South African Avocado Growers' Association Yearbook 1987. 10:15-19.
Proceedings of the First World Avocado Congress

Root distribution of avocado trees in different soil types

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SYNOPSIS
A healthy avocado tree in a homogenous soil with a relatively low bulk density has roots that are fairly uniformly distributed, vertically and horizontally. Where the roots were affected by Phytophthora root rot, the distribution became discontinuous horizontally and with depth. In a different soil, avocado roots did not effectively penetrate from one soil texture and structure into another and root mass was very low in a soil with a bulk density above 1,7 g/cm3.

INTRODUCTION

Avocados may be grown in a wide range of soils with varying rates of success. Nel (1983) describes an ideal avocado soil as having a red colour, a clay content of between 20 and 40 per cent, poor structure, no compacted, clayey or patchy layers, a depth of at least 2 m and a pH (water) of 6,0 to 6,5. A soil generally considered to be suitable for avocado growing is the Hutton soil form with an ortic A horizon and a red apedal B horizon.

Management need not be so intensive where avocados are planted in an ideal soil, provided the climatic conditions are suitable and rainfall is evenly distributed. However, for every factor that is sub-optimal, the shortcoming must be compensated for by improved management. A table was drawn up delimiting minimum depths above certain types of restrictrive layers for different soils (Nel, 1983). The minimum depth for a soil with a highly weathered (soft) granite C horizon is 0,7 m. Another soil characteristic stressed by Nel (1983) is that there should be no clear transition between horizons or soil layers in terms of texture, structure, density and colour within the avocado root depth of 1 m. Avila et al (1984) found that avocado roots did not penetrate sand lenses in alluvial soils, which supports the recommendation of Nel (1983) that there should not be textural changes in an avocado soil Uniform root distributions were found to depths of 1,2 m and 2,1 m for different cultivars in deep uniform soils, but more than 80 per cent of the roots were found in the top 1,5 m (Correa et al, 1984). Rowell (1979) found avocado roots growing to a depth of 3,3 m but the main concentration occurred in the top 1,5 m which concurs with the findings of Correa et al (1984). It has also been reported (Howell, 1979) that very few roots were found in a compacted zone in the soil profile. Therefore, avocado roots clearly have the ability to penetrate deeply in a uniform soil, but are limited by impervious layers and will not easily grow from one soil texture and structure into another.

The purpose of this study was to evaluate a technique for studying root distribution and to determine the effective root depth for avocado trees at Burgershall.

The study at Nelspruit was added to evaluate root distribution in a different kind of soil and to compare it with the results at Burgershall in an attempt to define soil factors that may control root distribution. The horizontal and vertical root distribution of the roots were investigated in this study.

MATERIAL AND METHODS

The soils at Burgershall are Hutton form soils of the Doveton series with an ortic A horizon and a red apedal B horizon, on top of partially weathered bedrock at a depth of 1 m. Clay content throughout the horizons was 48,5 per cent. At Nelspruit another Hutton form soil, Msinga series, was present with an ortic A horizon (9 percent clay content) and a red apedal B horizon (20 per cent clay) of unknown depth. There was a noticeable change in terms of texture, structure, density and colour between the A and B horizons at a depth of 0,5 m in the Nelspruit soil.

In order to compare the root distribution of different avocado trees, a technique described by Huguet (1973) and later by Moutounet et al (1977) was used and modified. The modification was that roots were excavated, sieved from the soil and weighed, rather than counted and measured. A trench was dug in a logarithmic spiral shape to cover as much of the root system as possible, without much damage to the tree. Roots were extracted from every 0,5 m x 0,5 m x 0,1 m deep block of soil in the trench to a maximum depth of 1,1 m along the length of the different trenches. The lengths of trenches depended on tree size, as the formula for calculating trench dimensions adjusts the starting and end points according to the diameter of the stem and the radius of the canopy. The number of trees available for this study were limited and therefore, the sizes and condition of the trees, as well as the management practices under which they were grown, differed.

