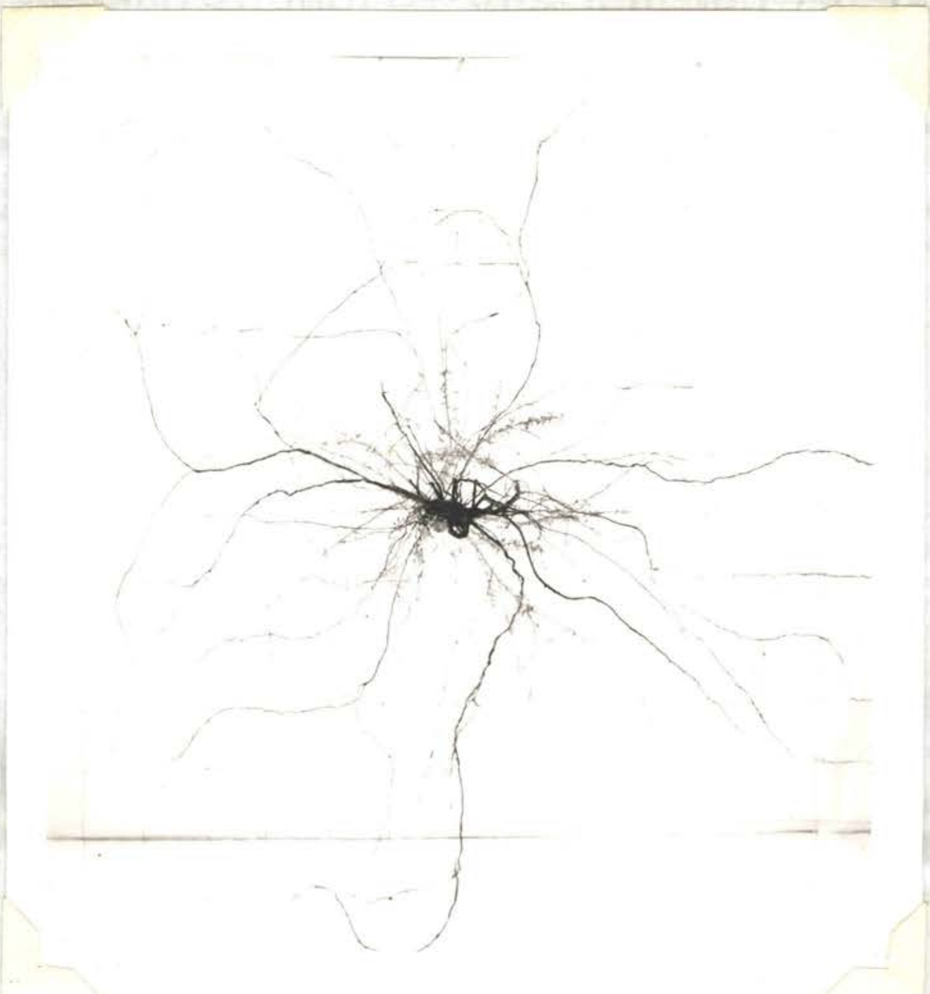

Plate 10. The comparison of the root to the top growth in spread for one year Fair Beauty peach growth in dynamite soil.

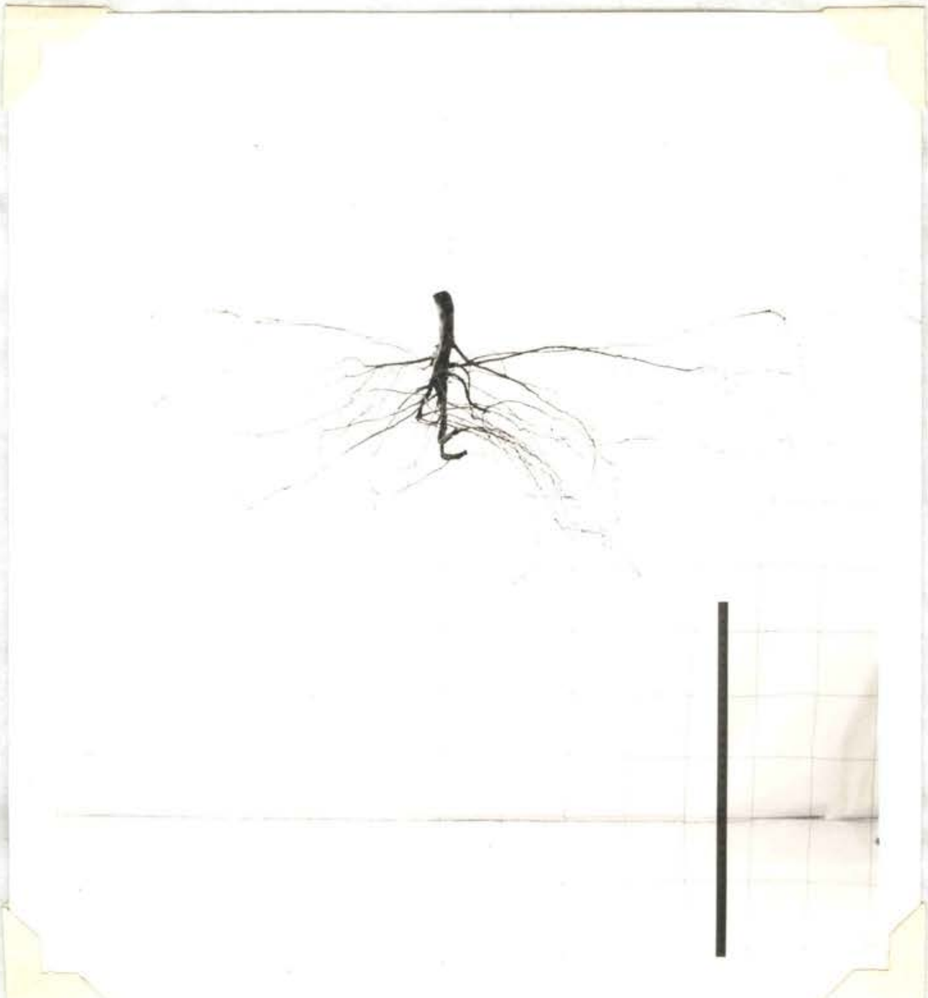

Plate 11. The vertical spread of Fair Beauty peach roots for one year's growth on undistrubed soil (ordinary planting).

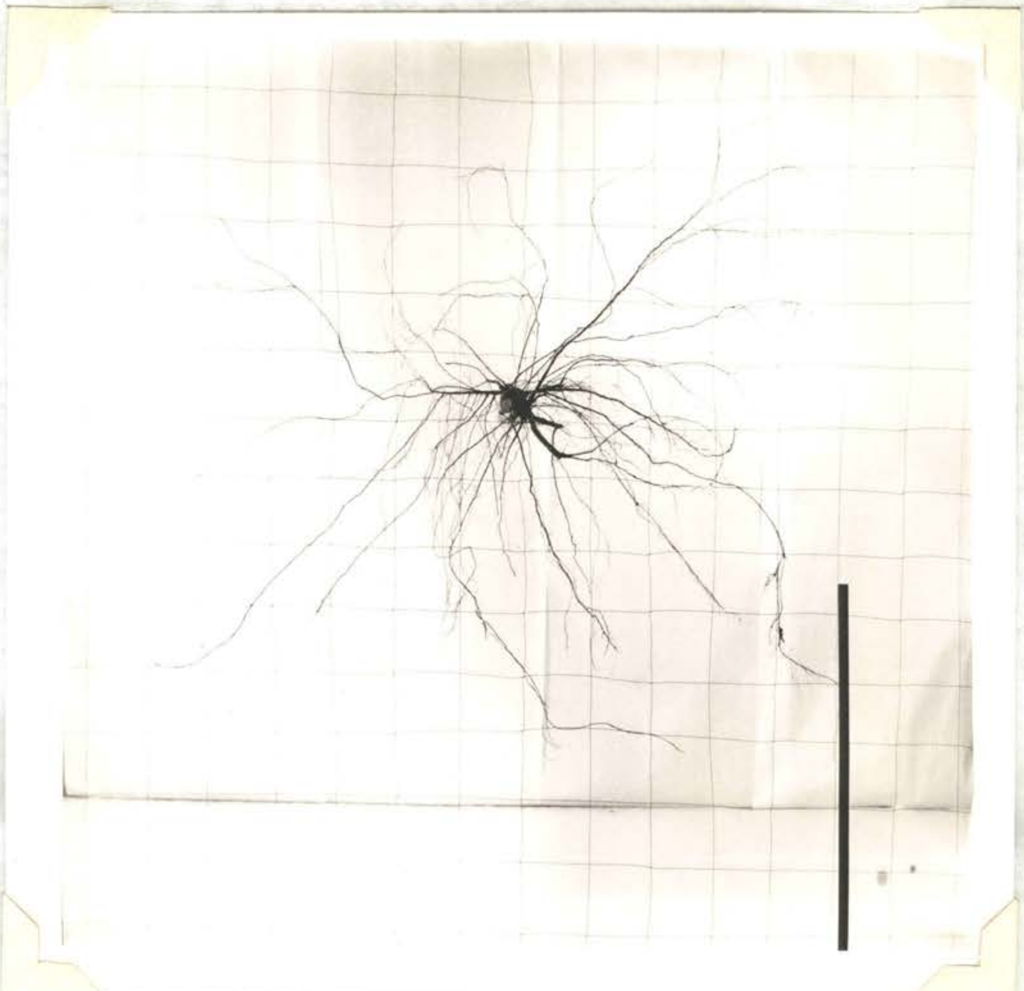

Plate 12. The horizontal spread of Fair Beauty peach roots for one year's growth on undisturbed soil (ordinary planting).

