SOIL DISTURBANCE REDUCES FEEDER ROOT MASS UNDER IRRIGATED OR NON-IRRIGATED 'HASS' AVOCADO TREES

J. Dixon, D.B. Smith and A.C. Greenwood
Avocado Industry Council Ltd., P.O. Box 13267, Tauranga 3110
Corresponding author: jonathandixon@nzavocado.co.nz

ABSTRACT

Alternate bearing of 'Hass' avocado trees is common in New Zealand and leads to reduced grower income. The causes of alternate bearing may be related to the reduced growth of new feeder roots in an "on" crop year. Feeder roots have an important role in the uptake of minerals and increasing the number of feeder roots in an "on" cropping year may help the avocado tree meet the demand for extra nutrients helping to break a tree out of a well entrenched alternate bearing cycle. To determine if feeder root numbers and mass could be increased under avocado trees holes were dug against the drip line to which compost and/or fertilizer were added. Avocado trees from an irrigated and non-irrigated orchard were given the following treatments: no soil disturbance, disturbed soil, a hole amended by addition of pine bark compost and further addition of fertiliser to the compost. Irrigated trees were left for 14 months and the non-irrigated trees were left for 15 months before assessment for feeder root mass and quality. Irrigated and non-irrigated trees had similar root mass in the top 30cm of undisturbed soil. There was trend for there to be more feeder roots in the 15 to 30cm soil layer than in the 0 to 15cm layer of topsoil. Disturbing the soil alone and addition of compost or compost and fertilizer to holes reduced the feeder root mass in the top 0 to 15cm of soil of irrigated and non-irrigated trees. The feeder root mass in the 15 to 30cm layer of soil was not affected. Under irrigated or non-irrigated trees the holes and undisturbed soil tended to be colonised by thin feeder roots rather than fat feeder roots. The holes were covered with a layer of soil 8 to 10cm thick and this soil had fewer feeder roots than the deeper soil layer. This implies that the compost and fertilizer did not greatly affect feeder root mass in the holes and the difference between holes and undisturbed soil was due to factors involved with the disturbed soil covering the holes. Irrigation alone did not overcome the negative effect of disturbing the soil. This implies that orchard activities where the soil is disturbed will result in soil that when re-colonized with feeder roots will have a low feeder root mass and the roots will tend to be thin feeder roots.

Keywords: *compost, holes*

INTRODUCTION

Alternate bearing of 'Hass' avocado trees where a large crop, an "on" year, is followed by a light crop, an "off" year, is common in New Zealand avocado orchards. The alternate bearing reduces avocado grower incomes as the orchards over a wide area tend to follow a similar cropping pattern. Bumper crops have tended to oversupply markets with fruit leading to low prices for fruit returned to the avocado grower. Light crops undersupply the markets with good prices realised but there is too little fruit and the avocado grower consequently has a low income. The causes of irregular bearing are not well understood but appear to be related to aspects of the tree growth cycle (Whiley, 2002). An obvious feature of a well entrenched alternate bearing cycle is the weak shoot flushes in an "on" cropping year followed by a strong shoot flush in an "off" cropping year (Whiley, 2002). As a consequence the amount of flowering and fruit set is much greater in an "on" cropping year than an "off" cropping year. One important aspect of the tree growth cycle is the lack of growth of new feeder roots when shoot growth is strong and fruit set is large (Dixon *et al.*, 2005). Feeder roots are considered to play an important role in the uptake of minerals used for shoot growth and fruit set (Scora *et al.*, 2002).

