Effect of different mulch materials, composts and organic treatments on tree condition and root health

Z Mavuso and A Willis

Westfalia Technological Services,
PO Box 1103, Tzaneen 0850, South Africa
E-mail: zilungiselem@hansmerensky.co.za

ABSTRACT

Pot and field trials were established to evaluate the effect of different mulch materials, compost and organic products on tree condition and root health. In the pot trial, ungrafted Duke 7 seedling plants were transplanted into a soil mixture and inoculated with *Phytophthora cinnamomi* (Pc), then treated with different mulches. The trial was evaluated after eight months. Root health was significantly improved by the application of gypsum, pine bark / antagonist mix, coarse eucalyptus wood chips and Braak's pine bark medium, when compared to the control. In the field trial, tree health ratings were done at the start of the trial in August 2005 and mulches were applied in October 2005. Small differences between treatments have been noted in the tree health ratings done in August 2006. Root health and density were assessed by means of digital photographs. Soil moisture fluctuations underneath the mulches were monitored with tensiometers. Initial results indicated that under wet conditions the sawdust mulch was saturated and this lead to higher soil moisture readings when compared to other mulches. Under dry conditions water did not easily reach the soil beneath the mulches when compared to the control. Pc infestation in the soil underneath the mulches was determined and the lowest inoculum of Pc was found associated with avocado wood chips. Leaf mineral analysis results indicated that partially composted Westfalia compost and cattle manure resulted in below normal nitrogen levels in the leaves. Mulch depth measurements have been taken in order to determine the mulch decomposition rate for each treatment. The trial was harvested in August 2006 and average yield per tree and count size distribution were determined per treatment. In addition, fruit samples were cold-stored for 28 days and post-harvest quality was evaluated upon ripening. No conclusions about the effect of mulches on yield and post-harvest quality will be made at this early stage.

INTRODUCTION

Root rot caused by *Phytophthora cinnamomi* (Pc) is considered the most important and widely distributed disease of avocados in countries where avocados are produced. Currently, the world avocado industry relies almost solely on phosphorous acid to control Pc root rot. Therefore alternative strategies need to be investigated to reduce dependence on phosphorous acid and prevent the danger of resistance development in the long term. Mulching has been widely recommended for avocado orchards worldwide and some of the benefits derived from mulching include: increased water and nutrient availability (Gregoriou & Rajkumar, 1984) and improved soil structure and porosity (Gallardo-Laro & Nogales, 1987). Mulching has also been found to promote the development of beneficial micro-organisms that are antagonistic to Pc (Turney & Menge, 1994). Some of these micro-organisms are wood decay fungi, which multiply abundantly in certain mulches and produce enzymes such as cellulase and laminarinase. These enzymes have been shown to dissolve the fungal hyphae of Pc (Downer, 1998 & Downer *et al*., 2001; Faber & Spiers, 2003). Different types of mulch materials are available to avocado growers in South Africa and these will have differing effects on plant health and Pc in the soil. It has therefore become important to identify cost-effective biological mulch materials that could be used by South African growers to improve tree condition and root health of avocado trees. The objective of this project is therefore to evaluate the effect of different mulch materials, composts and organic treatments on tree condition and root health of avocado trees through pot and field trials.

MATERIALS AND METHODS

Pot trial

Inoculum preparation:

Pc inoculum

A virulent strain of *Phytophthora cinnamomi* (Pc) was grown in a broth consisting of 1% glucose plus 0.1% yeast extract for 14 days at 25°C on a reciprocal shaker. The fungal mass was harvested by filtration through Whatman no 1 filter paper and was blotted dry with paper toweling. Mycelium was added to 0.1% agar solution at a rate of 0.5% (W/V) and macerated for 30 seconds with an Ultra Turax (Van der Merwe, 1992). This suspension was used as the inoculum and was applied at a rate of 400 ml per plant.

Plant material:

Ungrafted Duke-7 seedling plants were transplanted with the nursery medium still attached to the roots into a soil mixture in 10 L plastic bags and eighteen plants (replicates) per treatment were used. The soil mixture consisted of a 2:1:1 ratio of uninfested soil, polystyrene pebbles and pine bark media respectively. Plants were placed on top of concrete flumes, sheltered by 40% shadow netting and watered when necessary. Mulches or products were applied to the surface of the soil 21 days after inoculation with Pc (**Table 1**). Digital photographs were taken monthly to monitor changes in canopy condition. Plants were removed from their bags after eight months and the roots were cleaned by rinsing under running tap water. Root rot severity was rated on a percentage scale as follows:

0 = No visible sign of disease

Table 1: Treatments and application rates used in the Pot trial (Ungrafted Duke 7 seedlings).