Plate 13. The comparison of the root to the top growth in spread for one year Fair Beauty peach growth in dynamite soil.

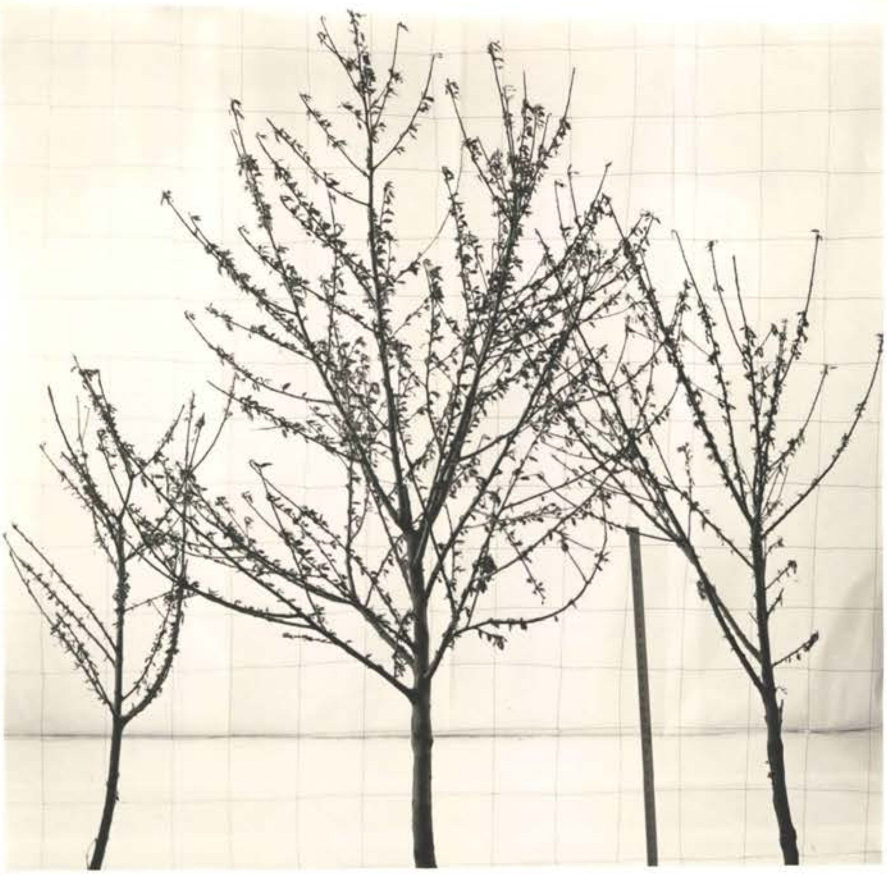

Plate 14. The top growth of Fair Beauty peach trees from each subsoil treatment. From left to right- ordinary planting hole, large hole, and dynamite hole tree.

Table 1. Effect of subsoil treatment on the root and top growth of one and two year old Fair Beauty peach trees.

Treatment of subsoil	Roots: Max. spread	Roots: Max. depth	Roots: Total wt. in pounds	Tops: Max. height	Tops: Max. spread	Tops: Total wt. in pounds	Tops: No. of blossoms
1 yr. growth							
Ordinary planting	6'0"	2'0"	1.0	4'5"	2'6"	1.3	65
Dynamite	8'4"	5'0"	1.6	6'0"	3'9"	2.4	42
Large holes	12'0"	7'6"	2.3	6'5"	4'6"	5.6	309
2 yrs. growth							
Ordinary planting	16'6"	4'0"	4.31	7'0"	4'6"	7.95	
Dynamite	18'0"	5'9"	8.50	7'5"	6'0"	12.00	
Large holes	22'0"	10'0"	10.60	9'6"	8'0"	23.31	

The growth of the top was in proportion to the amount of root development. Trees in large holes had the largest root development and they had the largest top growth. The main branches of these trees were much longer and had many more lateral branches develop than did the other two treatments of trees. Trees in dynamite holes made better growth than those in ordinary planting. Plate 14 compares the one year's top growth from each treatment.

The weight of the roots and the tops also were correlated to the growth development. After one year's growth the weight of the trees from large holes was more than twice that of the ordinary planted trees. After two year's growth the weight of roots and top were nearly three times that of the ordinary planting. Plate 15 shows the difference in size of top growth from each of the treatments. The largest tree comes from the large hole treatment, while the smallest tree comes from the ordinary planting. In Table 1 a comparison as to the growth of the roots and tops under each treatment is shown.

During the first and second year proportionate root development was greatest in the large holes. The roots had penetrated out farther and deeper than the others. The maximum penetration was 10 feet deep with a maximum spread of 22 feet. Small roots were more numerous and more extensive throughout the large holes than in either of the other treatments. As the roots reached the outer edge of the large hole, they branched and entered the undisturbed soil. Many roots were found at the five foot level. Plate 16 shows the vertical development, while Plate 17 shows the horizontal development of a two year's root growth from the large hole planting.

The ordinary planting had a maximum root spread and depth of 16 feet and 6 inches and 4 feet respectively while the dynamited trees had a maximum spread and depth of 18 feet to 5 feet and 9 inches respectively. The Plates 18 and 19 show the development of roots for two year's growth in dynamited soil. The few roots that reached the maximum depth of five feet and nine inches went through the area where the dynamite was exploded. The tree shows larger roots than the ordinary planting trees. Plate 20 and 21 on ordinary planting show the root development to be the least extensive from trees planted in small holes or holes of the size generally made. The penetration was considerable less than either of the other two treatments of trees.

The total number of blossoms per tree was higher in the large hole tree. It was quite noticeable at blossoming time. The number of blossoms per tree for large hole, dynamite, and ordinary planting are 309, 42 and 65 respectively. This count is from trees that were removed for the root and top study. The numbers of blossoms borne upon trees in dynamite and ordinary plantings probably were not significantly different although the dynamited trees had the least blossoms present. Frost killed the blossoms during the blooming period and prevented a comparison as to production from each of the treatments.

November 11, 1940, a severe freeze damaged the trees heavily, killing many of them. The trees were growing very vigorously at the time the sudden drop in temperature occurred. The temperature dropped to 7 degrees F. killing the phloem tissue around the trunk and the crotchs of the limbs. This was the coldest weather for the entire winter of 1940 and 1941. The Sun Glo was damaged more than the Fair Beauty variety. 25% of the dynamite Fair Beauty trees died while about 50% of the Sun Glo trees died. The dynamited trees were damaged more than the other treatments. This probably indicates prolonged growth in the fall as a result of dynamiting.

The comparison of the spread of the roots to the spread of the top growth is shown in Table 1. The roots extended far beyond the outer

Plate 15. The two year's top growth of Fair Beauty peach trees in each soil treatment. Left to right dynamite soil, large hole, and ordinary planting.

Plate 16. A two year's vertical root development of a Fair Beauty peach tree in large hole treatment.