Avocado trees develop relatively shallow root systems compared to other commercially grown fruit trees (Lahav and Whiley, 2002). The depth of feeder roots in the Western Bay of Plenty of New Zealand is typically in the top 0 to 60cm of the soil with the majority in the top 0 to 15cm of soil (Dixon *et al.*, 2005). Irrigation increases the number and depth of feeder roots to the lower soil layers (Lahav and Whiley, 2002). The number and mass of feeder roots was observed to be similar down the soil profile to a depth of 1m under two high performing 'Hass' avocado trees planted into a 2m x 2m wide x 2m deep hole. The hole was filled with one-third of a cubic meter of compost well mixed into the soil and amended with fertilizer (Sher and Dixon, 2003). The increase in feeder roots was observed down to over 1m depth compared to the amount of feeder roots that are only typically found down to 30cm depth. The greater depth of feeder roots was speculated to be due to the increased organic matter and fertilizer in the soil. While these observations were interesting only two trees were sampled for feeder roots. This was too few trees to draw more than very general conclusions but suggests that the numbers of feeder roots under avocado trees can be increased using soil amendments. The number of feeder roots under avocado trees in New Zealand has periods of growth and die back depending on the time of year and stage of the growth cycle (Ploetz *et al.*, 1992). Increasing the number of feeder roots in an "on" cropping year may be useful in helping the avocado tree to take up additional nutrients when the demand for minerals is high. This may then lead to increased shoot flush increasing the amount of flowering wood in the "off" year. More flowering wood in the "off" year could then result in a greater yield. Therefore, increases in feeder roots of avocado trees at the right phenological stage may then be useful in improving the productivity of the avocado trees in a well defined alternate bearing cycle. Manipulating the pattern of feeder root growth through forcing additional root growth may help to break a tree out of a well entrenched alternate bearing cycle. To determine if feeder root numbers and mass could be increased under avocado trees holes were dug against the drip line to which compost and/or fertilizer were added.

MATERIALS AND METHODS

Avocado trees cultivar 'Hass' grafted onto seedling 'Zutano' rootstock were selected from two adjacent commercial orchards in the Bay of Plenty region (37ºS, 176ºE) for application of treatments to holes excavated around the trees. The trees selected were in adjacent blocks separated by a shelter belt and received similar management. The trees in each orchard were 6 to 7 years old, between 4 to 5 meters in height and breadth and had been managed according to accepted industry norms. The trees in one orchard were irrigated with 9mm of water every 4 days in spring and summer. Sixteen similar sized irrigated trees were selected and randomly allocated to one of four treatments. Trees in the other orchard were not irrigated. On this orchard twenty-four similar sized non-irrigated trees within the same orchard block were selected and randomly allocated to one of four treatments.

The treatments were:

1. Control – no soil disturbance around the tree
2. The soil was disturbed by digging a hole then refilling the hole with the excavated soil
3. The soil was disturbed by digging a hole and amended by addition of about 0.2m^3 of well rotted pine bark compost
4. The soil was disturbed as in treatment 3 with the further addition of fertiliser to the compost.

Three holes, about 300mm deep x 600mm wide were excavated along the drip line on each of the eastern and western sides of each tree using a 'Kanga' motorized auger. The holes were positioned to be approximately equidistant from one another around the circumference of the canopy drip line. The holes were dug around the irrigated trees on 10/11/2004 to 12/11/2004 and the non-irrigated trees on 18/11/2004. Holes were not drilled on the northern and southern sides of trees due to the proximity of irrigation pipes. The sides of each hole were scraped with a garden rake before soil or amendments were placed into the hole. A layer of excavated soil about 80 to 100mm thick was placed over the top of the hole. For the control trees there was no soil disturbance treatment, *i.e.* no holes, around the tree.

The fertilser added to the compost in the holes in treatment 4 consisted of the following:

Lime ($CaCO_3$)	530g
Super phosphate	150g
Kieserite ($MgSO_4$)	94g
Gypsum ($CaSO_4$)	125g
Boric acid	6g
Trace elements (FTE 6403)	3g

The irrigated trees were left for 14 months and the non-irrigated trees were left for 15 months before the soil in the holes or in undisturbed soil between holes were assessed for feeder root mass and quality. Soil samples consisting of a soil plug 15cm wide by 15cm deep were collected using a hand operated auger. The soil from the top 15cm and soil from 15cm to 30cm was collected after removal of surface mulch. The roots were collected over a 5 minute period and placed into brown paper bags, then were taken to the AIC laboratory were the fresh mass of the roots was obtained using a digital balance. The quality of the roots was then assessed by counting the number of fat white feeder roots (about 2mm thickness) and thin white feeder roots (< 2mm thickness). The roots were placed into hot air driers 55ºC where the roots were dried to a constant mass before the dry weight was determined.

