South African Avocado Growers' Association Yearbook 1996. 19:87-91

Some Pros and Cons of Mulching Avocado Orchards

B.N. Wolstenholme[1] C. Moore-Gordon[1] S.D. Ansermino[2]
[1]*Department of Horticultural Science, University of Natal, Pietermaritzburg 3209*
[2]*Kynoch Soil Services, PO Box 38, Cramond 3420*

ABSTRACT

Mulching is a powerful manipulatory tool to ameliorate the root environment and reduce tree stress. It has been shown to improve both fruit size and yield in Hass in the cool, mesic KwaZulu-Natal midlands, and could be expected to be even more beneficial in more stressful areas. Pros and cons of mulching are discussed. Choice is affected by C: N ratio of the mulch, availability, expense and speed of decomposition. Timing is important, and tree nutrition and soil moisture must be monitored. Overall, in most situations the advantages of mulching, including water conservation, outweigh the disadvantages.

INTRODUCTION

Mulching is the application of any layer of plant material or other suitable material to the surface of the soil, without incorporation into the soil. It is an ancient technique and has three main benefits, viz. improved soil physical properties, improved water conservation and reduction of weed growth. Overriding these benefits are the effects on root growth and root health, i.e. amelioration of the root environment to improve conditions for the vitally important 'hidden half of the plant. Wolstenholme (1981) stressed the importance of the roots in avocado tree performance.

A wide range of materials are used for mulching, e.g. manure, sludge, sawdust, wood-chips, straw, shredded prunings, plant foliage, paper, plastic, sand and gravel (Turney & Menge, 1994). These authors reviewed the use of mulching to control root disease in avocado and citrus trees. Recent research by Moore-Gordon *et al.,* (1995, 1996) has highlighted the benefits of composted pine bark mulch in increasing Hass fruit size, through the partial alleviation of stress associated with improved root growth. This ongoing research, surprisingly one of the few detailed studies of avocado orchard mulching, has raised questions in the minds of growers, more particularly the practical and economic implications of the promising research results.

This paper gives a broad overview of the pros and cons of organic mulching, with particular reference to the South African situation. Readers wishing for more general detail are referred to the excellent book on growing media by Handreck & Black (1994). The principles of composting are, however, not discussed in this overview.

BENEFITS OF MULCHING

Water conservation

Mulching conserves water by reducing evaporation from the soil; decreasing water run-off, soil puddling, compaction and erosion; increasing soil permeability; and increasing soil water holding capacity (Turney & Menge, 1994). More water is therefore available during stress and drought periods. This is of cardinal importance for maintenance of tree function during prolonged droughts such as we have experienced for the past four or five years, and during critical periods such as fruit set and early fruit growth. Furthermore, substantial savings in irrigation water can be effected — a scarce resource which will become far more expensive in future. These water savings need to be quantified in avocado orchards.

Improved root growth and reduced physiological stress

Good mulches allow more root growth, both in the litter layer and in the more fertile topsoil. Addition of organic matter improves soil structure, porosity and aeration and therefore also allows deeper root growth. Avocado roots have a high oxygen requirement (Stolzy *et al.,* 1971). Moore-Gordon *et al.,* (1995; 1996) showed substantially more root growth, and for longer periods during the two main root growth flushes (Whiley *et al.,* 1988) as a result of mulching under the drip with composted pine bark.

More root growth means greater uptake of water and minerals, and probably also greater synthesis and translocation of growth-promoting hormones such as cytokinins and gibberellins in and from the roots. This is accompanied by reduced levels of the growth inhibitor abscisic acid in aerial parts. The net result is reduced stress, resulting in more cell division in flowers and fruits, better fruit set, larger fruits, and higher yields. Moore-Gordon *et al.,* (1995, 1996) have shown that anatomical (less ringneck of fruit stalks) and physiological (reduced incidence of premature seed coat abortion) indicators of stress are ameliorated.

More mesic soil environment

It is well known that mulched soils experience less temperature fluctuation, mainly because of improved moisture status (Gregoriou & Rajkumar, 1985; Lanini *et al.,* 1988). This also improves root growth and reduces plant stress. Optimum temperatures for root growth of Duke 7 and Velvick avocado rootstocks lay between 18 and 28 °C (Whiley *et al.,* 1990).

Suppressive soils for root disease reduction

The use of mulches and gypsum to help create more suppressive soils to combat *Phytophthora cinnamomi* root rot in avocado orchards was pioneered in Australia (Broadbent & Baker, 1974; Pegg *et al.,* 1982). In the 1970s, before chemical control of *Phytophthora* was available, the so-called 'Pegg Wheel' concept was widely promoted in South Africa (Wolstenholme, 1977). However, Trochoulias *et al.* (1986) showed in eastern Australia that organic amendments plus gypsum were unable to prevent tree decline on shallow and/or poorly drained soils, especially during high rainfall episodes. This has also been the South African experience, where Wolstenholme & Le Roux (1974) recommended unimpeded drainage to at least 1,5-2,0 m to ensure reasonable long-term success in the fight against root rot. The return of heavy rains during the 1995/96 season has resulted in rapid decline of many trees on poorly drained or shallow parts of orchards.

