OBSERVATIONS ON AVOCADO TREE ROOT SYSTEMS IN THE WESTERN BAY OF PLENTY

JONATHAN DIXON[1] AND DAVID J. SHER[2]

[1]*Avocado Industry Council Ltd, P.O. Box 16004, Bethlehem, Tauranga*
[2]*Agronomist, PO Box 11096, Papamoa*

E-mail: jonathandixon@nzavocado.co.nz

ABSTRACT

The root systems of 'Hass' avocado trees grafted onto either 'Zutano' seedling rootstocks or 'Duke 7' clonal rootstocks from two orchards in the Western Bay of Plenty were examined after removal from the ground as part of an orchard thinning programme. The root structure of young 'Zutano' seedling trees and young clonal 'Duke 7' trees from three avocado nurseries was also examined. Seedling rootstock root structure was very variable in comparison to the more uniform clonal rootstock structure. Such differences cannot be determined by visual observation of the above ground portion of the tree. The large variation in root structure may partially explain differences in yield performance and growth from tree to tree. The reasons for differences in root structure are unknown. It appears that the general nature and structure of the root system is set in the nursery before trees are planted.

INTRODUCTION

A strategy promoted by the New Zealand avocado industry to improve the horticultural management of avocado orchards is to increase the growers understanding of avocado phenology and biology. One method being used is to educate avocado growers to identify the symptoms of problems by visual observation of canopy health. The type and strength of symptoms then determine the horticultural management decisions taken. A system whereby orchard activity is undertaken based solely on the visible portion of the tree ignores the important contribution that the root system makes to supporting a large crop and maintaining tree health. The specifics of the size and distribution of avocado roots growing in the light, free draining, volcanic soils in the Western Bay of Plenty are poorly understood.

The root system of the avocado tree has an important role in water and nutrient uptake, and provides hormones that maintain essential tree functions like flowering and shoot growth (Scora *et al.*, 2002). Avocado roots have also been suggested to be an important storage area for carbohydrate within a tree and play an important role in changes in carbohydrate concentrations within a tree at different phenological stages (Whiley, 2002). Small root systems with limited

carbohydrate storage capacity may influence the pattern of alternate bearing shown by individual trees through a relatively greater depletion in carbohydrate reserves compared to trees with large root systems. Differences in the size of root systems from tree to tree may be related to both propagation technique, seedling versus clonal tree production systems and planting hole preparation.

There are two propagation systems used to produce avocado trees, the first described above uses seedling rootstocks the second uses clonal rootstocks. Clonal trees are technically more difficult to produce but they are considered to have the merits of producing a more uniform tree that grows and crops more evenly than trees produced on seedling rootstocks. In order to produce a clonal tree the nursery uses a nurse seedling technique where roots are induced to grow using an aerial layering technique on the stem of the rootstock scion wood grafted onto a 'nurse' seedling (usually 'Zutano'). The trees produced this way have an adventitious root system that may be different to the more 'natural' root system produced by a seedling.

There are several management activities undertaken by avocado growers that can reasonably be expected to affect root number, size and distribution. These activities include: irrigation, fertiliser distribution around the tree and the mulching practice used. In the 2002/2003 avocado export season the Avocado Growers Association, Perry Environmental Ltd and Living Earth Ltd implemented the first stages of a MAF Sustainable Farming Fund project looking at various aspects of mulches on avocado orchards. Measurements being undertaken include root growth, health and distribution to examine the effect of mulch treatments on roots and tree productivity. To develop a suitable root sampling protocol the root distribution under typical avocado trees was required to be measured. To determine root distribution a number of mature healthy avocado trees were excavated that allowed the root systems to be measured.

This study describes the pattern of root distribution observed on avocado trees scion 'Hass' grafted onto seedling 'Zutano' rootstocks and 'Hass' scions grafted onto clonal 'Duke 7' rootstocks in two orchards in the Western Bay of Plenty, New Zealand. Both orchards were former kiwifruit orchards. The roots of 12 month old seedling and clonal rootstocks were observed from three avocado nurseries located in the same region.

MATERIALS AND METHODS

Four 9 year old healthy avocado trees 'Hass' scion grafted onto 'Zutano' seedling rootstocks, that had been planted in 600 mm diameter postholes, were selected in an non-irrigated orchard located near Aongatete in the Western Bay of Plenty. The trees were selected on 12 February 2003 and were being removed as part of an orchard thinning programme. The trees selected were about 6 m in height and 5-6 m in canopy diameter. Mulch had not been applied for about three years but there remained a 20 mm layer of wood chip under each tree. Major limbs from

one side of each tree were removed using a chainsaw to reveal the basic trunk and branch structure of each tree. The leaf litter and mulch layer was removed using a rake to reveal the distribution of feeder roots present at the mulch-soil interface. Tree height was estimated to the nearest meter and the canopy diameter was measured with a tape measure. A small digger was used to dig a trench alongside the trunk of the tree to cut a profile down through the soil to a depth of 1.5 m. Once all measurements and photographs had been made the tree was dug up and pulled from the ground. Soil was cleaned off the roots using a water blaster. This left a tree stump revealing the structural roots holding the tree in the ground. The location and density of feeder roots were noted but no effort was made to excavate the feeder roots and examine them in detail.