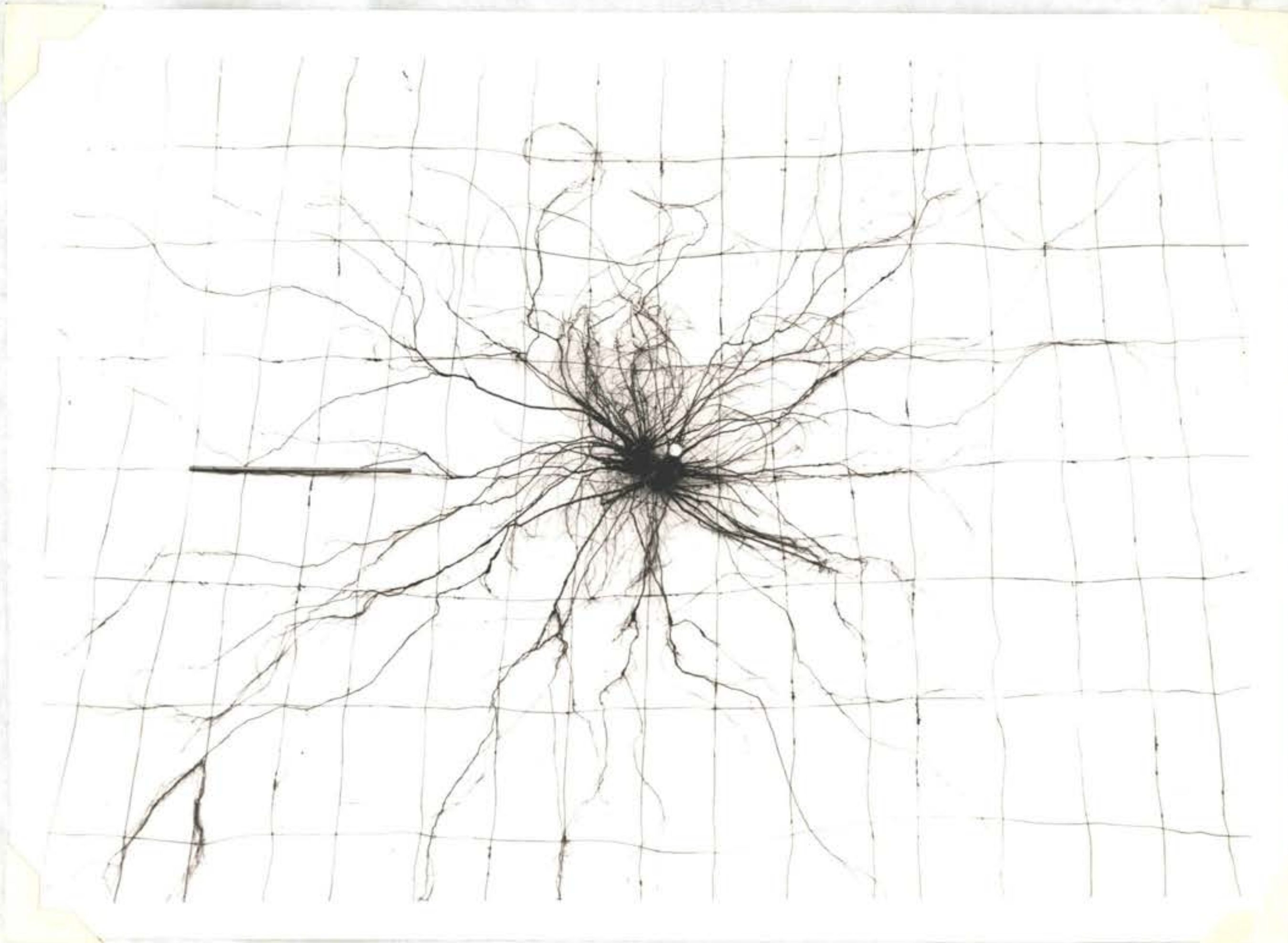

Plate 17. A two year's horizontal root development of a Fair Beauty peach tree in large hole treatment.

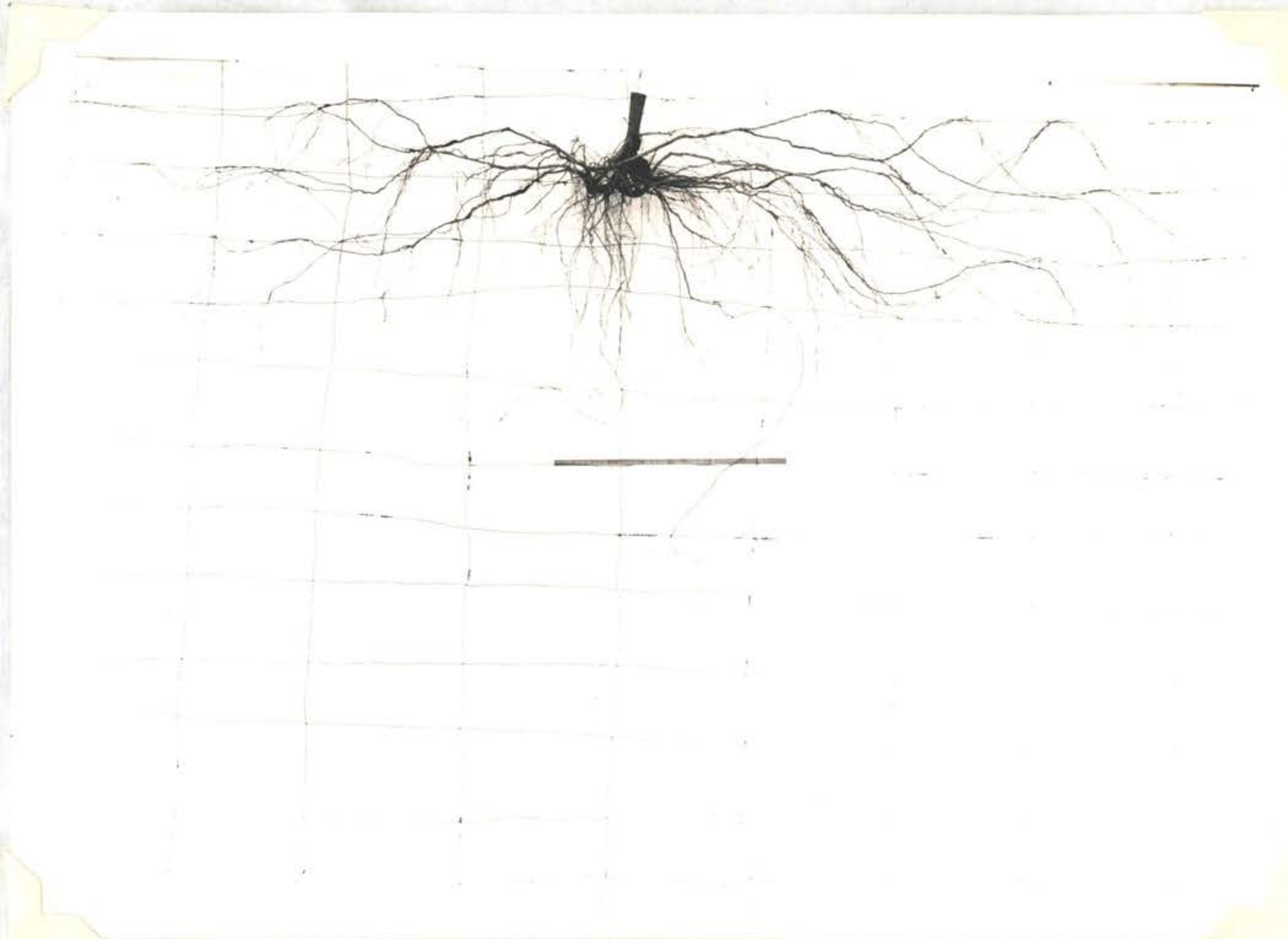

Plate 18. A two year's vertical root development of a Fair Beauty peach tree in dynamite soil.