The mechanisms of root disease and nematode control by mulching are fully discussed by Turney & Menge (1994). They include increased soil populations of microbial antagonists; production of inhibitory volátiles such as ammonia and nitrite, and toxins such as saponins and organic acids; encystment of *Phytophthora* zoospores by organic matter; increased host resistance (phytoalexins); and improved aeration and drainage in mulch and soil. Lower soil temperatures also favour the tree over *Phytophthora.*

The advent of effective chemical control, and especially phosphonate fungicides (Darvas *et al.,* 1984, Pegg *et al.,* 1985), has shifted the emphasis from biological to integrated control. Nevertheless, the principles of multi-faceted control still apply, and mulches are an important component.

Mineral nutrition

Although the primary aims of mulching are not specifically related to organic fertilization, all organic mulches decompose to release mineral elements for root uptake. Humus, the end-product of decomposition, substantially increases the cation exchange capacity of the soil. Nitrogen is initially released as ammonium, which can be taken up by plant roots or adsorbed to clay and humus particles. Ammonium can also be nitrified to nitrate, which is more subject to leaching and may pollute groundwater. However, the fact that nitrogen from organic matter is released slowly reduces this risk, and if the mulch has a low C: N ratio (see later) the need for inorganic N fertilization will be reduced (Maynard, 1989).

Three mineral elements are regarded as especially important for healthy and prolific root growth, viz. phosphorus (P), calcium (Ca) and boron (B). All three have been observed to increase under mulch (Stephenson & Schuster, 1945). Whiley *et al.,* (1996) regard better root boron uptake in deficient soils as one reason for the increased Hass fruit size in mulched trees found by Moore-Gordon *et al.* (1995; 1996). Composted pine bark mulches are good sources of, *inter alia,* potassium and boron. In fact, in acid leached soils most of the boron will be in the organic matter (and mulch), from where it is slowly released by the action of micro-organisms (Gupta, 1979).

Weed control

Mulches usually reduce weed problems by reducing weed seed germination or reducing light levels. However, the opposite may apply with uncomposted mulches infested with weed seed.

MULCHING PROBLEMS

Cost

One of the main reasons cited for not using mulches is their cost. This applies more to mulching materials not available on site. Costs of transport are high due to the bulky nature of mulches, and application costs must be considered. These costs must be balanced against the increased fruit size (Hass) and yield, and the water and fertilizer savings achieved. This is a difficult exercise in view of lack of data. However, where the very existence of trees and yield was seriously compromized, as in the recent prolonged drought where irrigation water often ran out, surely some form of mulching was obligatory! The senior author was amazed to see avocado trees and bare orchard soils in extreme water stress baking in the sun, while all around was grass and other litter which could have relieved their plight. A partial costing for commercial composted pine bark mulch is presented later.

Danger of nitrogen 'draw-down' (negative period)

Mulches with a high carbon to nitrogen (C: N) ratio have insufficient nitrogen for the increased populations of soil microorganisms which help to decompose them. This nitrogen must also be supplied by the soil. The result is a N 'draw-down' or 'negative period', when the tree roots cannot obtain sufficient N. This can be overcome, at some expense by extra N fertilization (Handreck & Black, 1994; Turney & Menge, 1994),

Table 1 gives typical N contents and C: N ratios for a range of materials which have been used as mulches. C: N ratios above 100 are very high, so that material such as sawdusts (containing mostly cellulose-rich wood) and uncomposted barks are not good mulching materials. On the other hand, humus has a C: N ratio of 10: 1. Proper composting usually reduces the C: N ratio of bark to about 30, and a ratio of 10: 1 is hardly ever achieved. Maggs (1985) and Wright (1987) found that uncomposted south African pine bark had ratio of more than 100, up to 450, the latter especially when the wood (cellulose) content is high.