Three 6 year old healthy avocado trees scion 'Hass' grafted onto 'Duke 7' clonal rootstocks were selected from trees being removed as part of an orchard thinning programme from an orchard located near Te Puna in the Western Bay of Plenty on 11 December 2003. The trees were planted into 1.5 m long x 1 m wide x 600 mm deep holes with a coarse bark mix added to the hole. Each tree was irrigated. Major limbs from one side of each tree were removed using a chainsaw to reveal the basic trunk and branch structure of each tree then the remaining limbs were removed to leave a stump. The trees were removed by digging around the tree stumps to allow the stump to be pulled out with a tractor.

The root structures of healthy young trees from three avocado nurseries were examined after they had been rejected by the nurseryman due to the grafts of 'Hass' scions failing to take. The potting media was washed off the trees to reveal the root structure.

RESULTS AND DISCUSSION

Zutano seedling rootstock

Each tree had two distinct root systems: feeder roots (Figure 1) consisting of a mixture of fine (<1 mm thickness) to white roots (up to 4 mm diameter) and woody structural roots between 100 mm to 250 mm thick that emerged from the trunk (Figure 2). The structural roots appear to anchor the tree into the ground but were not extensive in comparison to the above ground portions of the tree. The area covered by the main structural roots was about 1 to 1.5 m in diameter; this provides an estimate of the ratio of roots to shoots of approximately 1:4 to 1:5. Once the main structural roots had extended past the trunk by about 600 mm they had grown vertically down and branched many times giving a tentacle-like appearance to the root system (Figure 1). These roots were about 15 mm in diameter and could extend more than several meters into the soil. Only one tree had an obvious tap root but this was less than 1 m long before dividing into many smaller roots. There were numerous roots in a small volume of soil and root to root grafts were common (Figure 2). Overall the structural root system was small in comparison to the rest of the tree (Figure 3). The size and distribution of

Figure 1. Avocado feeder roots at the soil/mulch interface for a 9 year old Hass tree grafted onto seedling Zutano rootstock.

Figure 2. Avocado feeder roots growing out from main structural roots close to the trunk (left) and from anchoring roots near a root graft (right) for a 9 year old Hass tree grafted onto seedling Zutano rootstock.

avocado roots in the excavated trees was consistent with the general description of avocado roots by Lahav and Whiley (2002) where most roots (70-80%) occupy the top 0 to 600 mm of well drained soils.

Figure 3. Composite picture of a 9 year old avocado tree Hass grafted onto Zutano rootstock showing above ground tree structure with the roots superimposed underneath. Tree canopy size approximately 5 m height with about 5 m canopy spread, root size across the stump is about 1 m.

Large numbers of feeder roots were present at the soil surface (Figure 1) with the greatest concentration of roots in the top 50 mm of soil. This top soil layer appeared to have the greatest concentration of organic matter. There were small numbers of feeder roots down to 600 mm depth after which no more feeder roots were observed. Feeder roots were distributed from the trunk through to the canopy drip line where there was a grass sward at which point the number of roots were very low. This distribution of feeder roots would suggest that fertiliser should be spread right up to the trunk of the tree for maximum utilisation.

Feeder roots were observed to be growing directly off some of the large woody structural roots (Figure 2). The ability to produce feeder roots from any part of the

root system would explain why mature trees can be successfully replanted using tree spades. The feeder roots were relatively evenly distributed around the tree under the canopy suggesting that a root sampling system that randomly sampled within the canopy could be used for sampling avocado roots.

While the general nature of the root systems observed under each tree was similar there was considerable variation in the size, location and number of structural roots present. On some of the trees the main roots appeared to be twisted around as though they had been in a pot or planter bag. There was also a great density of roots in a very confined space suggesting that the roots do not readily grow beyond 1 m from the trunk as the soil becomes more compacted. The structural appearance of the roots may resemble the root structure at the time of planting when removed from the planter bag. To determine if the root system in mature trees was simply a larger version of the root system when the tree was planted, the roots on young trees were examined just after grafting in the nursery.

Zutano seedling root systems at grafting in nursery trees

At the time of planting the nature and structure of the young avocado tree roots is unknown. Avocado roots are easily damaged by rough handling when planting. The planter bags are generally handled such that the roots remain covered by potting media not allowing the root system to be examined before planting. Differences in the size and strength of newly planted trees' roots may possibly explain differences in growth and productivity when the trees are mature despite the young trees having a similar above ground appearance. The overall physical shape and distribution of roots of the trees planted may define the root system of the mature tree.

The root structure of six 'Zutano' seedling rootstocks, from two avocado nurseries, were examined just after grafting in trees where the graft had failed to take despite a strong and healthy rootstock. There was considerable variation in the type and nature of roots on seedling trees (Figure 4). Some seedlings produce a strong vigorous tap root that extends to the end of the planter bag before burning off once in contact with air or twisting around in the bag. Other seedlings had weak roots with no tap root, branched main roots and lots of fibrous roots but little or no main 'structural' roots. On occasion only one side of the roots had developed or the roots reached the side of the bags and started to spiral around the bag. The variability and appearance of the seedling roots would suggest that the general nature and 'structure' of the root system is set in the nursery by the seedling. It was possible to visualize from the nursery trees how a mature root system would appear. The variation in the root structures seen in seedling trees would also explain the lack of uniformity in the root systems of mature seedling rootstocks.

