GROWTH AND DISTRIBUTION OF ROOTS OF THE PERFECTION PIMIENTO IN GEORGIA[1]

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INTRODUCTION

The pimiento, or mild-flavored type of pepper (*Capsicum frutescens* L. var. *grossum* Bailey), is the most important vegetable cash crop grown in the lower piedmont section of Georgia, and from the standpoint of both value and quantity of pack, it ranks high among the commercial canning crops of the State. The acreage planted to pimientos in Georgia increased more than 35 percent from 1937 to 1938.

Growers often find difficulty in getting good stands of plants that will live and produce fruits until frost. Many of the plants are killed by the fungus *Sclerotium rolfsii*, but not all the losses can be attributed to this organism. Observations during the last four growing seasons have led the writer to conclude that another important contributing factor is the burning of the roots by the fertilizer applied. The method of fertilizer application may, therefore, be of considerable practical importance to the grower, but before this problem could be considered it was necessary to make a study of the development and distribution of the roots in the soil. The results of the study are reported in this paper.

MATERIALS AND METHODS

The study was conducted in the horticultural plots of the Georgia Experiment Station, which is situated in Spalding County, the center of the pimiento industry in Georgia. Although mechanical analysis shows the soil on which the plants were grown to be a sandy loam, it closely approaches the texture of a sandy clay loam, Cecil series, as interpreted by the classification of Davis and Bennett.[3] Both of these are predominant soil types of the pimiento-growing area.

A selected strain of Perfection pimiento seed was planted in an electrically heated hotbed on February 10, 1938. By February 20 most of the seeds had germinated and small plants were showing above the soil. In order to obtain a progressive knowledge of the development and distribution of the roots, an examination was made at the end of each 30-day period beginning February 28, 7 days after the seeds were up, and continuing through October 28, when the plants were approximately 8 months old. The first three examinations were made while the plants were growing in the hotbed. This was done by carefully removing the loose composted soil from around the roots with a hand fork and with water under light pressure from a garden hose.

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[2] The author is indebted to M. M. Murphy, Jr., of the Department of Horticulture, for taking the photographs used in this paper, and to L. C. Olson, of the Department of Agronomy, for assisting in taking the soil samples and for making the mechanical analyses.

[3] DAVIS, R. O. E., and BENNETT, H. H. GROUPING SOILS ON THE BASIS OF MECHANICAL ANALYSIS. U. S. Dept. Agr. Dept. Cir. 419, 15 pp., illus. 1927.

A few days prior to setting the plants in the field the soil was thoroughly prepared and fertilized with 600 pounds per acre of a 4–8–6 (N–P–K) fertilizer placed under the plants, as is the usual method of application for this crop. In order to facilitate handling and tracing the root system, two methods of spacing the rows and plants were used. The plants to be examined during the first 2 months after transplantation were set 5 feet apart in the row and the rows were spaced 5 feet apart. The rest of the plants were set 10 feet apart in rows spaced 10 feet apart, thus allowing ample room for root development in all directions. To avoid disturbing the roots during the growing season, weeds and grass were kept down by frequently scraping the plots with hoes rather than by cultivating them with plows.

The direct or digging method of examination, with the use of water under pressure in some cases to uncover the smaller roots, was employed in this work. (See fig. 8.) The method consisted of digging a trench by the side of the experimental plants to a depth below the deepest roots and of sufficient size to permit two persons to move about in it. The trench afforded a rather smooth perpendicular wall surface into which one could dig with a sharp hand pick and uncover and trace the root system. Several plants were examined in this manner each month. In some cases, especially on the older and larger plants, there were so many rootlets that it was impossible to show all of them in the drawings of the root systems. When this occurred a circular excavation (see fig. 13) was made around the plant, the inner face of which was 8 inches from the main stem of the plant, and the inner surface of the excavation was marked off into square feet with string. The root ends were then charted on coordinate paper in as nearly their exact position as it was possible to locate them.

Air temperature records were taken with a calibrated hygrothermograph at a point 12 inches above the soil among the plants, while the soil temperature was taken with a calibrated soil thermograph the bulb of which was placed among the roots 4 inches below the soil surface. Rainfall and evaporation records were secured from the nearby experiment station weather station.

