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Fibrous Root Distribution of 'Pineapple' Orange Trees on Rough Lemon Rootstock at Three Tree Spacings[1]

William S. Castle
University of Florida, Institute of Food and Agricultural Sciences, Agricultural Research and Education Center, P. O. Box 1088, Lake Alfred, FL 33850

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Abstract. **Fibrous root densities were determined for 16-year-old 'Pineapple' orange [*Citrus sinensis* (L.) Osb.] trees on rough lemon (*C. jambhiri* Lush.) rootstock spaced 3.0 × 4.6 m, 4.6 × 6.1 m, and 6.1 × 7.6 m and growing in a deep, central Florida sandy soil. Samples were taken from 1.9 m deep borings at 2 dripline locations and mid-way between trees in the row and between adjacent rows. The fibrous root systems penetrated to 1.9 m and were well-distributed. Samples from the widest spaced trees generally had lower root densities while the densities of samples from the other spacings were greater and suggested the overlapping of adjacent root systems. Root density was greatest in the surface sample for all spacings and generally decreased with depth. The extensive development and density of the fibrous root systems suggested that root competition was not likely to be a primary limiting factor in higher density plantings grown under comparable conditions.**

Citrus tree spacing investigations have demonstrated the potential of closely spaced trees to increase yield per unit of land area; however, certain limitations have also been identified (1, 2, 3, 8, 9, 10). Trees may be spaced so closely that any early yield advantage is soon lost and tree performance actually begins to decline (3, 9). The cause of this decline is generally thought to be the result of tree crowding. The competition which develops between tree canopies for light and among roots for water and nutrients becomes excessive and limits tree growth and yield. It is not known how rapidly, if at all, either above- or below-ground competition may become a limiting factor in different soil types or under different cultural management schemes. In a Florida spacing trial, the closest set trees have out-yielded for 15 years on a unit area basis, the wider spaced ones (8, 9, 10) in contrast to a California experiment in which the most closely spaced trees were soon surpassed in productivity by the more widely spaced ones (2, 3). This difference in tree performance at each location may be related to differences in the distribution and density of the respective root systems and the relative significance of root competition.

The objective of this study was to determine the effect of tree spacing on the fibrous root distribution of citrus trees growing in a deep, well-drained, sandy soil.

Materials and Methods

An overhead sprinkler irrigated experimental planting of 'Pineapple' sweet orange trees on rough lemon rootstock spaced 3.0 × 4.6, 4.6 × 6.1, and 6.1 × 7.6 m was used for this study. Three replications of each spacing with north-south oriented rows were planted in 1960 in a typical Florida citrus soil, Astatula fine sand (Typic Quartzipsamment), with the depth to an underlying clay layer being approximately 3 to 4 m. The trees have been hedged as needed to allow for cultural operations. Trees spaced 3.0 × 4.6 m were first hedged in 1966. Data concerning tree size and fruit yield, size, and quality appeared along with other details in earlier reports (8, 9).

Sampling was conducted in September, 1976. Three borings, 1.9 m deep, were made at each of 4 locations within groups of 6 adjacent trees (Fig. 1) using a 20.3 cm diameter auger that removed a 12.7 cm-deep sample (6). Thus, the sampling locations were not equidistant from the tree trunk in each spacing. Borings were made at the same relative location. The samples were screened and roots approximately 2 mm in diameter or smaller were retained, oven-dried, and weighed. One group of trees in each spacing and replication of the original planting was sampled.

Data are expressed as fibrous root dry weight/4.1 liter sample. Data from each of the 12 borings made within each group of 6 trees were combined to give mean values for each sampling location. These means were used for an analysis of variance as a factorial experiment.

Results

The dry weight of citrus fibrous roots varied significantly according to tree spacing, sampling location, and sampling depth (Table 1). When the main effect of each factor is considered, the largest changes in fibrous root density occurred with depth (Table 2). Mean fibrous root weight was greatest in the surface sample, 6.4 g, it decreased to 1.6 g in the next sample, and then changed very little to a depth of 120.7 cm with only small decreases thereafter.