Figure 4. Seedling root systems at grafting. Trees are from two different nurseries.

Six-year old 'Duke 7' clonal tree roots

The trees examined were about 5-6 m in height and 5-6 m in canopy diameter. The mulch layer was leaf litter that had been allowed to accumulate under the tree. The root system consisted of feeder roots and woody structural roots as found in for the seedling rootstock but the number, size and distribution of roots differed. The structural roots were, in general, smaller than those in seedling trees but were more numerous and grew out directly from the trunk then down in a similar way to the seedling rootstocks (Figure 5). Despite being planted in bigger holes than the seedling rootstocks the main root mass was a similar size at about 1 m to 1.5 m across. Root thickness was about 50 mm to 75 mm in diameter. The depth of the main root mass was between 600 mm to 800 mm giving a slightly greater root to shoot ratio of about 1:6 to 1:8 than for seedling rootstocks planted in postholes. The main roots did not branch as extensively as those of the seedling rootstocks. Overall the structural root system appeared to be smaller although relatively uniform in comparison to the seedling rootstocks. The only difference in feeder roots from the seedling rootstocks trees examined was in the distribution of roots under the canopy of the tree. The feeder roots appeared to diminish about 0.5 m before the canopy drip line but did extend from the trunk as in seedling rootstocks. Feeder roots also grew directly out from the main structural roots. The reason for the lack of feeder root growth out under the entire canopy is not known but could be related to the differences in mulch, irrigation and planting hole size between the two orchards used in this study.

Figure 5. Composite picture of a 6 year old avocado tree Hass grafted onto Duke 7 clonal rootstock showing above ground tree structure with the roots superimposed underneath. Tree canopy size approximately 5 m height with about 6 m canopy spread, root size across the stump before branching is about 1 m.

'Duke 7' clonal root systems at grafting in nursery trees

The root structure of six trees were examined just after grafting in trees where the graft had failed after successful growth of adventitious roots on the rootstock graft despite a healthy rootstock (Figure 6). The root structure was relatively uniform having a more consistent size and shape than for the seedling rootstocks. The main differences observed in the clonal rootstocks were in the placement and density of roots. The young trees also looked like they may have established better as they initially may have the extra support of the nurse seedling root system before it is strangled off by a washer. In general, the roots from the clonal rootstock appeared to define the appearance of the root system in a mature tree.

Figure 6. Clonal tree root system at grafting. Note the absence of roots on the stem in the tree on the right.

CONCLUSIONS

The root structure of seedling rootstocks can be very variable but the differences in root systems from tree to tree cannot be determined visually from the above ground portion of the tree. Having a large variation in root structure may partially explain differences in yield performance and growth from tree to tree. Clonal rootstock root systems were more uniform and may be an important factor in why avocado trees with clonal rootstocks appear to grow more uniformly than trees

originating from seedling rootstocks. However, much remains that is unknown about why the seedling root structure is so variable. The differences in root structure may be due to the seed source, nursery cultural practice and propagation technique (such as the age of the seedling before grafting). Factors that may affect root growth and development after planting are not known but it appears that the general nature and structure of the root system is set in the nursery before trees are planted. It is unknown if the root development can be altered from that seen on the young tree in the nursery. There could be advantages in developing larger and stronger root systems for maintaining consistently high yielding trees. The question must therefore be posed: Is there a management strategy or technique that can alter and improve the root structure in mature trees?

ACKNOWLEDGEMENTS

The authors wish to thank Ravensdown Fertiliser Co-Operative Ltd for the kind financial assistance to excavate the mature avocado trees. The authors wish to further thank the New Zealand Avocado Nursery Association members Chris Bailey (Bailey Farms Ltd), Alex Barker (North Park Orchard) and Penny and Jim Rule (Moananui Avocado Nursery) for allowing us to document the root systems of young seedling and clonal rootstocks. The authors would also like to thank John Cotterell, Alex Barker and Stephen Barker for kindly donating the mature trees to be dug up and for their time and help.

REFERENCES

Lahav, E. and Whiley A.W. (2002). Chapter 11 Irrigation and Mineral Nutrition. In *The Avocado: Botany, Production and Uses* (eds A.W. Whiley, B. Schaffer and B.N. Wolstenholme). CAB International ISBN 0-85199-357-5.

Scora, R.W., Wolstenholme B.N. and Lavi U. (2002). Chapter 2 Taxonomy and Botany. In *The Avocado: Botany, Production and Uses* (eds A.W. Whiley, B. Schaffer and B.N. Wolstenholme). CAB International ISBN 0-85199-357-5.

Whiley, A.W. (2002). Chapter 10 Crop Management. In *The Avocado: Botany, Production and Uses* (eds A.W. Whiley, B. Schaffer and B.N. Wolstenholme). CAB International ISBN 0-85199-357-5.