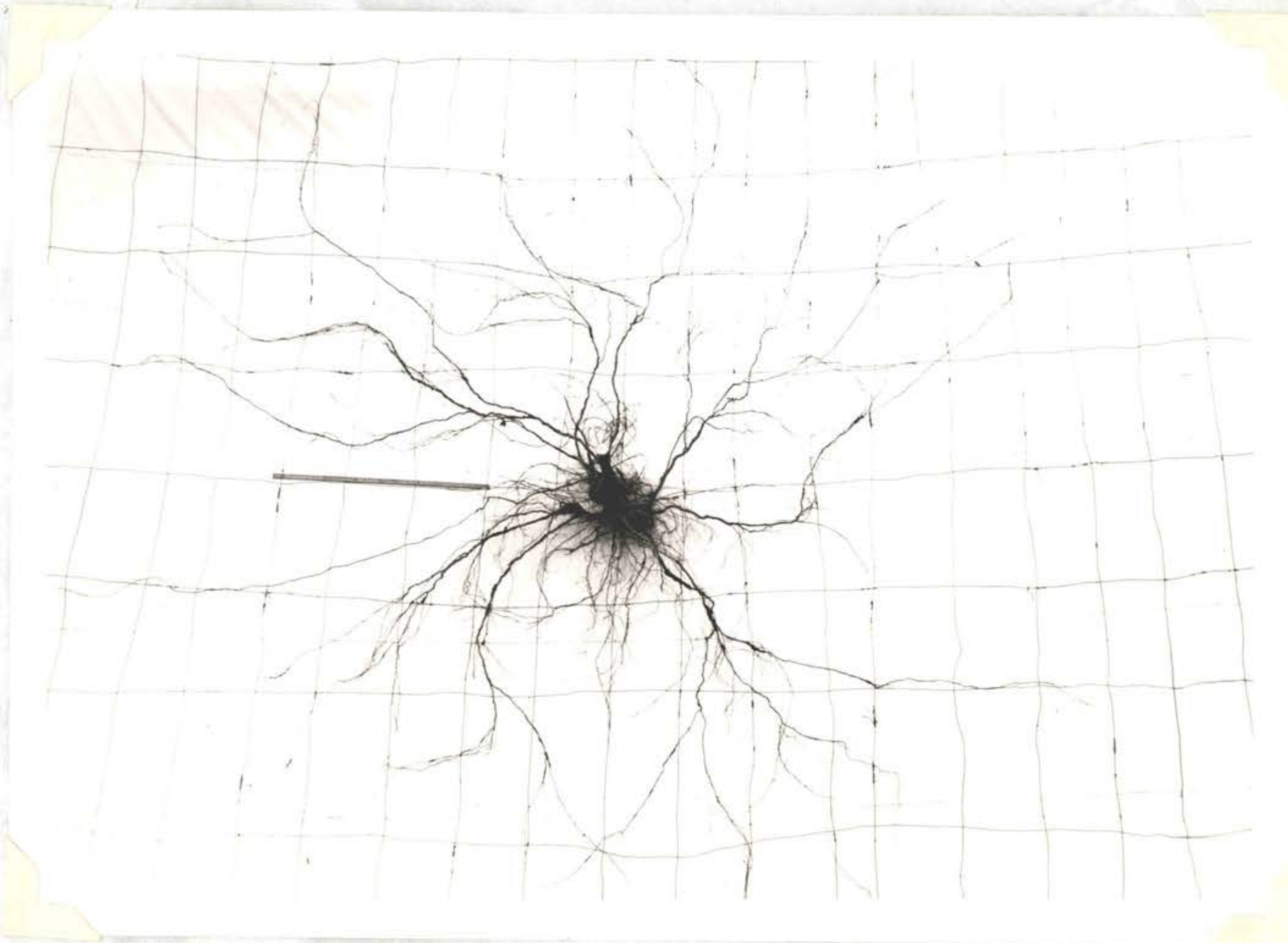

Plate 19. A two year's horizontal root development of a Fair Beauty peach tree in dynamite soil.

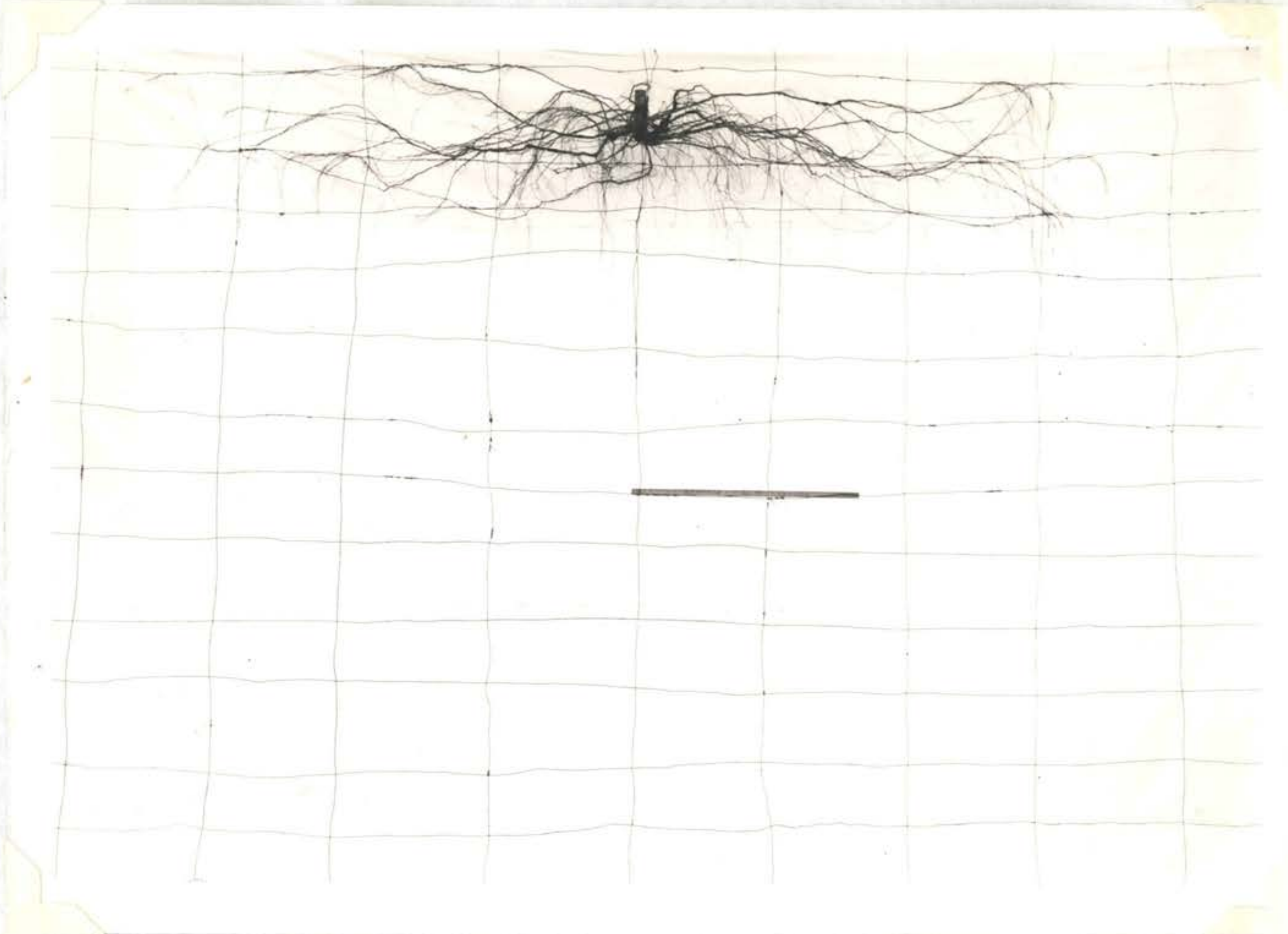

Plate 20. A two year's vertical root development of a Fair Beauty peach tree in undisturbed soil (ordinary planting).

Plate 21. A two year's horizontal root development of a Fair Beauty peach tree in undisturbed soil (ordinary planting).

branches of the tree even the first year. The maximum spread of roots to the top in the large holes during the first year was 12 feet to 4 feet and 6 inches and the second year was 22 feet to 8 feet. The ordinary planting had a root and top spread of 6 feet to 2 feet 6 inches in the first year, while the second year there was a spread of 16 feet and 6 inches to 4 feet and 6 inches.

Trees in the large holes made the greatest trunk growth. It was comparable to root and top development of the tree. The trees in dynamited soil were better than those planted by the ordinary planting in small holes. The trunk growth was highly significant in analysis of variance for the first year's growth and the total growth made in two years but the second year's growth was not significant. All the trees had grown about equally during the second year. The Fair Beauty and Sun Glo also made about an equal amount of growth as compared to each other for the second year. However, the two year's growth of the Sun Glo did show to be significant on the 5 per cent level and the Fair Beauty was not significant. The total growth of Sun Glo was not as great as the Fair Beauty because of the delayed planting of the variety. The Fair Beauty had a better start although there may be a varietial difference as to growth. Table 2 shows the trunk growth of the two varieties for the one and two year's growth period.

The top growth in one year as indicated by the average branch length on the Fair Beauty and the Sun Glo is found in Table 3. The length of the main branches and of the lateral branches was much greater where the subsoil was altered. Trees in large hole had the greatest growth. Highly significant odds were found in favor of the treatment for the average branch length. The average branch length was less in the Sun Glo than in the Fair Beauty, but the average lateral branch growth was about the same.

From the analysis of variance the location and replication showed significant odds on the Sun Glo peach trees. This means the soil was not uniform under all trees for this variety. The average branch length in Fair Beauty for large holes, dynamite, and ordinary planting was 29.69, 22.47, and 17.92 inches respectively while the Sun Glo was 24.90, 20.61 and 15.61 inches respectively.

The soil samples that were taken with a sampling tube on September 30, 1939, showed that the relative amount of moisture from the three treatments was considerably lower in the large holes. This treatment had the most roots present in the soil and had depleted the soil of its moisture content. The ordinary planting had the least amount of moisture in the top foot. This would be expected since the roots were more concentrated in this area. A large percentage of the roots had grown horizontally just above the plow line. The analysis of variance, however, showed the top foot was not significant for the amount of moisture found in each treatment.