Excavated roots were weighed fresh, oven-dried and then separated into feeding roots (of less than 1 mm in diameter) and larger roots, which were then weighed separately. Bulk density determinations were made for every sample depth in the soil profile. Three trees of the Fuerte cultivar were investigated at the Burgershall Experimental Station and one tree (Sharpless cultivar) at the CSFRI in Nelspruit. All the trees were approximately 18 years old and in production. One of the Fuerte trees was severely affected by Phytophthora root rot. Both the healthier trees at Burgershall had skirts lying on the ground, while the sick tree had a very sparse canopy. The Sharpless tree was a relatively healthy tree in a cultivar collection orchard that had declined severely, mainly due to Phytophthora root rot. This tree was skirted to about a metre above the ground. All the trees investigated were originally established on Zutano seedling rootstocks.

Irrigation at Nelspruit was by dragline sprinklers, wetting the total area versus micro-jet irrigation at Burgershall, wetting only under the canopy of the trees.

RESULTS

The results for the three Fuerte trees at Burgershall are discussed together. Differences in root distributions will be highlighted and explanations offered, where possible. Individual trees are identified by referring to their health status, namely healthy, apparently healthy and sick. The difference between the healthy and the apparently healthy tree was that the latter tree had a smaller proportion of feeder roots compared to the healthy tree (Table 1).

The distribution of avocado roots for the 'healthy' tree in a soil type suitable for avocados, is illustrated in Figure 1. Throughout the profile, root distribution is fairly uniform, with root mass tending to increase gradually further away from the stem. The second Fuerte tree is apparently healthy and no external difference can be detected between this tree and the 'healthy' tree. A trend of decreasing root mass towards the periphery of the tree, with a noticeable increase at the edge of the dripline, is illustrated in Figure 2. The root distribution of a Fuerte avocado tree affected by Phytophthora cinnamomi Rands, is shown in Figure 3. The root distribution of the 'sick' tree is much less continuous than that of the 'healthy' and the 'apparently healthy' trees.

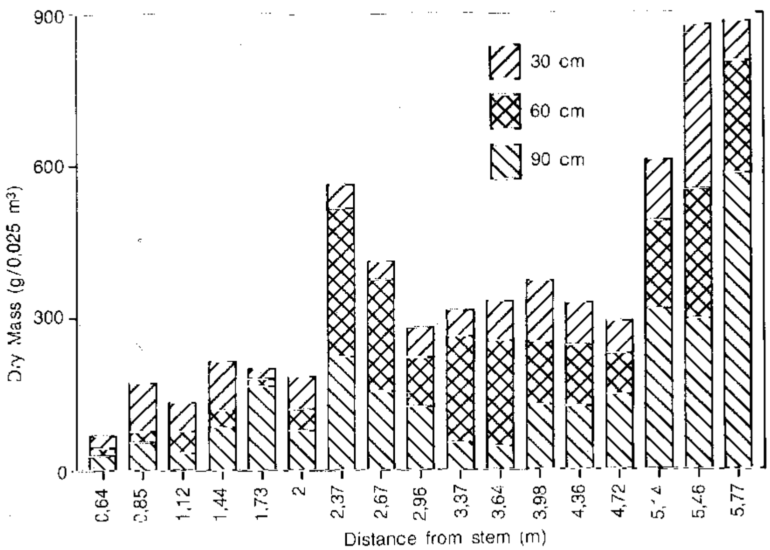

Fig 1. Distribution of total dry root mass along the profile of a logarithmic spiral trench for a healthy avocado tree.