Soil samples for mechanical and quick chemical analysis were taken from 20 holes dug at random over the field where the studies were being made. The holes, which were 36 inches wide, 54 inches long, and 36 inches deep, were large enough to permit accurate samples to be secured and further studies to be made of the various profile horizons in relation to root growth and distribution.

ROOT GROWTH IN THE HOTBED

Immediately after germination of the pimiento seed the young primary root typically grows directly downward. It penetrates the warm friable soil of the hotbed readily and by the time the plant is a week old it has usually reached a depth of 3 to 6 inches (fig 1, *A*). At this stage in the growth of the primary root no lateral or secondary roots can be detected. However, a few subsequent daily examinations show that they make their appearance within 8 to 10 days after germination, depending to a large extent on the moisture content and temperature of the soil. The first secondary roots originate at the upper extremities of the primary or taproot, and others develop

in rapid succession throughout its entire length with the exception of the immediate end.

At the time of the second monthly examination of the root system in the hotbed (March 28), it was found that most of the secondary roots were confined to about the first 3 or 4 inches below the soil surface (fig. 1, *B*). These roots extended outward in a somewhat horizontal direction to a distance of 6 inches on either side of the plant for a total spread of 1 foot, while the primary or taproot had increased in length to about 10 inches. Other lateral roots below this particular group had produced tertiary roots, all of which tended to penetrate the soil in a rather oblique or vertical direction.

By April 28, the last date on which the roots were examined in the hotbed, the lateral or secondary roots had increased in number, length, and size, as compared with those of the previous month (fig. 1, *C*). Some had reached a length of slightly over 10 inches, were very much branched, and averaged 0.6 mm. in diameter. The

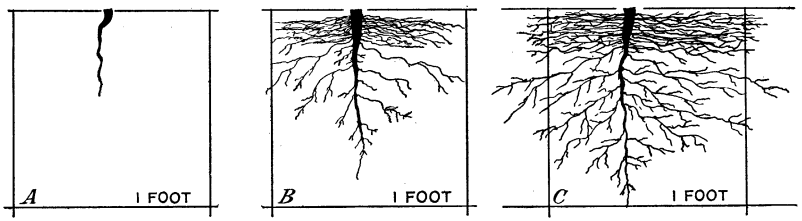

FIGURE 1.—Young primary root (*A*) of pimiento 7 days after germination and root system of the young pimiento plant 37 (*B*) and 68 (*C*) days after germination.

growth of the primary or taproot during this 30-day period, however. was only about one-half as much as that made by the laterals.

GROWTH AND DISTRIBUTION OF ROOTS IN THE FIELD

The heating units were turned off in the hotbed on March 31 and the plants allowed to harden. The total amount of rainfall in April exceeded by far the total amount of evaporation for the same period (table 1); thus the soil in the field remained in good physical condition and was well supplied with moisture during the entire month.

TABLE 1.—*Total monthly rainfall, evaporation, and rainfall-evaporation ratio during the 1938 growing season at Experiment, Ga.*

Month	Total rainfall	Total evaporation	R/E ratio	Month	Total rainfall	Total evaporation	R/E ratio
	Inches	*Inches*			*Inches*	*Inches*	
April	10.46	4.79	2.183	August	2.00	6.14	.325
May	3.14	7.05	.445	September	1.16	5.62	.206
June	8.48	7.39	1.147	October	.26	5.71	.045
July	5.88	6.34	.927				

The plants were carefully taken up from the bed and transplanted to the nearby field, as shown in the lay-out in figure 2, during the late afternoon of April 28. At this time they were about 68 days old, averaged 8 inches in height, and had many small flower buds. Wea-

ther conditions were ideal for the transplanting, and the plants scarcely wilted after being set out, but later it could be seen that the move had distinctly checked their growth.