The second and third foot were higher in per cent of moisture in the dynamite and ordinary planting than in the large holes. This showed the root development is not so extensive in the dynamite and ordinary planting at this level and that the moisture was restricted from moving on down. The per cent moisture for the large holes, dynamite, and ordinary planting in second foot were 6.19, 9.8 and 8.39 per cent respectively and for the third foot 5.86, 10.13 and 9.40 per cent respectively. The large holes were highly significant over the other two treatments in either the second or third foot. The dynamited soil was higher in percentage of moisture but was not significant over the ordinary planting. A difference of .61 per cent is required to be significant in the second foot and .84 per cent in the third foot. The fourth foot was more uniform

Table 2. One and two year's trunk growth of Fair Beauty and Sun Glo peach trees under soil treatments.

Treatment	Fair Beauty			Sun Glo		
	1 year*	2 year**	Total***	1 year[a]	2 year[b]	Total[c]
Large holes	.84	1.09	1.93	.60	1.18	1.78
Dynamite	.52	1.08	1.60	.42	1.09	1.51
Ordinary planting	.38	1.04	1.42	.28	1.01	1.29

* Treatment very highly significant F value 81.073 exceeds the 1% level 5.45
** Treatment not significant
*** Treatment highly significant F value 20.28 exceeds the 1% level 5.45

a Treatment highly significant F value 25.14 exceeds the 1% level 5.25
Location showed to significant on 5% level
b Treatment significant F value 3.63 exceeds the 5% level 3.26
c Treatment highly significant F value 13.17 exceeds the 1% level 5.25
Location showed to significant on 5% level

Table 3. Effect of growth on the main branches and lateral branches of 1 year old Fair Beauty and Sun Glo peach trees in each subsoil treatment.

Treatment	Fair Beauty: Ave. branch length*	Fair Beauty: Ave. lateral br. length**	Sun Glo: Ave. branch length[a]	Sun Glo: Ave. lateral br. length[b]
Large holes	29.69	9.78	24.90	10.32
Dynamite	22.47	8.43	20.61	8.92
Ordinary Planting	17.92	5.90	15.61	5.94

* Treatment very highly significant F value 68.29 exceeds 1% level 5.45
** Treatment very highly significant F value 32.29 exceeds 1% level 5.45

a Treatment highly significant F value 17.43 exceeds 1% level 5.25
b Treatment very highly significant F value 74.81 exceeds 1% level 5.25

Table 4. The mean percent of moisture for each depth under three treatments. September 30, 1939.

Depth in inches	Treatment: Large hole	Treatment: Dynamite	Treatment: Ordinary	Difference needed to be significant
0-12	5.12	5.05	3.83	Not sig.
13-24*	6.10	9.81	8.40	.61
25-36**	5.85	10.03	9.40	.846
37-48	7.85	8.05	7.80	Not sign.
Total	24.92	32.94	29.43	
Ave.[a]	6.23	8.23	7.36	

* Treatment highly significant F value 24.79 exceeds 1% level 8.65

** Treatment highly significant F value 18.78 exceeds 1% level 8.65

a Treatment highly significant

Table 5. Analysis of variance of percent moisture. September 30, 1939.

Source of variation	Degree of freedom	Sum of squares	Mean square	F. value
Total	59	286.67		
Depth	3	138.28	46.0934	38.18*
Treatment	2	40.30	20.1500	16.69*
Repl.	4	4.59	1.1475	.95
Treatment-Depth	6	40.79	6.798	5.63*
Treatment-Repl.	8	19.25	2.406	1.99
Error	36	43.46	1.207	σ = 1.09

* Highly significant

in the amount of moisture present in each treatment showing it not to be significant from the analysis. Thus the percolation in the fourth foot was offset by the same amount of moisture that was removed by the roots from the large holes. The roots being able to penetrate deeper with better soil drainage in the large hole depleted the soil uniformly of its moisture supplies. In the analysis of variance treatment plus depth showed to be highly significant. This means there is a great variance in the amount of moisture present in each level of soil for all three treatments. Table 4 gives the moisture for each level in the three treatments. The analysis of variance of the moisture percentage for the first sampling is shown in Table 5.

The second sampling was taken April 20, 1940, just after growth had started. The moisture content of the soil was much higher than the September sampling because of the accumulation during winter months and the lack of evaporation from the soil and transpiration by the tree. The treatment as a whole for all depths had about the same amount of total moisture present which means that it was not significant. However, the second and fourth foot showed to be significant. Since very little water is used in the winter months, the difference in moisture percentage would be due to the difference in the rate of percolation. Percolation was more rapid in the large holes and more evenly distributed throughout the area. The dynamite and ordinary planting trees had less moisture in the third foot than the large holes, but the moisture was uniform enough that it was not significant from the analysis. The fourth foot, however, showed a variation in moisture. The large hole contained more moisture at this depth. The additional amount of moisture held in the second foot offset the shortage in the fourth foot. Table 6 shows the mean per cent of moisture for each depth in each treatment, and Table 7 shows the analysis of variance of the second sampling. The replication was variable as indicated in the analysis.

The root development is correlated to the amount of water removed from the soil during the growing season. Areas with greater root development had lower moisture content. Each soil, however, has different ranges of moisture holding capacity.

The moisture percentages of the soil indicated by readings taken with a conductivity bridge, that is, taken in place at different depths under a tree gives a very good picture as to what is happening in the soil. By taking the moisture percentages in place, the rate of percolation and the relative rate of root development can be determined in each area of soil. The percolation was very rapid in the large holes. This would be expected because the soil was loose being all top soil and containing less clay and more organic matter than the undisturbed soil at lower levels. Where the roots were most extensive, the most moisture was removed from the soil. The soil moisture became depleted much more rapidly and at lower depths in the large hole planting than under the dynamite or ordinary planted trees. The dynamited soil still retarded the movement of water but was somewhat better than the ordinary planting. It was evident that the soil was loosened or shattered so that the water and roots were going down.

After the subsoil became dry, the moisture traveled very slowly downward and took several months to go down four feet. It took about two months longer for the moisture to travel down to the fourth foot under the ordinary planting trees than under the large hole planting trees. A soil that restricts the movement of water downward will lose more water from run off and will have less area from which the roots can

Table 6. The mean percent moisture for each depth under each treatment. April 20, 1940.

Depth in inches	Treatment			Difference required to be significant
	Large holes	Dynamite	Ordinary Planting	
0-12	13.64	14.74	13.60	
13-24*	14.54	17.11	16.74	.554
25-36	15.79	14.89	15.29	
37-48**	14.94	12.03	11.97	.339
Total	58.91	58.77	57.60	
Ave.	14.73	14.69	14.40	

* Treatment highly significant F value 15.94 surpassed the 1% level 6.11

** Treatment highly significant F value 15.26 surpassed the 1% level 6.11

a Ave. treatment not significant

draw a water supply. The restriction causes the roots to grow near the surface.

Figures 3 and 4 show the range of moisture in the soil under large hole trees. During the latter part of the summer when moisture is removed rapidly, the moisture is depleted about the same for each level. The top soil had the lowest percentage of moisture but the others came very close to it. This shows that roots have penetrated to all the levels. However, the fourth foot was slower in drying out because the roots had just begun to penetrate in this area. During the dormant season and the early part of the growing season, the moisture increases with the depth. 7.31 per cent of moisture was found, during the driest season in the top soil.

Figure 5 and 6 showed a greater range of per cent of moisture than that of the large holes. They show the per cent of moisture in the soil under dynamited trees. Figure 7 and 8 are from the ordinary planted trees and also show a variation in range and much similar to the per cent of moisture in the soil under dynamite plantings. The first foot of soil corresponds to the first foot in the large holes being the lowest in per cent of moisture over the other three levels. The moisture, however, was higher than that found in the large holes. The first foot and the fourth foot contained about the same amount of moisture in the ordinary planting but the dynamited soil showed more moisture in the fourth foot during the season of high moisture. This shows more moisture is reaching the fourth foot under dynamiting than the ordinary planting during the dormant season. Of these two treatments the third foot contains the most moisture and remains the highest throughout the season. During the driest time in August and September, the fourth foot contains the least amount of

Table 7. Analysis of variance of percent moisture. April 20, 1940.

Source of variations	Degree of freedom	Sum of squares	Mean square	F value
Total	95	315.4899		
Depth	3	139.5550	46.518	47.84*
Treat.	2	2.0820	1.041	1.07
Rep.	3	8.1453	2.715	2.79**
Loc.	1	0.0154	.015	.015
Depth-Treat.	6	86.209	14.368	14.77*
Loc.-Treat.	2	5.5891	2.794	2.87
Error	76	73.8941	69.722	.986

* Highly significant
** Significant on 5% level

moisture in the dynamited soil. Only one of the ordinary planted trees showed this condition because the roots had penetrated around each block to remove the moisture. The other ordinary planted tree, having the roots more shallow, had a much higher moisture percentage at the lower depths. There were enough roots present in this lower area of dynamite trees to extract most of the moisture. About 5.00 per cent moisture is present in the fourth foot.