	Treatment	Application rate
1	Eucalyptus wood chips – coarse	1L / tree
2	Avocado wood chips – from chipper	1L / tree
3	Mature Westfalia compost	1L / tree
4	Composted pine bark (Braak's)	1L / tree
5	Eucalyptus chips /compost mix	1L / tree
6	Eucalyptus wood shavings	1L / tree
7	Eucalyptus saw-dust – coarse	1L / tree
8	Eucalyptus saw-dust – fine	1L / tree
9	Compost tea- soil drench + foliar application.	500ml / tree once per month
10	Grass mulch	1L / tree
11	Cattle manure	1L / tree
12	Pine bark + antagonist	1L / tree
13	Gypsum	125g / tree
14	Untreated control	No mulch

Table 2: Various treatments and application rates used in the field trial.

	Treatments	Application rate / tree
1	Eucalyptus wood shavings	1m^3
2	Compost tea / Cattle manure	Foliar 1.5L, Drench 0.5L & 200kg
3	Partially mature Westfalia compost (50% mature)	1m^3
4	Fully mature Westfalia compost (100% mature)	1m^3
5	Eucalyptus wood chips	1m^3
6	Westfalia compost / Eucalyptus wood chips (1:1)	1m^3
7	Eucalyptus saw dust – fine	1m^3
8	Cattle manure	200kg
9	Avocado wood chips	1m^3
10	Organic gypsum + Avocado wood chips	15kg & 1/2 m^3
11	*Untreated control (mulch removed)*	-

1 = Less than 20% root rot
2 = 21 – 40% root rot
3 = 41 – 60% root rot
4 = 61 – 80% root rot
5 = More than 80% root rot.

Individual fresh weight of avocado shoots and roots were recorded separately. Finally isolations from 10 growing root tips per plant were made to measure percentage Pc infection. Results were statistically analysed using StatSoft, Inc. (2003). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Field trial

The trial site is an organically managed orchard on Westfalia Estate, near Tzaneen, South Africa. The trees are twenty years old, on seedling Duke-7 rootstocks and top-worked to 'Lamb Hass'. Tree health ratings according to the Ciba-Geigy (Bezuidenhout, Darvas & Toerien, 1987) rating scale, were done for all the trees in the orchard in August 2005. Trees were then grouped into replicates and treatments according to tree health ratings, and eleven treatments were allocated randomly to blocks of four trees, each replicated five times. The average tree health rating for each treatment ranged from 2.7 to 3.2 with no statistically significant differences between treatments. The second round of tree health ratings was done after harvest in August 2006, and will continue annually. Raw materials for mulches and compost were collected from Wesfalia Estate's compost site and the organic gypsum was obtained from BPB Gypsum (ER Lightweight Building Solutions). Mulches were applied at a rate of 1 m^3 per tree in October 2005 and spread in a wide band underneath the tree canopy. **Table 2** shows the various treatments and application rates used.

In order to evaluate root health and root density, root viewing "windows" were created by placing squares of shade-cloth (500 x 500 mm) underneath the mulch layer under one tree per replicate. Digital photographs of the window area were taken twice (November 2005 and May 2006) and will be analyzed according to the technique described by Bekker, Kaiser & Labuschagne 2006.

The amount of Pc in the soil beneath the different mulches was estimated by using a semi-quantitative baiting assay system. Soil

Table 3: Mean root health ratings, root and shoot weights as affected by the various treatments applied in the pot trial (N = 18).