For each tree the root mass from the six treatment holes and six undisturbed soil sites were separately summed to give one value for root mass from holes and one value for undisturbed soil. For control trees roots were collected from 12 undisturbed sampling sites around each control treatment tree from location similar to those of treatment trees. The root mass from each control tree was the sum of 12 sampling sites of undisturbed soil rather than six sampling sites of undisturbed soil from treatment trees. The average root mass reported in the results section is the average of the sum of root mass for trees in each treatment. Root quality is reported as the average percentage per tree of fat or thin white feeder roots. The percentage of brown or black feeder roots is not reported here. The results were analysed as a complete randomised block design using General Linear Models Analysis of Variance procedure of MINITAB version 13.31.

RESULTS

Irrigated and non-irrigated trees in undisturbed soil had similar average root mass in the top 30cm of soil (Tables 1 and 2). While there was about the same feeder root mass under irrigated and non-irrigated trees there was a trend for the non-irrigated trees to have fewer roots. There was trend for more feeder roots in the 15 to 30cm soil layer than in the 0 to 15cm layer of topsoil.

Feeder root dry mass trends were similar to those observed for fresh weight (Tables 1 and 2) therefore description of treatment effects on feeder roots will be described in relation to the feeder root fresh weight. Disturbing the soil and addition of compost or compost and fertilizer to holes did not increase feeder root mass under irrigated or non-irrigated trees (Tables 1 and 2). There was a non-significant trend for the fresh weight of feeder roots from holes to be less than the undisturbed soil. Disturbing the soil by digging a hole and refilling it with the same soil tended to reduce the feeder root mass in the top 0 to 15cm of soil of irrigated and non-irrigated trees (Tables 1 and 2). Feeder root mass of refilled holes and undisturbed soil from the 15 to 30cm soil layer was similar. Feeder root mass in the top 15cm of soil was reduced in the holes where compost was added for irrigated ($p < 0.05$) or non-irrigated trees ($p<0.01$). While the feeder root mass in the 15 to 30cm layer of soil was not significantly different in holes where compost was added there was a trend for the root mass to be reduced. When fertilizer was added to the compost used to add to the holes the feeder root mass was not different under irrigated trees compared to undisturbed soil (Table 1). Feeder root mass was less ($p < 0.05$) in the top 15cm of soil under non-irrigated trees where compost and fertilizer had been added to holes than in undisturbed soil (Table 2).

Overall there was a trend for there to be a greater proportion of fat feeder roots at the 15 to 30cm soil layer than in the top 15cm of the soil. There was a similar proportion of fat feeder roots under irrigated or non-irrigated trees at each soil depth investigated (Tables 1 and 2). Non-irrigated trees had smaller proportions of fat feeder roots in the treatment holes than in undisturbed soil (Table 2). There was a general trend for the proportion of fat feeder roots to decline with greater amendments in the holes (Table 2). There was the opposite trend for the proportion of thin feeder roots to increase in the 15 to 30cm soil layer compared to the undisturbed soil. Irrigated trees had similar trends in the proportions of fat and thin feeder roots to non-irrigated trees but the difference between holes and undisturbed soil was only significant for the compost only treatment ($p < 0.01$) for the top 30cm and refilled holes at 15 to 30cm only ($p < 0.05$, Table 1).