The per cent of moisture as determined by the oven dry basis was similar to the per cent of moisture found by the conductivity bridge method during corresponding seasons. The moisture runs low during the dry part of the growing season, but it will attain field capacity during the winter months. With a normal rain fall of about 32 inches per year, the tree will deplete the soil of most of its available moisture by the middle of July. The rain fall being the highest here for the months of April and May will sustain a high moisture level in the soil longer than if the rain fall was lower for that period. During the growing season large quantities of water are taken from the soil.

In removing the porous blocks from the field, it was observed that the blocks showing the lowest moisture percentage had the most roots in the area around the block. In the sand of the fourth foot which showed very low moisture for the dynamited soil there were a few roots in the area which probably removed the available moisture. The sand cannot hold as much water as the overlying heavier top soil and with the few roots present to remove the moisture it was much the lowest. In the large holes, roots were more extensive and larger than in the other two treatments.

The large holes had root development from six to 42 inches and medium root development on down to 48 inches. Several roots were found

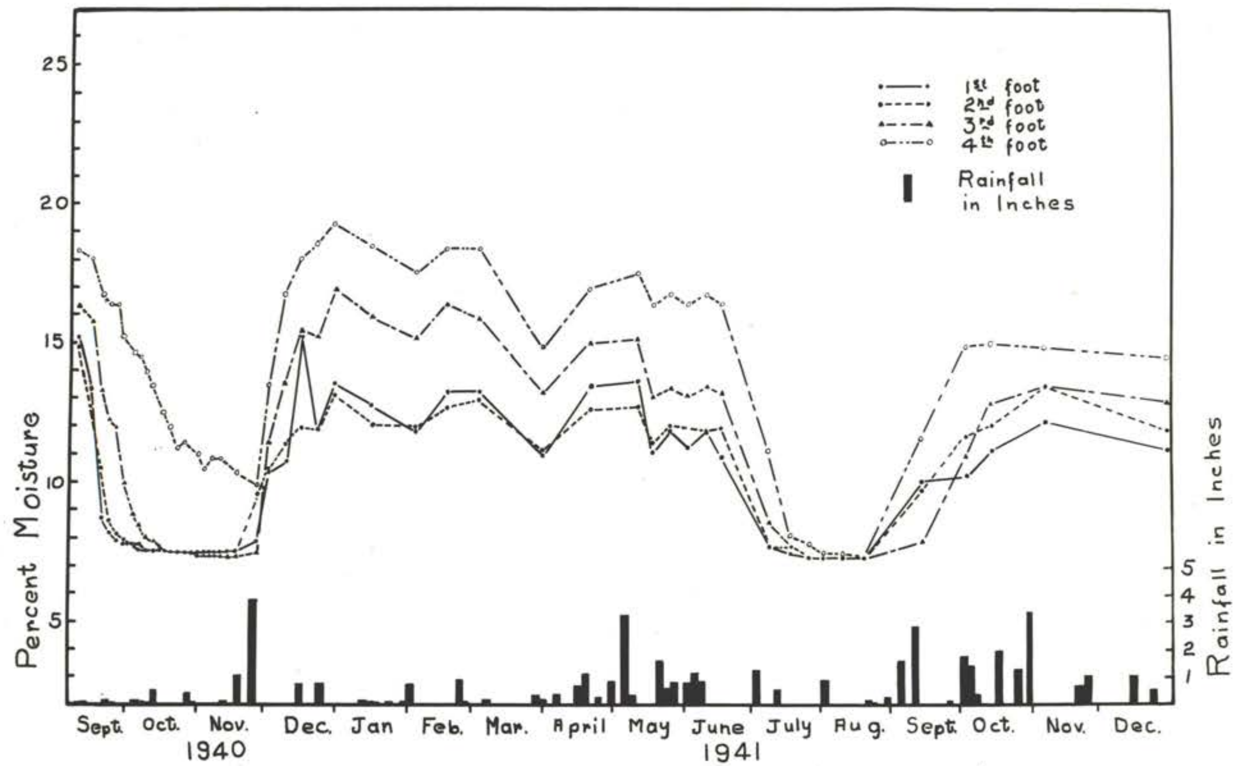

Figure 3. The range of moisture in each depth and the rainfall corresponding for peach tree planted in a large hole. Tree number 1.

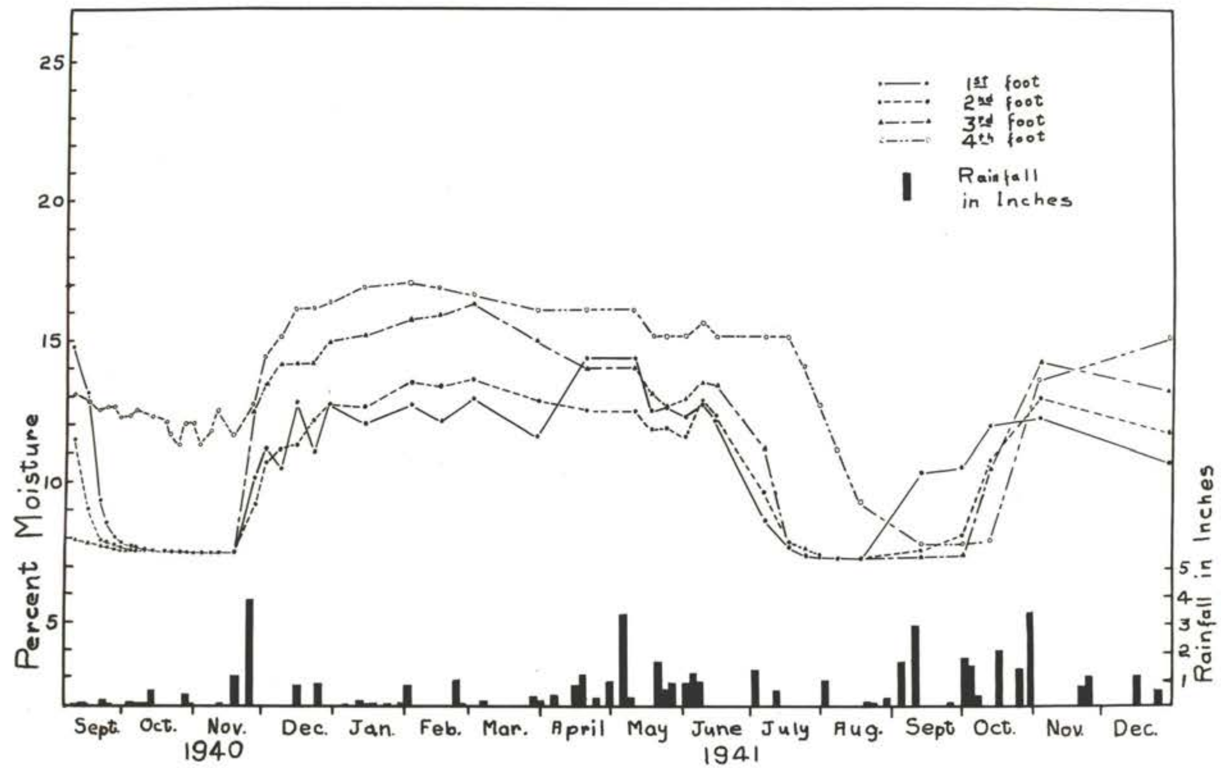

Figure 4. The range of moisture under peach tree number 2. The tree is in a large hole treatment. The root development was not as rapid as in Figure 3 at the fourth foot but by August and September it had penetrated into the area and depleted the soil moisture.