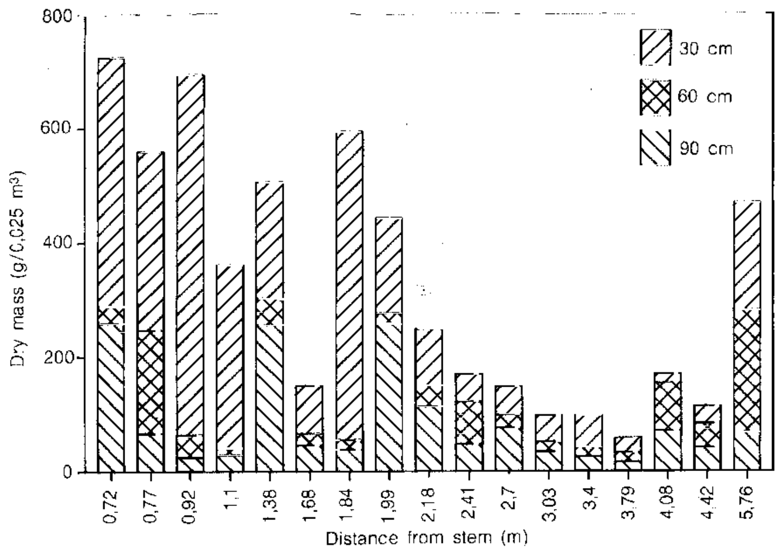

Fig 2. Distribution of total dry root mass along the profile of a logarithmic spiral trench for an apparently healthy avocado tree.

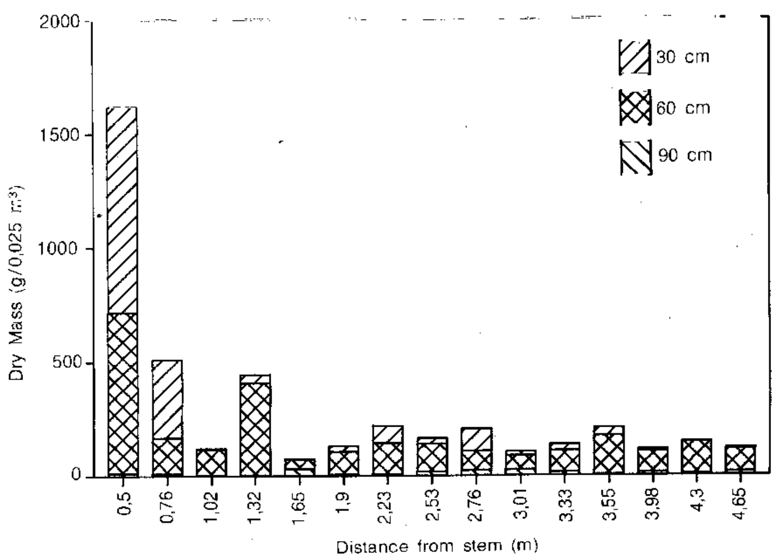

Fig 3. Distribution of total dry root mass along the profile of a logarithmic spiral trench for a root rot-affected avocado tree.

A decreasing root mass away from the trunk is expected in all trees. The unusual trend in root distribution of the 'healthy' tree is ascribed to the fact that no large roots were encountered near the trunk of the tree. Large roots near the trunk account for the declining root mass distributions away from the trunk, as observed for the other two trees.

Due to differences in the depths and lengths of the trenches, all mass data were calculated as dry mass per cubic metre of soil for comparing the root systems of the trees (Table 1).

The 50,9 per cent feeder roots of the healthy tree is probably unrealistic, because of the absence of large roots near the trunk, as already mentioned. There is, however, a trend for the proportion of large roots to increase relatively, and feeder roots to decrease, as root rot-infection intensifies. Total root mass tends to decline. The percentage dry matter for avocado roots was lower in root rot-affected trees.

Regression analysis suggests that the feeder root mass increases from the stem to the periphery of the trees, while large root mass declines. The correlations are poor and non-significant, due to variance of the data. As the feeder root distribution was the primary concern, feeder root mass was the dependent variable, large root mass and distance from the stem the independent variables. Only the results for the 'apparently healthy' tree is presented, as the 'sick' tree exhibited no correlation and the data for the 'healthy' tree was considered nontypical. The equation is $y=96,24+0,1585X+0,5668Z$, where X equals large root mass and Z equals distance from the stem. $R2 = 0,398$, R-squared adjusted for degrees of freedom = 0,312.