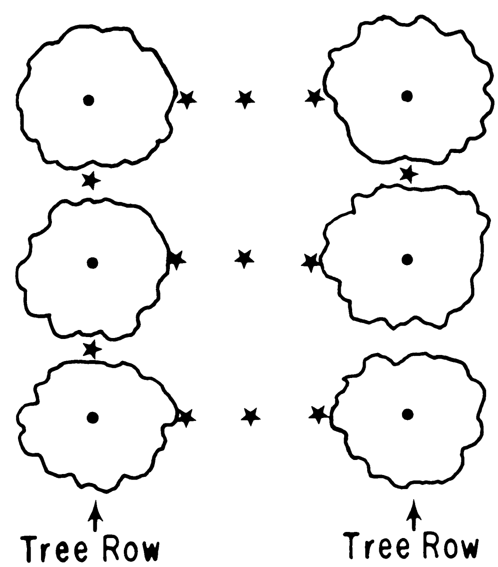

Fig. 1. Location of between-tree, between-row, and dripline sampling sites.

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Table 1. Summary of analysis of variance of fibrous root dry weights/4.1 liter soil sample, of citrus trees at 3 spacings.

Source of variance	Degrees of freedom	F value	Level of probability
Tree spacing	2	38.85	<1%
Sampling location	3	10.61	1%
Sampling depth	14	224.75	<1%
Spacing x location	6	3.35	1%
Spacing x depth	28	4.86	1%
Location x depth	42	.63	NS[z]
Spacing x location x depth	84	.72	NS

[z]NS = not significant.

Table 2. Main effect of tree spacing and sampling location and depth on the mean dry weight of citrus fibrous roots in 20.3 cm diameter x 1.9 m deep borings.

Treatment	Root wt (g)
Tree spacing	
3.0 x 4.6 m	1.5
4.6 x 6.1 m	1.3
6.1 x 7.6 m	1.0
Sampling location:	
East side of tree	1.2
West side of tree	1.2
Between trees in row	1.5
Center between rows	1.1
Sampling depth[z] (cm)	
6	6.4
19	1.6
32	1.0
44	1.0
57	1.0
70	1.1
83	1.0
95	1.0
108	0.9
121	0.9
133	0.7
146	0.7
159	0.6
172	0.6
184	0.5

[z]Each depth is the center of a 13 cm deep sample.

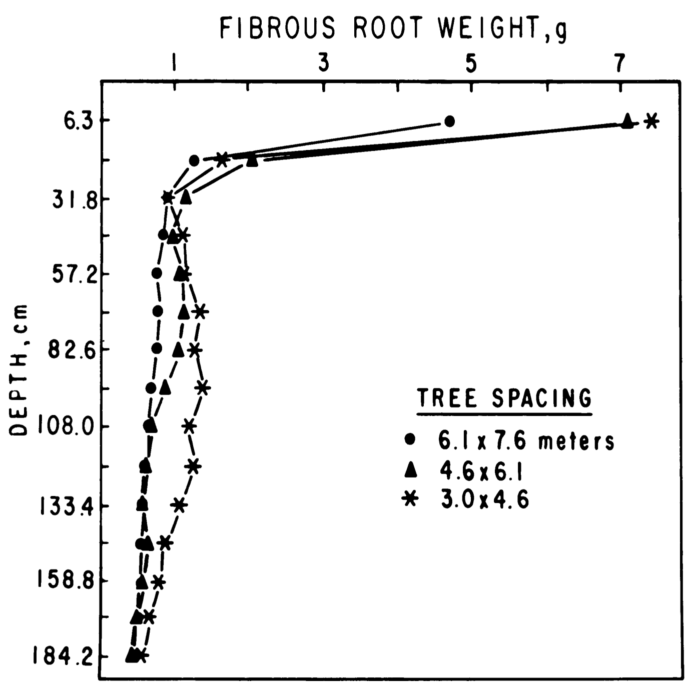

Fig. 2. Mean effect of tree spacing on the dry weight of fibrous roots/4.1 liter soil sample of 16-year-old 'Pineapple' orange trees on rough lemon rootstock.