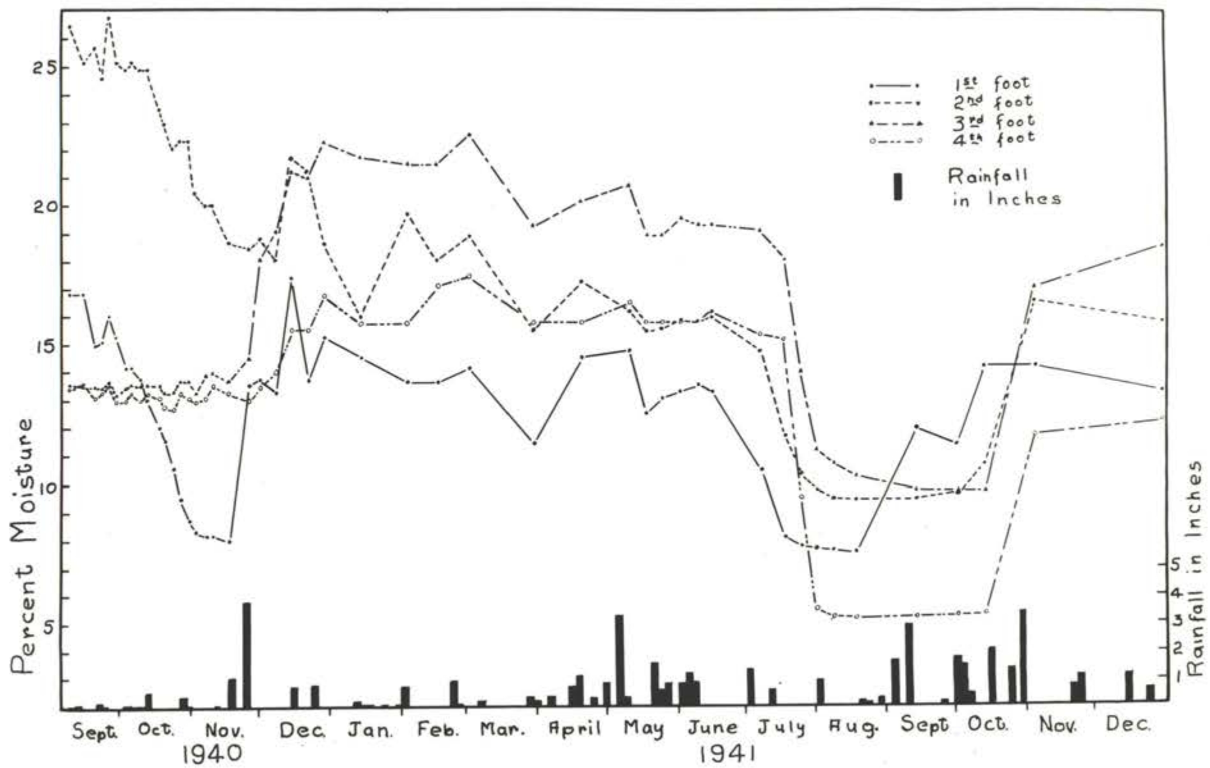

Figure 5. The range of moisture under peach tree number 3. This tree is in a dynamited soil. The moisture is high in third foot during winter months. Only top shows a reduction in moisture in Oct., 1940. The fourth foot drops lowest in Aug. to Sept. in 1941.

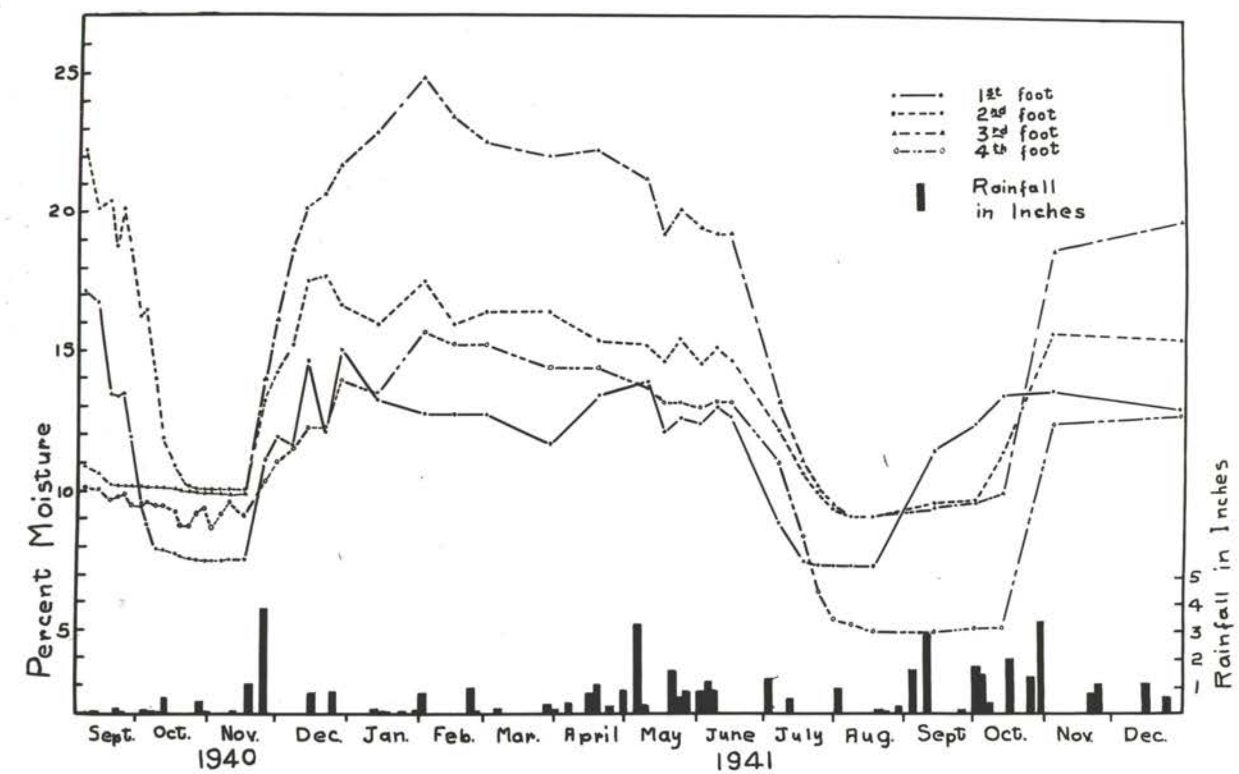

Figure 6. The range of moisture under peach tree number 4. From a dynamited soil.

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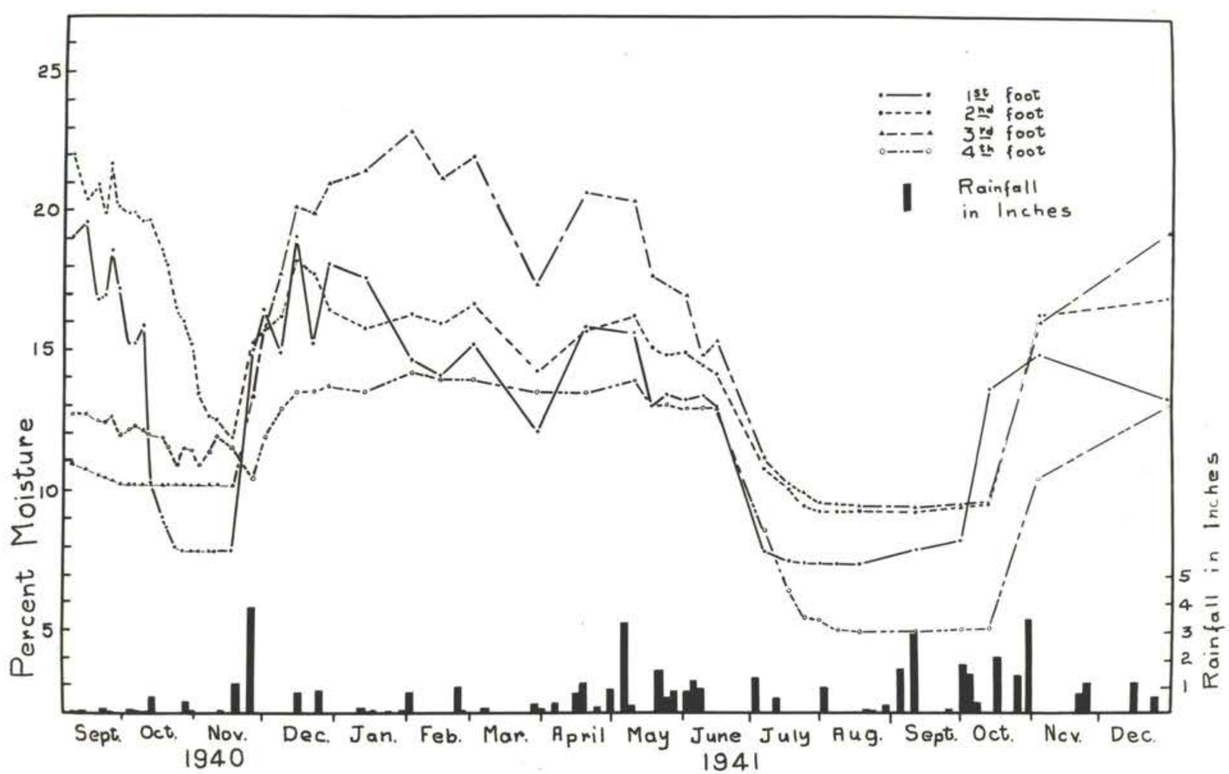

Figure 7. The range of moisture under peach tree number 5. Planted in undisturbed soil (ordinary planting). Roots found around the block in the fourth foot accounts for low moisture content during Aug. to Oct., 1941.