The first examination of the root system in the field was made on May 27. Here, too, the effects of transplanting were evident in

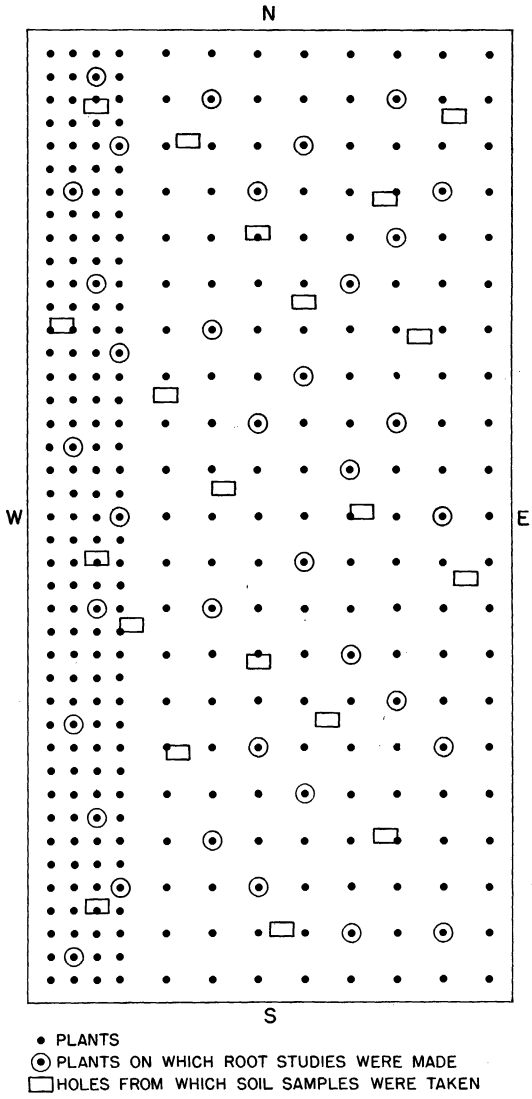

FIGURE 2.—Lay-out of plants in field after being transplanted from hotbed.

that the tap or primary root had been broken, which resulted in the initiation and development of a great many laterals (fig. 3). Although the spread of the root system was practically the same as that of the previous month, about 24 of the older and more prominent lateral roots had increased to 1 mm. in diameter. From these, as well as from the stub of the old taproot, grew the new secondary and tertiary

roots. These findings concerning the effects of transplanting young pepper plants on lateral root formation are in complete agreement with those of Weaver and Bruner,[4] who studied the development of the root system of the Bell, or Bull Nose, variety of pepper under

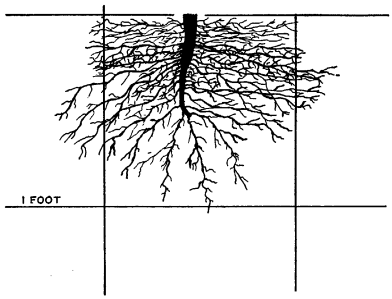

FIGURE 3.—Root system of pimiento 30 days after being transplanted to the field.

field conditions at Norman, Okla. On May 27, the vertical penetrating roots were found to extend 14 inches deep. These roots, together with their young laterals and the ones from the old taproot immediately above, almost completely filled the surface foot of soil at the end of the first 30-day period in the field.

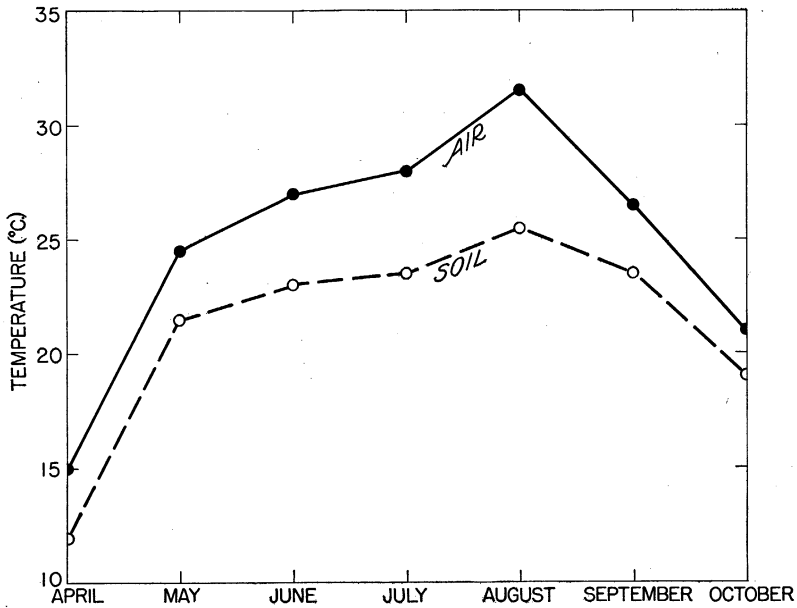

FIGURE 4.—Air and soil temperatures in the pimiento field during the experiment.