TABLE 1 A comparison of dry root mass and percentage feeder roots for three Fuerte avocado trees with different health statuses. Results for a Sharpless tree at Nelspruit in a different soil is included.

	% Dry matter	Large roots g/m3	Feeder roots g/m3	Total root mass (g/m3)	% Feeder roots
Healthy	48,7	732,7	759,5	1492,2	50,9
Healthy	48,2	978,8	510,3	1489,1	34,3
Sick	44,6	1038,2	124,3	1162,5	10,7
Nelspt	53,0	1591,5	220,6	1812,1	12,2

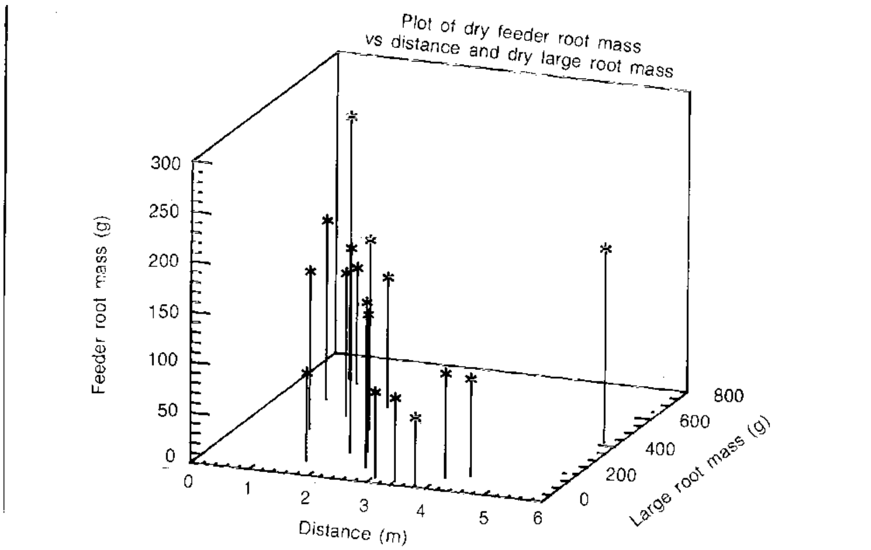

Fig 4. Plot of dry feeder root mass over dry, large root mass and sample distance from the stem for the healthy avocado tree.

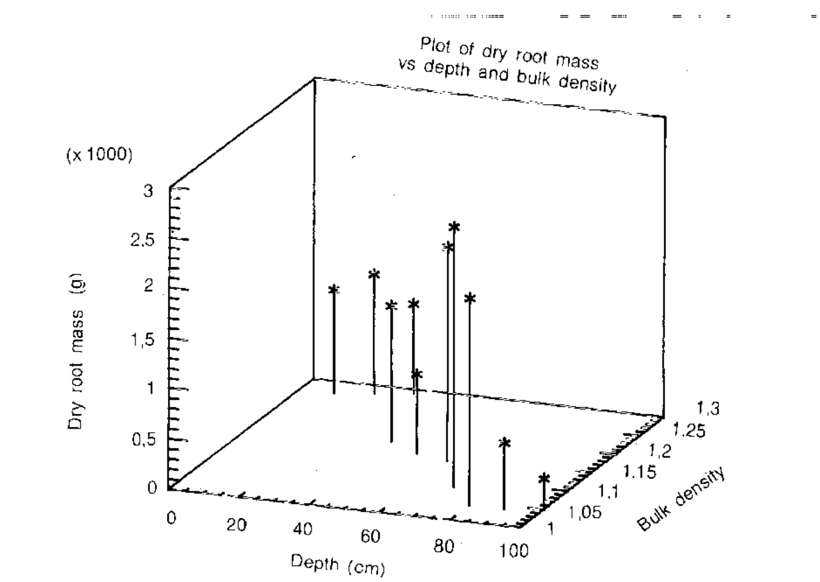

Fig 5. Plot of total dry root mass for every depth sampled over bulk density for every sample depth and the depth of every layer.