DISCUSSION

Holes amended with compost or compost and fertilizer decreased feeder root mass and tended to be colonised by thin feeder roots rather than fat feeder roots. Disturbed soil, holes dug then refilled with the same soil, also had fewer feeder roots than undisturbed soil under the same trees. The changes to the feeder root mass and proportion of fat and thin feeder roots was most noticeable in the top 15cm of soil. Feeder roots in the soil layer 15 to 30cm were relatively unaffected by treatments. While the fresh mass of feeder roots was different in the holes the roots tended to be thinner which implies that the total root surface area between

Table 1. Average root mass and average percentage of fat or thin feeder roots in the top 30cm of soil under the mulch of irrigated 'Hass' avocado trees.

		Average Root mass (g)				Average Root quality (% of total)			
Treatment	Location	Wet[1] 15cm2	Dry 15cm	Wet 30cm	Dry 30cm	Fat[3] 15cm	Fat 30cm	Thin[4] 15cm	Thin 30cm
Control	Undisturbed	29.1	7.9	48.7	15.5	35.8	49.2	47.3	34.2
Refilled	Hole	13.1	3.3	37.5	8.7	27.9	35.0	42.9	44.2
	Undisturbed	28.6	7.1	33.5	9.8	42.5	61.7	45.0	21.7
Compost	Hole	8.6	2.0	21.0	5.6	20.0	40.8	25.8	38.3
	Undisturbed	41.1	10.9	54.5	14.8	50.8	69.2	45.0	22.5
Compost +fertilizer	Hole	10.3	2.8	20.3	6.1	28.5	38.8	17.3	23.8
	Undisturbed	13.3	3.4	30.6	10.2	32.1	43.8	36.5	27.1
Treatments (hole only)		NS[5]	NS	NS	NS	NS	NS	NS	NS
Control x Refilled hole		NS	*[6]	NS	NS	NS	NS	NS	NS
Refilled x Location		NS	NS	NS	NS	NS	**	NS	*
Compost x Location		*	*	NS	NS	**	**	NS	NS
Compost+F[7] x Location		NS	NS	NS	NS	NS	NS	NS	NS

[1]Mass of roots before drying; [2]Top 15cm of soil, 30cm is the band of soil from 15cm to 30cm deep; [3]White feeder roots about 2mm or greater thickness; [4]White feeder roots about 0.5 to 2 mm thickness; [5]Not significant; [6] = significant at p<0.05, ** = significant at p<0.01; [7]Compost plus fertilizer treatment.*

Table 2. Average root mass and average percentage of fat or thin feeder roots in the top 30cm of soil under the mulch of non-irrigated 'Hass' avocado trees.

		Average Root mass (g)				Average Root quality (% of total)			
Treatment	Location	Wet[1] 15cm[2]	Dry 15cm	Wet 30cm	Dry 30cm	Fat[3] 15cm	Fat 30cm	Thin[4] 15cm	Thin 30cm
Control	Undisturbed	21.1	6.4	33.4	11.1	30.8	57.4	59.6	40.2
Refilled	Hole	16.8	4.4	26.1	7.6	20.6	41.4	60.0	53.1
	Undisturbed	29.6	8.5	26.4	8.8	43.3	66.7	53.9	27.8
Compost	Hole	7.3	1.9	22.3	6.5	12.4	38.8	46.0	50.1
	Undisturbed	34.4	11.0	28.5	9.8	39.3	63.2	57.9	34.0
Compost +fertilizer	Hole	6.4	1.6	24.6	6.8	10.0	33.3	31.7	50.0
	Undisturbed	23.6	7.6	42.4	14.0	26.1	61.7	57.2	38.3
Treatments (hole only)		NS[5]	NS	NS	NS	NS	NS	NS	NS
Control x Refilled hole		NS	NS	NS	NS	NS	NS	NS	NS
Refilled x Location		NS	NS	NS	NS	**6	**	NS	**
Compost x Location		**	***	NS	NS	**	*	NS	NS
Compost+F[7] x Location		*	*	NS	NS	*	*	NS	NS