	Treatment	Root health rating (0-5)[1]	Root weight (kg)	Shoot weight (kg)
1	Eucalyptus wood chips – coarse	2.28 ab[2]	0.10 ab	0.08 ab
2	Avocado wood chips	3.5 cde	0.08 ab	0.07 ab
3	Mature Westfalia compost	4 e	0.09 ab	0.08 ab
4	Composted pine bark (Braak's)	2.28 ab	0.07 ab	0.06 a
5	Eucalyptus chips /compost mix	2.61 abc	0.08 ab	0.07 ab
6	Eucalyptus wood shavings	3.67 cde	0.1 ab	0.07 ab
7	Eucalyptus saw-dust- coarse	2.78 abcd	0.09 ab	0.07 ab
8	Eucalyptus saw-dust- fine	3.06 bcde	0.08 ab	0.06 ab
9	Compost tea	3.78 de	0.10 ab	0.06 a
10	Grass mulch	3.50 cde	0.11 b	0.07 ab
11	Cattle manure	4.11 e	0.07 a	0.09 b
12	Pine bark + antagonist	2.11 ab	0.09 ab	0.08 ab
13	Gypsum	1.89 a	0.08 ab	0.06 a
14	Untreated control	3.5 cde	0.09 ab	0.07 ab

[1] Root health rating done according to a rating scale where 0 = 100% healthy roots and 5 = 100% diseased roots.
[2] For each treatment values with a letter in common are not significantly different at p=0.05%.

sampling for this purpose was done in May 2006 and five trees with a similar canopy condition were selected in each treatment, that is one tree per replicate. Three sub-samples were taken from each tree and the five samples from each treatment were combined and thoroughly mixed. The combined soil from each treatment was then used for the assay. The avocado leaf baiting technique described by Pegg (1977) was used to determine the Pc population levels in the soil. The percentages of leaf discs yielding growth of Pc were recorded.

Mulch decomposition rate was recorded by measuring the mulch depth (cm) under each of five trees per treatment, that is one tree per replicate. Mulch depth has been measured twice so far and will continue. Soil moisture fluctuations underneath the mulches were recorded by means of tensiometers. One 12-inch tensiometer was installed per treatment and readings were recorded twice a week. Irrigation scheduling was done according to a tensiometer placed in the partially mature compost treatment (50% mature).

Leaf sampling for leaf mineral analysis was done in April 2006 according to recommended protocols (Köhne *et al*., 1990). Five trees per treatment that were homogenous in appearance were chosen for sampling and two leaves were collected from each side of each tree. In total fourty leaves per treatment were collected and pooled as one sample. The leaf samples were sent to the ARC-Institute for Tropical and Subtropical Crops, Nelspruit, for standard mineral analysis 24 hours after sampling.

The trial was harvested in August 2006 and individual tree yield (kg / tree) was recorded. This was then extrapolated to tons per hectare for 200 trees / ha. The fruit was pooled per treatment and sent through the commercial pack line to determine fruit size distribution (according to a 4 kg carton) and pack-out figures according to export, local and factory grades. Fruit samples (10 cartons per treatment), were placed into cold storage at 6°C for 28 days and post-harvest quality was evaluated upon ripening. All results were statistically analysed using StatSoft, Inc. (2003). STATISTICA (data analysis software system), version 6. www.statsoft.com.

RESULTS AND DISCUSSION

Pot trial

Statistically significant differences in root health ratings according to the described scale were observed. These showed that gypsum, the pine bark / antagonist mix, coarse eucalyptus wood chips and Braaks' pine bark alone all improved root health when compared to the untreated control (**Table 3**). Treatment with cattle manure appeared to have a detrimental effect on root health, resulting in a significantly higher disease rating than the untreated control and the lowest mean root weight. Cattle manure also resulted in leaf browning and dieback (**Figure 1**), although plants did recover and produced healthy leaf flushes after six months. This treatment eventually resulted in the highest mean shoot weight, although this was not significantly different from the untreated control. Animal manures are known to reduce populations of Pc, probably because they often release ammonia which is very toxic to Pc (Tsao and Oster, 1981). However avocado roots are also very sensitive to ammonia and the damaged roots may even be more susceptible to avocado root rot. According to Pegg *et al*., 1982, animal manures should be broadcast sparingly and not used as mulches directly on top of avocado roots. Additionally, if animal manures are used they could be spread over other organic mulches with a high C : N ratio.

Figure 1: Leaf browning and dieback on avocado plants three months after treatment with cattle manure in the pot trial.