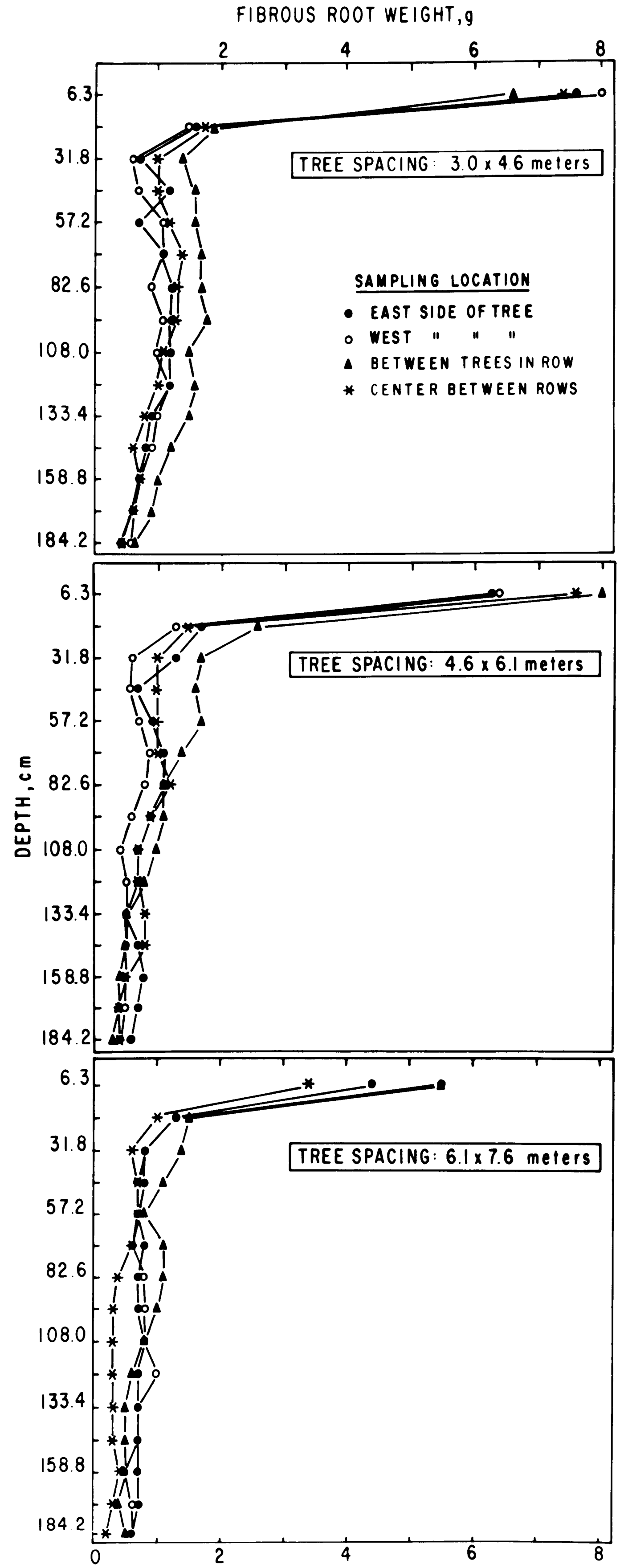

Fig. 3. Mean dry weight by depth of fibrous roots in 4.1 liter soil samples at 4 sampling locations of 16-year-old 'Pineapple' orange trees on rough lemon rootstock.

Differences among sampling locations were small with roots from the between-tree location along the row having the largest mean weight, 1.5 g. Fibrous root weight in each boring, averaged over all sampling locations and depths, increased as tree spacing decreased; however, spacing effects were not independent of sampling location or sampling depth (significant interactions, Table 1).