[1]*Mass of roots before drying;* [2]*Top 15cm of soil, 30cm is the band of soil from 15cm to 30cm deep;* [3]*White feeder roots about 2mm or greater thickness;* [4]*White feeder roots about 0.5 to 2 mm thickness;* [5]*Not significant;* [6]*Significiant at p<0.05, ** = significant at p<0.01, *** = significant at p<0.001;* [7]*Compost plus fertilizer treatment.*

holes and undisturbed soil may be similar. Avocado tree feeder roots do not have root hairs (Burgis and Wolfe, 1945) but appear to produce feeder roots of a wide range of thicknesses from less than 1mm to about 3mm (Durand and Claassens, 1987; Zilberstaine *et al.*, 1992; Winer *et al.*, 1995). Different feeder root thicknesses in different parts of the soil may be due to the soil having different characteristics, such as a region of higher fertility. Mineral nutrition using nitrogen and phosphorous can also increase the length and density of thin roots (Winer *et al.*, 1995). In Israel, 'Hass' avocado trees on 'Nabal' rootstocks, the highest concentrations of nitrogen, magnesium, zinc, manganese and copper were in feeder roots < 1.0mm and these concentrations decreased with increase in root thickness (Winer *et al.*, 1995). In addition, potassium uptake has been reported to be higher per unit fresh weight and per unit surface area in thin roots than thick roots (Zilberstaine *et al.*, 1992). This would imply that although the total mass of feeder roots was less in the holes a greater proportion of thin avocado roots were found within the holes. Therefore, it is possible that the trees were able to successfully exploit the increased fertility of the compost and additional fertilizer without increasing total feeder root mass.

The amount of feeder roots was not increased in a specific location when the soil was amended to have more organic matter and/or fertilizer. The density of plant roots is affected by varietal differences, soil oxygen levels, soil moisture content (Labanauskas *et al.*, 1978) and soil bulk density (Durand and Claassens, 1987). The amended holes may have had an unsuitable environment for the development of avocado feeder roots in the top 15cm of soil. The compost was not mixed with soil and may have been too dry and have too great air gaps between particles for good development of feeder roots. The holes were covered with a layer of soil 8 to 10cm thick and this soil had fewer feeder roots than the deeper soil layer. The amount of feeder roots in the soil layer 15 to 30cm while tending to be less in the holes than in undisturbed soil had smaller differences than holes and undisturbed soil at the top 15cm of soil. This may suggest that the compost and fertilizer did not greatly affect feeder root mass in the holes the difference between holes and undisturbed soil being more due to factors involved with the soil covering the holes. Avocado feeder roots are known to be greater in wetted soil under irrigation sprinklers than the drier soil outside of the irrigated area (Meyer *et al.*, 1992; Salgado and Toro, 1995). Irrigated trees while tending to have more feeder roots than non-irrigated trees in treatment holes had the same trend of decreased feeder root mass and thinner feeder roots this implies that irrigation alone did not overcome the negative effect of disturbing the soil. Irrigation alone, however, does appear to have a positive effect on increasing feeder root mass under avocado trees in the Western Bay of Plenty.

Feeder roots tended to be less in disturbed soil than undisturbed soil under trees across both orchards. While these differences were not significant there was a consistently lower root mass in disturbed soils. A negative effect on feeder root re-colonization of disturbed soil by compost and additional fertilizer may have been outweighed by the negative effect on feeder roots of simply disturbing the soil. This may mean that orchard activities where the soil is disturbed will result in soil that when re-colonized with feeder roots the root mass will be low and the roots will tend to be thin feeder roots. The reduction in feeder root mass may affect future tree productivity.

CONCLUSIONS

Feeder root mass was not increased under avocado trees by filling holes with compost or fertilizer and compost. Disturbing the soil simply through refilling a hole with soil was enough to reduce feeder root mass and encourage the development of predominately thin feeder roots. Irrigation tended to increase feeder root mass under trees but did not compensate for the decreased feeder root mass in disturbed soil. On the basis of these findings orchard activities that disturb soil may reduce feeder root mass that may have an effect on the productivity of the tree.

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