Field trial

There were no statistically significant differences between treatments in average tree health ratings done in August 2005, however small differences were observed in the tree health ratings done in August 2006 (**Table 4**). The compost tea / manure treatment and partially mature Westfalia compost (50% mature) resulted in significantly better tree health ratings than treatment with wood shavings; compost / wood chips combination; gypsum / avocado wood chips combination and eucalyptus wood chips. The poorer canopy condition of these treatments could be due to slight nitrogen draw-back caused by the high C: N ratio of the woody mulches. There was no significant improvement or decline in the tree health ratings from 2005 to 2006 for each treatment.

Digital photographs of root health and density have not yet been analysed, using the Image-J 1.33u software (Bekker *et*

Table 4: Mean tree condition ratings per treatment in August 2005 and August 2006 as affected by different mulches and treatments applied in October 2005 (N = 20).

	Treatment	Tree condition rating (0-10)[1]		
		2005	2006	Difference
1	Eucalyptus wood shavings	3.15a[2]	4.05a	- 0.8a
2	Compost tea / Cattle manure	2.35a	2.5bc	-0.15a
3	Partially mature Westfalia compost (50% mature)	2.5a	2.3c	0.2a
4	Fully mature Westfalia compost (100% mature)	2.75a	3.13abc	-0.64a
5	Eucalyptus wood chips	3.4a	3.8a	-0.4a
6	Westfalia compost / Eucalyptus wood chips (1:1)	3.25a	3.93a	-0.47a
7	Eucalyptus saw dust- fine	3.05a	3.65ab	-0.6a
8	Cattle manure	2.95a	3.36abc	-0.42a
9	Avocado wood chips	2.8a	2.8abc	0a
10	Organic gypsum + Avocado wood chips	3.2a	3.91a	-0.72a
11	Untreated control	2.9a	2.71abc	0.08a

[1] Tree condition rating done according to Ciba-Geigy rating scale where 0 = a healthy tree and 10 = a dead tree.

[2] For each treatment values with a letter in common are not significantly different at p=0.05%.

al., 2006), however, it is the author's impression that there were no obvious visual differences in root health and density in the viewing windows thus far. The amount of Pc detected in the soil beneath the mulches was affected by the different mulches and the lowest level of Pc was found associated with the avocado wood chips and eucalyptus wood chips (**Figure 2**). These initial findings are in agreement with work done in the USA and New Zealand. Downer *et al*., 2001, found that enzymes, with the potential to attack the components of *Phytophthora* cell walls, are common in eucalyptus mulches and that Pc does not populate this mulch. They also found that root health is improved in mulch layers where the highest enzyme concentrations are detected. The highest incidence of Pc was found associated with the compost tea / cattle manure combination and this could be due to the high nutrient concentration in the compost tea that Pc populations were able to utilize. Initial results of tensiometer readings show that soil moisture was affected by the different mulches that have been applied (results not shown). During the dry season (May to September 2006) tensiometer readings were high for all mulches when compared to the control. It seems that water did not easily reach the soil beneath the mulches. This highlights the importance of correct irrigation scheduling when using mulches, since mulch materials may absorb water before it reaches the soil. Additionally the physical properties of different mulch materials may affect the penetration of water through the mulch layer (Pers. comm., Hans Boyum, Westfalia Marketing, SA).

The leaf mineral analysis showed that leaf nitrogen content was affected by the different mulches. Due to the sampling method, there was insufficient data for statistical analysis, therefore the results reflected are a trend (**Figure 3**). Cattle manure and the partially composted compost (50% mature) resulted in slightly