With approximately 8½ inches of rainfall during June and an average atmospheric and soil temperature of 27° and 23° C. respectively (table 1 and fig. 4) conditions for plant growth were relatively good.

[4] WEAVER, JOHN E., and BRUNER, WILLIAM E. ROOT DEVELOPMENT OF VEGETABLE CROPS. 351 pp., illus. New York. See pp. 268–273.

A second field examination was made on June 27. The plants at this stage averaged 16 inches in height and had a spread of 22 inches. There were many buds and blooms and also a few green fruits, the largest of which scarcely exceeded 7 mm. in diameter

The stem was 13 mm. in diameter at the surface of the soil and tapered gradually to a rather blunt root end which extended 6 inches in depth, the taproot having been broken in transplanting. As will be recalled, in the above examinations the prominent part of the root

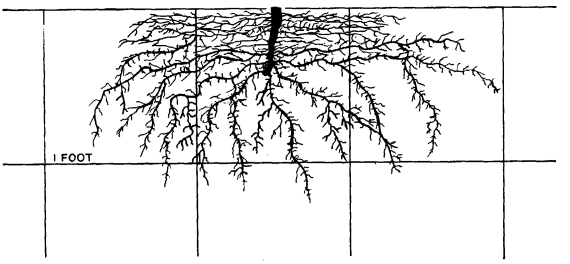

FIGURE 5.—Root system of the pimiento 60 days after being transplanted to the field.

system consisted of many laterals. Some of these had now extended outward 18 inches, mostly in the A horizon or surface 6 inches of soil, and measured 1.5 mm. in diameter. Other shorter ones ran for distances of 4 to 12 inches. They had branched at the rate of 4 to 10 laterals per inch and ranged from ½ to 1½ inches in length. Nearly all the larger roots extended horizontally or slightly obliquely downward for some 10 to 14 inches and then turned downward and ran vertically or again obliquely to a maximum depth of 16 inches (fig. 5).

By the date of the third field examination, July 28, the plants had

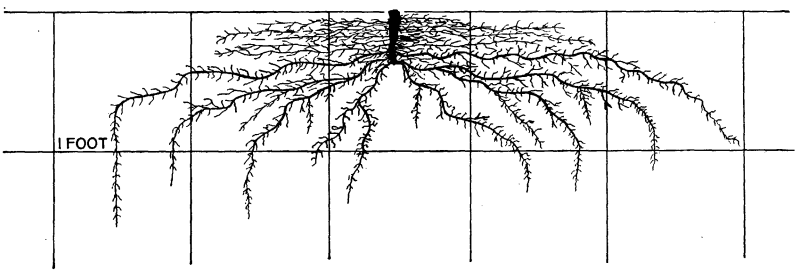

FIGURE 6.—Root system of the pimiento 90 days after being transplanted to the field.

attained an average height of 26 inches and a spread of 25 inches. The old stubby portion of the taproot measured only a little more than 5 inches in length but had a large number of lateral roots growing out from it in all directions, some as long as 30 inches. The majority of these roots, however, were confined to a radius of 24 inches. The larger ones were attached near the end of the old primary or taproot (fig. 6) and measured 3 mm. in diameter, while the smaller secondary roots, although relatively short and averaging but 1 mm. in thickness, were numerous and very well branched. Some of them were found

within the first inch of topsoil. As during the previous examination it was found that the longer roots, after running in a horizontal direction for 18 to 20 inches, turned downward in an oblique and some in a distinctly vertical direction. The vertical penetrating roots had at this stage reached a maximum depth of 20 inches. One small root, however, was traced to a depth of 26 inches but was not included in the drawing because a closer examination revealed that it had not penetrated the subsoil normally but had followed the course of a channel made by the root of a pecan tree that in former years had grown close by.

As shown in table 1, only 2 inches of rain fell during August, while the total evaporation for the month was 6.14 inches, giving a rainfall-evaporation ratio of 0.325. The accompanying average air temperature was 31.5° C., the highest recorded for the entire growing season. During this 30-day period the plants grew less than 2 inches in height, although it will be seen below that root extention proceeded at a rapid rate.