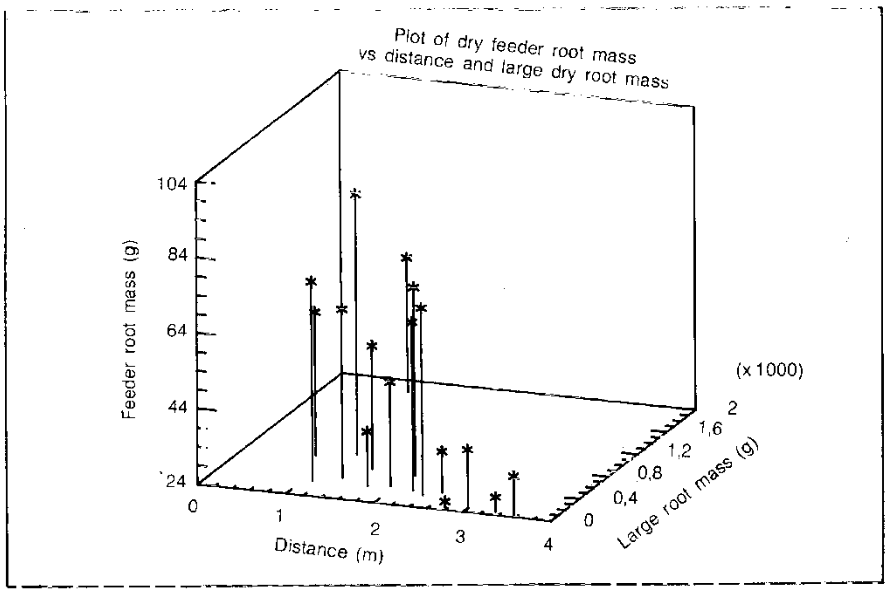

Fig 6. Distribution of total dry root mass along the profile of a logarithmic spiral trench for the avocado tree at Nelspruit.

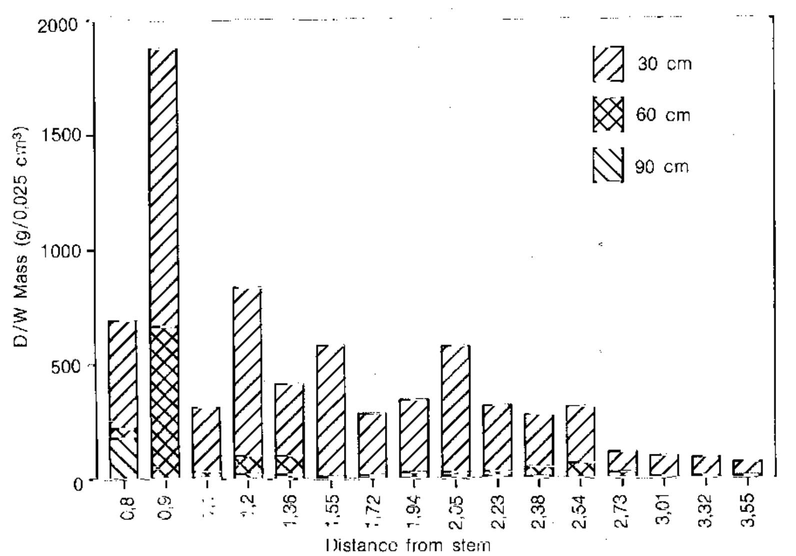

Fig 7. Plot of dry feeder root mass over dry, large root mass and sample distance from the stem of the tree.