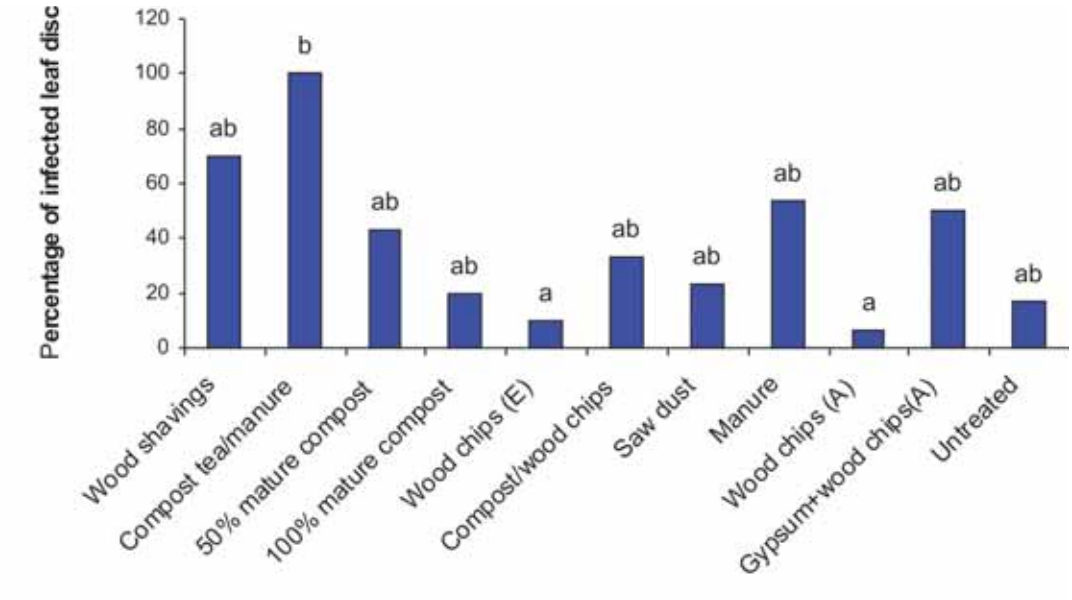

Figure 2: Mean percentages of avocado leaf discs yielding growth of Pc as affected by different mulch treatments in the field trial. For each treatment columns with a letter in common are not significantly different at p=0.05%.

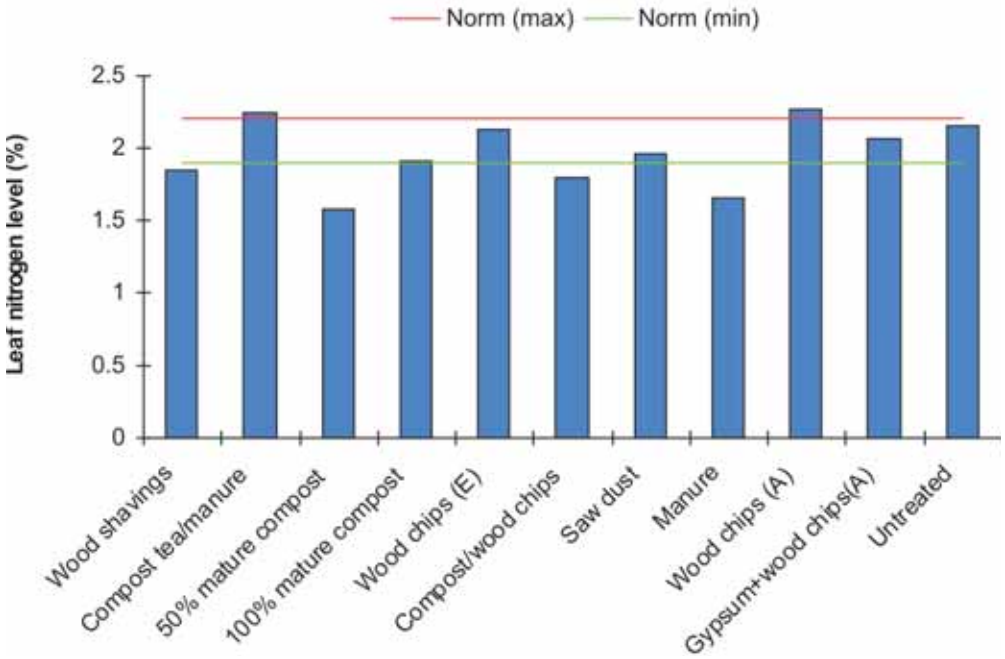

Figure 3: Leaf nitrogen levels in April 2006 as affected by different mulches in the field trial.

lower leaf nitrogen levels than the untreated control. Therefore some nitrogen drawback is suspected because both mulches were not fully composted when applied. Further leaf and soil mineral analyses will continue on a larger scale so as to detect statistically significant differences between treatments and no fertilization will be done for the duration of the trial.

There were no significant differences in yield between treatments as a result of a high variation between trees. It was, however, noted that the highest yield was recorded for the trees treated with partially mature Westfalia compost (data not shown). Since this represents the first season's yield data, no conclusions about the effect of different mulches on yield will be drawn at this stage. All treatments had a similar fruit size distribution, peaking at count 16 (236 g – 265 g) (results not shown).

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