The fourth field examination of roots was made on August 27. The taproot at this stage of growth was 45 mm. thick at the soil

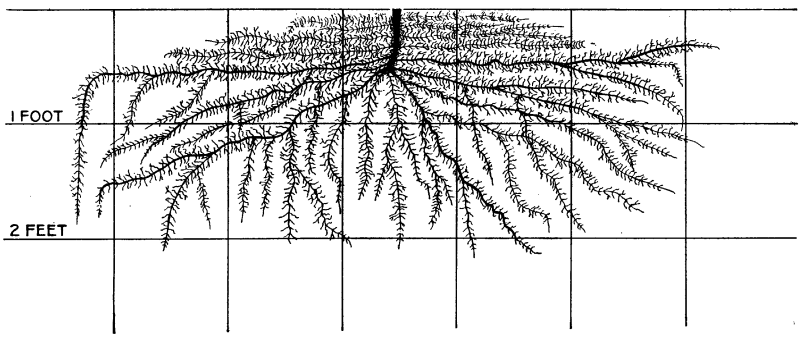

FIGURE 7.—Root system of the pimiento 120 days after being transplanted to the field.

surface, tapered to a diameter of 13 mm. at the end, and gave rise to many laterals. The previously small roots found in the surface 6 inches of soil had increased greatly in both diameter and length. Many were as much as 1.5 mm. in thickness and extended horizontally for a distance of 24 inches. The larger roots near the base of the taproot had made even greater growth (fig. 7). From 6 to 10 were found that measured as much as 6 mm. in diameter. Even as far as 2 feet from the base of the plant some of these strong roots were 2.5 to 3 mm. thick. The maximum lateral spread of the root system had increased from 29 inches in July to 40 inches in August for a total gain in root length of 11 inches. It will be noted further in figure 7 that nearly all the larger and more deeply penetrating roots again ran horizontally for about 24 inches and then turned obliquely downward near their extremities or else abruptly downward and paralleled the course of the old taproot. However, the vertical growth at this stage, reaching a little more than 2 feet in depth, had not kept pace with that horizontally, due in all probability to the difference in soil texture and compactness. Some properties of the A and B horizons of the Cecil sandy loam soil are shown in table 2.

From the large vertically growing roots mentioned above numerous smaller roots originated, and most of these grew in the same vertical direction. These roots ranged in length from 6 to 18 inches and

FIGURE 8.—Lateral root growth in the A soil horizon of the pimiento 150 days after being transplanted to the field.

averaged approximately 0.6 mm. in diameter. Some had rebranched and all were covered with young rootlets at the rate of three to eight per inch. This network of roots was, no doubt, very effective in bsorbing moisture.

TABLE 2.—*Some properties of a typical Cecil sandy loam soil profile in the pimiento-growing district of central Georgia, 1938*

Profile layer	Depth of layer	Description of layer	Combined sand	Clay	Silt	pH
	Inches		*Percent*	*Percent*	*Percent*	
A	0–6	Brownish-red sandy loam	69.9	17.2	12.9	4.89
B	6–50	Red, stiff clay	45.6	45.7	8.7	4.76

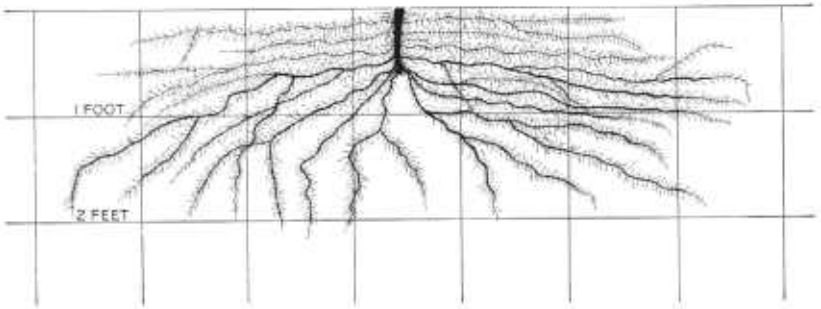

FIGURE 9.—Root system of the pimiento 150 days after being transplanted to the field.