Inspection of the spacing × sampling depth interaction (Fig. 2) shows that the depth trends were similar for the 2 wider spacings; however, fibrous root density increased between 31.8 and 95.3 cm for trees spaced 3.0 × 4.6 m before gradually decreasing with depth as occurred in the other spacings.

Fig. 3 illustrates the effect of each factor studied. The spacing × sampling location interaction can be observed by noting the relative root distribution for each sampling location and spacing. For example, at the closest spacing, fibrous root density was greater (except at the surface) between trees in the row as compared to other locations. There were fewer roots between rows and between trees as tree spacing increased. Root density east and west of all trees was similar, and below 19.1 cm in the soil, remained essentially constant or decreased gradually with depth.

Fibrous root weight ranged from 6.5 to 8.0 g per sample at the surface for the close and intermediate spacings and from 3.5 to 5.5 g for the widest set trees.

Discussion

'Pineapple' orange trees on rough lemon rootstock had extensive lateral and vertical root development, typical of this vigorous scion-stock combination in the deep, well-drained sandy soils of central Florida (4, 6). Fibrous root density was influenced by tree spacing and differed with sampling location and depth. Many of the lower fibrous root densities for trees at the widest spacing (Fig. 2) may simply reflect the greater distance between trees and lack of root penetration to the boring sites.

It appeared that roots from adjacent trees had grown to and beyond certain sampling locations in the intermediate and closest spacings. For example, the mean fibrous root weight in the surface dripline sample at the closest spacing was larger than the weight from the other locations. This may have resulted from the overlap of roots from trees in adjacent rows. Water shed by the tree canopy during a rain or irrigation may also have contributed to a higher root density by providing a more favorable environment. The greater fibrous root densities at the other depths, between trees in the row, also suggest an overlap of adjacent root systems.

The overlap of adjacent root systems is meaningful for 2 reasons. First, the presence of roots in one area of the soil does not necessarily prevent or inhibit additional permeation by roots from another part of the root system or from an adjacent tree. The factors affecting root growth are more likely to be the physical and chemical characteristics of the soil. In a California citrus tree spacing experiment on Troyer citrange rootstock (2, 3), the soil was a fine sandy loam. Maximum fibrous root density was approximately 0.5 g/liter of soil (7). The fine sand of this Florida experiment is characterized by poor water and nutrient retention yet it supported up to 1.9 g of fibrous roots/liter of sand. Rootstock was probably a factor which contributed to this difference in root density. Few rootstocks have fibrous root systems as dense as those of RL (4, 6).

The intermingling of adjacent root systems is also meaningful because, like the canopy of close-set trees, the root system may eventually lose its individual identity. Each tree does not maintain a soil reservoir that has inviolable boundaries. Therefore, there may be some justification for treating the soil as a root bearing volume over a unit land area, in the same manner fruit-bearing foliage is considered in higher density plantings. If this approach is valid, the rate at which a soil volume is occupied by roots after planting of the trees, would be desirable information.

The root density data do not suggest that the close spacing of the trees severely limited root development or resulted in a level of root competition which hindered canopy growth or yield/unit of land area. The root systems of trees at all spacings were similar with roots extending nearly 2 m vertically, and over 50% of the fibrous roots were below 32 cm. These deeper roots may be particularly important for closely spaced trees where water and nutrients can be rapidly depleted near the surface (5). Moreover, the closest-set trees are the tallest and their annual yield/hectare has continued to equal or surpass the productivity of those at the other spacings (8, 9).

Rootstock and soil type were uniform in this study. The extensive root development reported here occurred in a soil where root growth is relatively unrestricted. Other soils may encourage shallower rooting or physically prevent growth. Furthermore, all rootstocks do not have the same rooting pattern in a sandy soil (4, 6). Therefore, soils in which extensive root growth occurs may allow trees to be successfully spaced closer together as compared to other soils but root distribution is likely to be a determinant of tree spacing in all soil types.

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