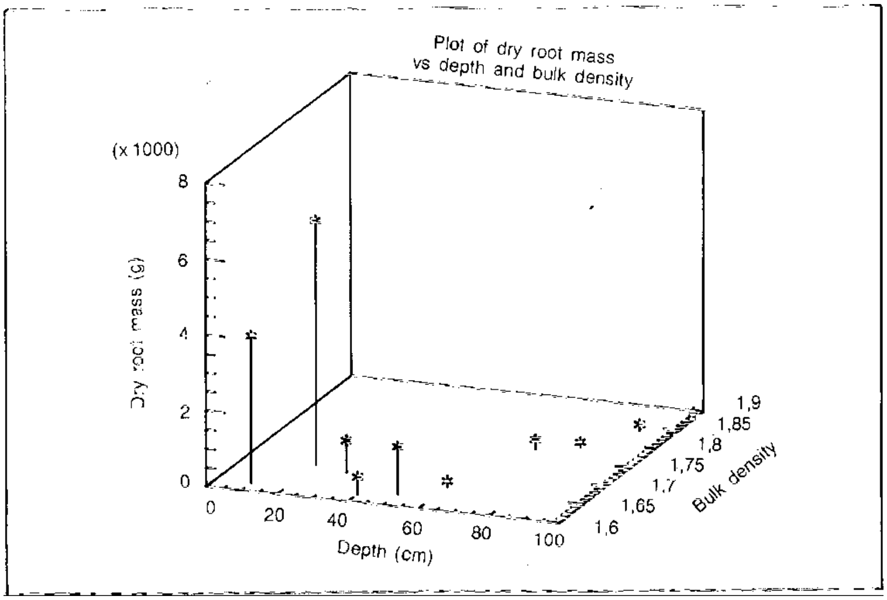

Fig 8. Plot of total dry root mass for every layer over bulk density and the depth of every layer.

The above-mentioned raw data are plotted in Figure 4. A multiple linear regression was performed on rootmass, as the dependent variable, bulk density and the depth of every sample layer as independent variables, for the 'healthy' tree. The correlation was very poor and non-significant and the raw data are plotted in Figure 5. Root distribution is fairly uniform in depth, but declines rapidly at the soil/rock interface, as can be expected. No root preferance for a range of bulk densities could be established. Bulk density decreased from 1,27 g/cm3 at the surface to 1,14 g/cm3 at 600 mm, and 1,04 g/cm3 at 900 mm.

Root distribution of a relatively healthy Sharpless tree under unsuitable soil conditions at Nelspruit, is illustrated in Figure 6. Most of the roots occurred in the top 200 mm depth of the soil profile, decreasing sharply with depth. Root mass also decreased toward the periphery of the tree. The root mass found in the coarse gravelly clay layer was very low in comparison with the rest of the profile, and in general the roots had a stunted appearance. A summary of the root mass distribution and percentage feeder roots is included in Table 1.

Regression analysis indicated that feeder root mass and the mass of larger roots decreased with increasing distance from the stem. The correlation was nonsignificant. The relationship between the dry mass of feeder roots, larger roots and sample position in the trench, is depicted in Figure 7.

A multiple linear regression was performed on root mass as the dependent variable, while bulk density and soil depth were the independent variables. The equation is y=-2,659E+ 19639,69X+-104297Z, where X is equal to large root mass and Z equals distance from the stem. R2 = 0,710 and is significant at the five per cent level of confidence. R-squared adjusted for degrees of freedom = 0,628 and is not significant at the five per cent level. The correlation is not dependable because the R-square value is significant at the five per cent level of confidence, but the adjusted R-square is not.

Bulk density increased from 1,62 g/ cm3 at the surface, to 1,66 g/cm3 at 600 mm and 1,84 g/cm3 at 900 mm, Avocado roots occurred mainly in soil with a bulk density less than 1,7 g/cm3. The increase in bulk density affected root growth, but a change in soil texture and structure had an even greater effect, as illustrated in Figure 8. Total root mass per cubic metre of soil was higher in the Nelspruit soil than at Burgershall. The percentage dry matter for the roots was also higher. No explanation can be offered for these results.

A comparison of the 'healthy' and the apparently healthy' trees in relatively deep soils at Burgershall and the tree in shallow soil at Nelspruit (Figure 9), indicated that two depths in the profile at Burgershall were more favourable for the development of avocado roots than other depths. These depths vary from tree to tree according to the exposure of the soil to sunlight, wind, desiccation and factors unknown at present. In the shallow soil at Nelspruit, the only region where significant amounts of roots developed at all, was in the upper 200 mm, where the bulk density was relatively low.