By the time the September examination was made the plants had been growing in the field for 5 months. Owing to a prolongation of the

FIGURE 10.—Extent of lateral root growth of a mature pimiento plant.

drought and hot weather, the top growth was very little greater than that of the previous month, but root growth was still making progress. The smaller and more fibrous lateral roots of the A horizon

now extended outward as far as 32 inches from the base of the plant and were so numerous that they completely filled that portion of the soil (fig. 8). Many of them were relatively close to the soil surface. The larger, horizontally growing roots from near the base of the

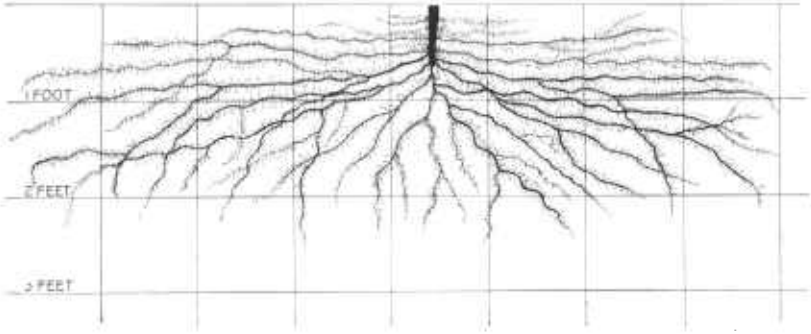

FIGURE 11.—Part of the root system of the pimiento 180 days after being transplanted to the field.

old taproot made about 6 inches if growth in September. They now extended outward 36 inches on all sides of the plant, having a total spread of 6 feet, and some measured as much as 10 mm. in diameter at the largest point. As can be seen in figure 9, however,

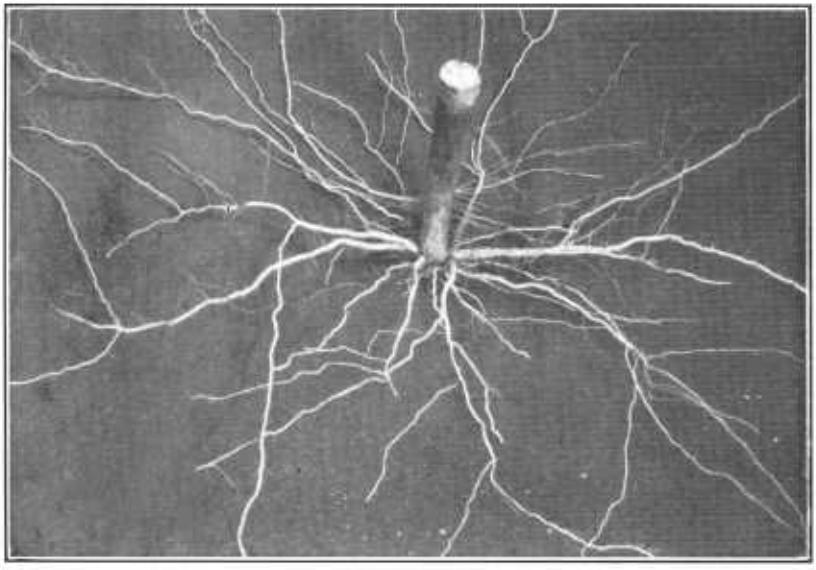

FIGURE 12.—Upper part of the primary root of a mature pimiento plant showing absence of laterals.

the progress made by the roots in penetrating the heavy clay-subsoil was small as compared with that of similar roots examined a month earlier.

As the average date of the first killing frost in central Georgia is November 10, the final monthly examination of roots was made on

October 28. The plants averaged 34 inches in height and 29 inches across. They were loaded with fruits of all ages and some were still blooming. As is shown to some extent in figure 10, and more in