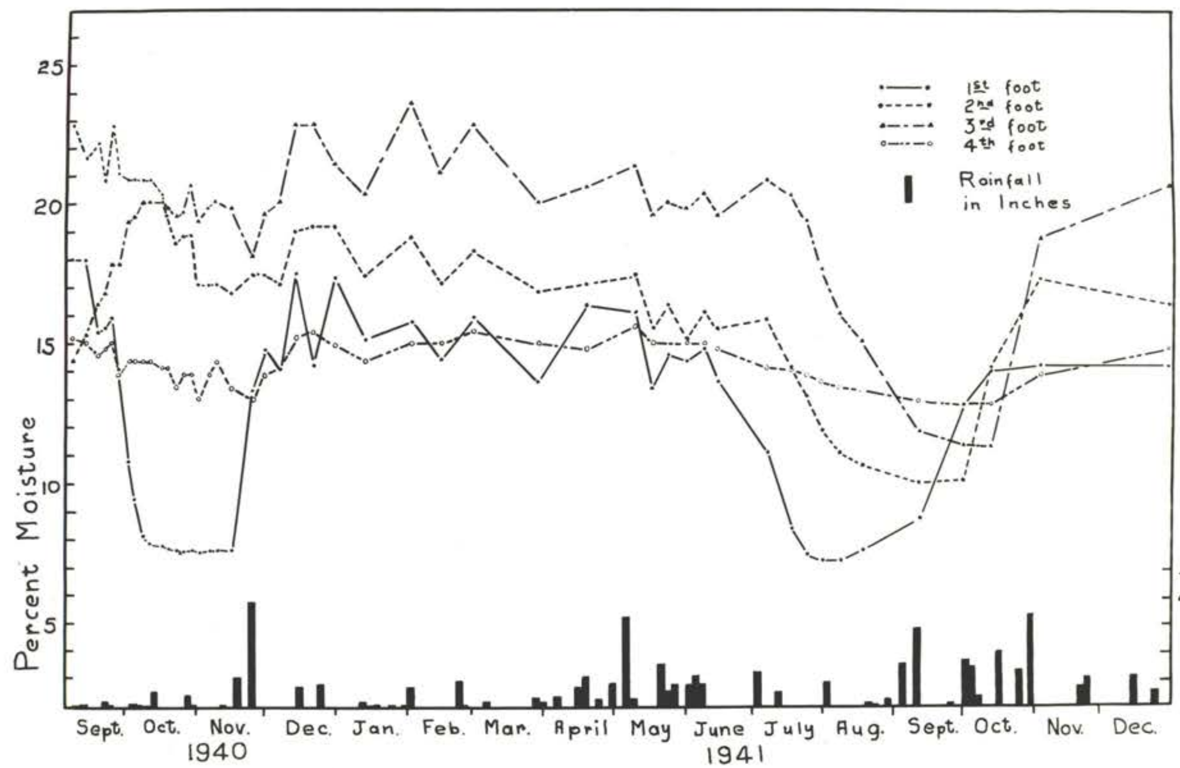

Figure 8. The range of moisture under peach tree number 6 that planted in undisturbed soil (ordinary planting). The moisture under this tree is higher in the 2nd, 3rd, and 4th foot than in Figure 7. The roots have not penetrated into this area.

through the profile of the dynamited soil where the block was located. The tree shown in Figure 6 had several roots coming around the block at the second foot and one of the large roots went straight down passing the other two blocks. The tree from Figure 7 in the ordinary planting had the same root distribution except one root went upward and the other one went downward passing all the blocks. This would account for the fact that the per cent of moisture dropped so low in the fourth foot of soil under this tree which was in this respect similar to the dynamited trees. The other ordinary planted tree had most of the roots around the top block with one or two at the second foot. This is in line with the reading found during growth of the dry season from the tree.

In Table 8, the per cent of pore space as indicated is low in the 18 to 36 inch layer. This shows that the area is more compact and would restrict the movement of water and root growth. The pore space is the lowest at 24 inches and at 48 inches it is the same as in the first six inches. The roots require a certain amount of air to carry on good growth and the 7 to 10 per cent of air space found in the soil from 18 to 36 inches with the moisture level at field capacity is too low. The soil is practically water-logged at field capacity. There is plenty of moisture available, but not enough air space at field capacity to carry on good growth and as the air space increases for proper root growth the available moisture decreases to an undesirable level. This is in line with statements by L. D. Baver (4), who found that the average soil has a pore space of about 50 per cent.

From the pH determination, the soil is quite acid, being 5.24 to 5.37 in the four levels of the soils.

Table 8. The pore space, air space, percent moisture, and pH of the peach orchard soil.

	Depth in Inches					
	6"	12"	18"**	24"**	36"	48"
% pore space	42.15	39.72	34.99	33.45	33.88	42.15
% moisture *	14.96	15.83	16.49	16.47	13.05	10.34
% air space under above moisture	21.06	16.34	9.22	7.23	11.69	27.15
pH	5.27	5.37	5.25	5.24	5.25	5.30

* Percent moisture in soil February 26, 1942

** The pore space and air space too low under field moisture capacity for proper root development

CONCLUSIONS

The data indicates that the soil in the large holes is very favorable for good root development and top growth. The soil has a higher percentage of pore space (around 42 per cent) and has enough air space and available moisture to bring about the additional growth. Dynamiting the soil proved to be advantageous to tree growth but to a lesser extent than large holes. The maximum spread of the roots and depth of the large hole treatment for the first year was 12 feet to 7 feet and 6 inches respectively, while the dynamite and ordinary planting had a maximum spread and depth of 8 feet and 4 inches to 5 feet and 6 feet to 2 feet respectively. The trees in each treatment had a total root extension of 10 feet in diameter during the second year. Top growth was proportional to the root growth. The trunk diameter was largest for the trees in large holes. The total number of blossoms was much greater for the trees in the large holes, indicating that fruit production would have been greater.

The severe freeze in November 11, 1940, killed many of the trees and damaged other trees heavily. The dynamited soil trees were more susceptible to this damage.

The moisture was much lower where the root development was most intensive. In the large hole in which the soil was more open, the roots penetrated to lower levels with a corresponding decrease in the percentage of moisture. The soil moisture was low or well depleted during August and September. Soon after the leaves dropped and with good rains the moisture was increased at all levels to field capacity. The ordinary planted trees were more shallowly rooted, had more moisture present in the lower depths of the soil both before and after the leaves dropped.

The conductivity bridge used to determine the moisture in place shows a very good picture of what is happening to moisture with reference to the rate of absorption by the roots and the rate of percolation in the soil. Each type of soil has a different range of electrical resistance to the per cent of moisture present.

The air space was too low in the subsoil (second and third foot levels) for root development and dynamiting the soil did not increase the development of the roots sufficiently to make it practical. The higher cost of digging can thus be justified.

The Sun Glo which was planted very late did not respond so favorably as the Fair Beauty to the treatments. The Fair Beauty had a chance to get its roots better established. The second year's growth was very much the same for the two varieties.

SUMMARY

1. The compactness of the subsoil restricts the development of roots and the movement of moisture downward.
2. When planted in large holes, peach trees develop larger absorbing root systems that penetrate deeper and also a more vigorous top growth.
3. Root penetration is extensive during the first and second years of growth. The maximum spread of peach roots for the first year in large hole, dynamited, and ordinary planting was 12 feet, 8 feet and 4 inches, and 6 feet respectively while the second years growth attained a maximum spread of 22 feet, 18 feet, and 16 feet and 6 inches respectively. The spread of the top is small as compared to the root spread in the first year. Top growth and root growth are coordinated and increase in one results in a comparable increase in the other.
4. Dynamiting to loosen the subsoil results in an increase in root development and top growth for the first year but not to the same extent as the large hole method of planting. There were less fibrous roots developed.
5. The moisture content of the soil was more equally distributed throughout the large holes. The undisturbed and the dynamited soil, as compared to the large hole, had a higher per cent of moisture in the third foot. This is the hard pan level.
6. When roots penetrate to the lower levels, the extraction of moisture from all horizons is at a uniform rate.
7. The pore space data indicate that the soil from 18 to 36 inches in the area investigated was too compact to produce a well developed root system. The pore space should be above 40 per cent but was found to be 32 per cent.
8. The air space which was from 7 to 10 per cent when moisture was at field capacity, was too low. The air space is very important to root growth.

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TYPISTS

AVIS PARRETT MAVIS SAKER

CONSTANCE PAUL