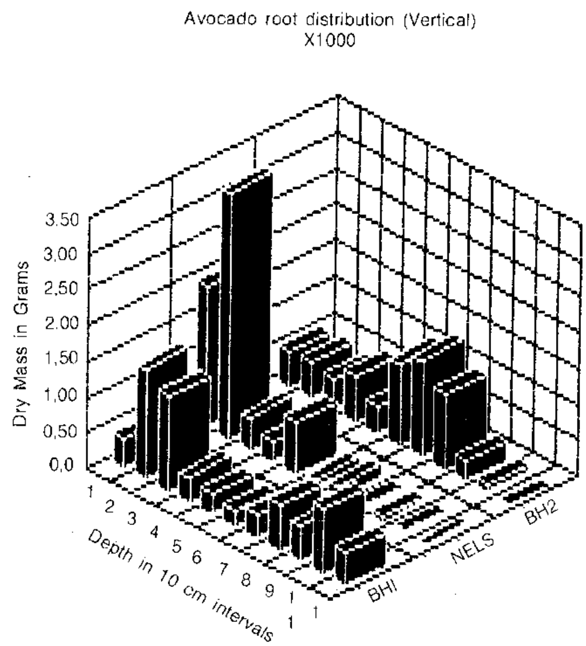

Fig 9. Comparison of the vertical root distributions for two relatively healthy avocado trees (BHI and BH2), with that of the Nelspruit tree (NELS) growing in a soil with distinct soil horizons.

CONCLUSIONS

Avocado roots are fairly uniformly distributed, vertically and horizontally, in a homogenous Hutton-type soil. The restrictive bed rock at 1 m affected the root mass near that depth, probably due to occasional over-wet conditions, although there were no signs of waterlogging at any stage. Bulk density had no measurable effect on root distribution in the Burgershall soil, which implies that other factors, such as soil temperature, may contribute more to determining root distribution. Horizontal feeder root distributions tended to increase toward the periphery of the trees at Bt rgershall, according to the regression analyses. This is attributed to the canopy skirts touching the ground and keeping the soil cool and probably to the micro-jet irrigation that only wets the soil under the canopy of the tree. The loam soil retains sufficient moisture to keep roots alive in protracted drought periods and excessive root die-back should not occur frequently, Due to Phytophthora infection, this general trend is obscured in infected trees.

The soil at Nelspruit exhibited a sharp transition from sandy loam to coarse gravelly clay at a depth of 0,5 m, and very little root mass was found beyond the transition zone. Vertical root distribution was restricted to the upper soil layers and horizontally, root mass decreased away from the tree trunk. Three factors may account for this root distribution, apart from the obvious restrictive coarse gravelly clay layer:

1. Irrigation is by dragline sprinkler system which wets the total orchard floor in every cycle. Due to the shallowness of the upper soil, roots are confined between the surface and deeper layers that may be overwet after rain and even after irrigation.
2. The sandy-loam soil will dry out faster than the Burgershall soil, because it is more exposed and its soil moisture holding capacity is less. Roots, especially feeder roots, will die-back more frequently, due to temporary drought.
3. Phytophthora root rot is probably partly responsible for the decreasing root mass toward the periphery of the tree, as the relation of feeder root mass to total root mass is similar to that of the diseased tree at Burgershall.

A correlation can be demonstrated between root mass, bulk density and depth in the Nelspruit soil, but it is noticeable that a sudden change in soil texture seems to have a greater effect on' root penetration. Bulk density in the order of 1,7 g/cm3 and higher, contributes to restricting root penetration. This concurs with the findings of Rowell (1979) that few, if any, roots occur in a compacted soil layer.

Where no physical restrictions or over-wet conditions occur, other factors such as soil temperature, fertility and available oxygen probably contribute more to determine avocado root distribution.

The method used in the study, yielded data that made it possible to study avocado root distribution in the soil without damaging the trees unduly. Effective root depth of the trees was determined to be about 100-200 mm above a restrictive layer or abrupt change in soil texture and structure.

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