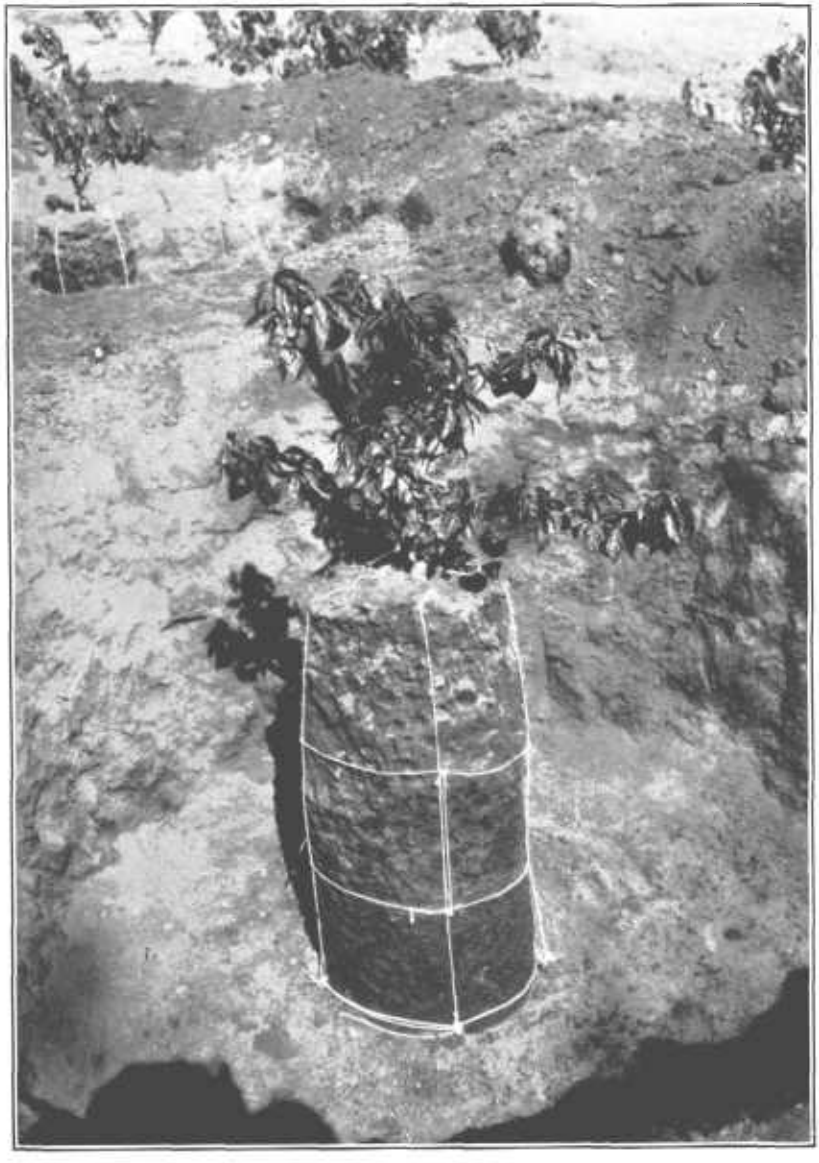

FIGURE 13.—Mature pimiento plant removed by the circular method of excavation.

detail in figure 11, the root system now extended outward to a distance of 48 to 52 inches from the base of the plant. As a rule the horizontally growing roots were a few inches longer when growing parallel with or in the immediate row channel than when at right angles

to it. The larger and more prominent of these roots usually turned downward about 30 inches from the place of attachment and extended well into the second foot of soil. The distinctly vertically penetrating roots generally extended a few inches deeper. Thirty-two inches was the maximum depth at which any roots were found during the experiment and only a few of these appeared in the October excavation.

It is to be noted particularly in figures 11 and 12 that lateral roots are not always initiated throughout the entire length of the primary or upper portion of the taproot, especially in plants that are grown on heavy clay-loam soils. Neither deep setting nor high mounding of the plants under field conditions was found to have any noticeable

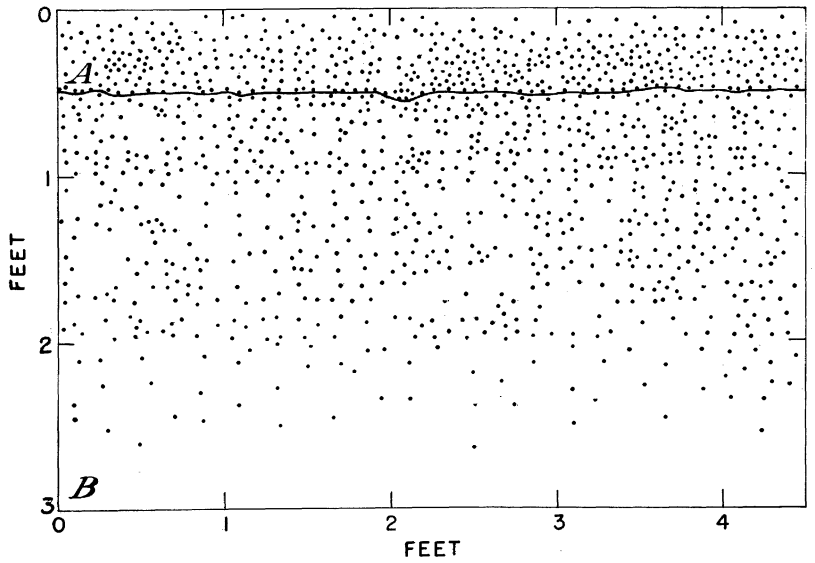

FIGURE 14.—Root concentration and penetration of a mature pimiento plant in two soil profile horizons. Each dot represents a root end.

effect on lateral root initiation at points above those at which they ordinarily occur.

The second method employed for studying the distribution of roots of mature plants (figs. 13 and 14), which is similar to that used on deciduous fruit trees by Oskamp,[5] also showed that the pimiento roots thoroughly occupy the soil from within a few inches of the surface to a depth of 24 inches. Some roots extend deeper, as was found by the first method of study, but with an increase in depth below 24 inches there is a corresponding decrease in both number and size of roots.

In general conformation the root system of the Perfection pimiento as found in this study is much the same as that reported by Weaver and Bruner [6] for the Bell, or Bull Nose, variety of pepper. The results of this study also substantiate in large measure those obtained by Mohammad and Deshpande [7] in similar work on chilies in India.

[5] OSKAMP, JOSEPH. THE ROOTING HABIT OF DECIDUOUS FRUITS ON DIFFERENT SOILS. Amer. Soc. Hort. Sci. Proc. (1932) 29: 23–219, illus. 1933.

[6] See footnote 4.

[7] MOHAMMAD, ALI, and DESHPANDE, R. B. STUDIES IN INDIAN CHILIES. 2 THE ROOT SYSTEM. Agr. Jour. India 24: 251–258, illus. 1929.

DISCUSSION

At present the usual spacing of pimiento plants in central Georgia is 18 to 36 inches in rows 36 to 42 inches apart. Within the first 3 months after the plants are transplanted to the field their roots thoroughly occupy the soil both in and between the rows and many of them are relatively close to the surface. Largely as a matter of custom pimiento growers cultivate their plants regularly about every 2 weeks whether there are weeds to be killed or not. There is little justification for this practice, for it cuts nearly all of the shallow feed roots between the rows and makes it impossible for the plants to utilize the maximum amount of nutrients in the soil. The effects of this practice are especially detrimental in late dry seasons when the plants are loaded with mature fruits. Weed-control measures should be instituted if possible before the weeds can become established and compete with the crop for moisture and nutrients. When no weeds are present and a soil mulch has formed, cultivation is an unnecessary expense.

As much as 100 to 200 pounds per acre of extra commercial fertilizer is usually applied as a side dressing around pimiento plants twice during the growing season, the first about June 1 and the second in early September. In the light of the results of this investigation, it appears that a greater utilization of the fertilizer may be accomplished if it is scattered over the entire area between the rows, rather than in bands near the base of the plants.

SUMMARY

As soon as the pimiento seed germinates in the hotbed, which usually takes about 10 days, the young primary root grows typically directly downward. After 2 months in the hotbed, with relatively good care, the plants are well hardened and ready to be transplanted to the field. At this stage the primary root extends down to about the 10- to 12-inch level and is well supplied with laterals measuring from 4 to 10 inches in length and about 0.6 mm. in diameter.

The primary or taproot is usually more or less damaged in the process of transplanting. The remaining short portion of the taproot does not appear to make up a very important part of the root system as such, but from this and the base of the stem arise many laterals, except in some cases on heavy clay soils, that continue to develop and eventually constitute a very efficient absorbing system. These roots grow horizontally outward to vertically downward and by the time they have been in the field for 60 days they completely occupy the soil on all sides of the plant to a depth of 10 to 14 inches. By the last of August the larger and more deeply penetrating roots extend outward 40 inches from the base of the plant and downward as deep as 26 inches. Mature or 8-month-old plants have a root spread of 48 to 52 inches on each side, many of the laterals being found in the second foot of the soil. Relatively few roots penetrate the stiff clay subsoil deeper than 24 inches.