Table 1
Carbon : nitrogen ratios, and percentage nitrogen content of a range of mulching materials (modified from Handreck & Black, 1994)

Material	*%N in D.M.*	*C : N Ratio*
Pinus radiata sawdust	0,09	550
Cardboard	—	500
Pinus radiata bark	0,1	500
Eucalyptus sawdust	0,1	500
Eucalyptus bark	0,2	250
Paper	0,2	170
Bagasse	0,4	120
Woody prunings	—	100
Composted eucalyptus sawdust	0,45	100
Composted *P. radiata* bark	0,4	100
Wheat or oats, straw	0,4	100
Mature leaves	0,7	60
Composted pine bark[1]	1,1	30–40
Maize stalks	1,2	33
Peat	1,5	30
Grasses	1,8	22
Mixed weeds	2,0	19
Cow manure	2,6	15
Lucerne hay	3,1	13
Peanut shells	4,4	12
Poultry litter	2,4	10–11
Poultry droppings	5,5	7
Pig manure	—	5
Urine	—	2

[1]The Gromed Organics composted pine bark used in the mulching trial at Everdon had a nitrogen content of 1,1 % and a C : N ratio of about 37.

Availability of mulch

Availability is determined by the nature of nearby farming operations. Most avocado growing areas in South Africa are adjacent to exotic forestry plantations of eucalyptus or pines. Waste materials, especially barks (composted and/or thoroughly aged) should be utilized, but sawdusts make poor mulches. In KwaZuluNatal, aged sugarcane bagasse can be used, although it's C: N ratio is rather high. Poultry droppings and broiler/pullet and breeder deep litter, as well as kraal manure can be considered, but have a very low C: N ratio and a high N content. Van Ryssen *et al.,* (1977) also noted their high copper content.

Stubbles of various kinds (wheat, oats, barley etc.) have been widely used in subtropical high rainfall Australia, usually together with gypsum ($CaSO_4$). They make excellent mulches. Similarly, stalky grasses with high fibre content can be used. Remains of weeds, grasses and cover crops in the orchard can and should be used to reinforce the natural leaf mulch under avocado trees. However, fresh blady grass clippings (e.g. kikuyu) are relatively high in N, low in fibre, compact easily, get slimy, and are poor mulches. In Australia, peanut shell mulches are discouraged because they increase *Verticillium* root rot.

Increased frost hazard

In the U.S.A., mulches extending beyond the tree drip have increased the frost hazard in orchards where frost is a danger. They do this by reducing soil heating and storage of heat (from the sun) in the soil, and by raising the coldest air by the height of the mulch (Leyden & Rohrbaugh, 1963). In South Africa this is unlikely to be a problem, since frost hazard is lower and most mulches are placed only under the drip of the tree.

Increased fire hazard in winter

Dry winters increase the possibility of runaway fires gaining access to orchards, especially if dry vegetation is present. Mulches may then act as 'funeral pyres' for trees, and the result can be devastating. Sensible precautions will reduce this risk.

Incorrect use of mulches

Mulches are a powerful management tool if correctly used. Problems arise where the wrong mulch is chosen, or applied at the wrong time. These issues are discussed further below.

Upset nutrient balance

Again, mulches (especially those with a low C : N ratio and which decompose rapidly) can supply significant amounts of nutrients. The danger then exists of upsetting the vegetative-reproductive balance of the tree (Wolstenholme & Whiley, 1990). It stands to reason that leaf and soil analysis becomes even more important in the correct management of mulches in avocado orchards. Farm-yard and chicken manures applied to heavy soils in Israel reduced avocado yields, possibly through reducing soil hydraulic conductivity and through nutrient imbalances (Lahav, 1984).

IDEAL MULCHES

Ideal avocado orchard mulches include those with the following properties:

- C: N ratio of more than 25 : 1, but less than 100: 1
- Fibrous, stalky, strawy materials with a moderate rate of breakdown
- Composted, chunky pine barks

As previously noted, sawdust is a poor mulch material. It was widely used in avocado orchards in the drought years of the 1960s, and did help to save drought-stricken trees.

However, its disadvantages became apparent when the rains returned — poor physical properties; very low N content; excessive wetness; and toxic residues (pine sawdust) if not composted or aged. Similarly, paper and waste cardboard make poor mulches — they must be forked to allow water infiltration, are untidy, also have a high C : N ratio, and soon become a soggy mess (Handreck & Black, 1994).

Rapidity of mulch decomposition

The speed of decomposition (mineralization) of mulch depends on its nature, and on environmental conditions. Organic mulch should not break down quickly — its prime function is soil cover rather than organic fertilizer. To reduce decomposition, it is never worked into the soil.

- *Quick:* Mulches derived from young plant materials with low C: N ratios and little fibre break down very quickly, e.g. young leaves, weeds, green manure crops and most animal manures (Handreck & Black, 1994). More stalky materials such as hay and straw do not last much longer, as they are usually well chopped up.
- *More slowly:* Bulkier, fibrous materials such as mealie cobs and stubble, and wood chips break down fairly slowly.
- *Very slowly:* Composted pine barks with medium particle size, and bark products as used for landscaping decompose very slowly. The same applies to large wood prunings.

Cromed avocado mulch (composted pine bark)

The mulch chosen for the Hass small-fruit trial at Everdon Estate, Howick was initially a commercial composted pine bark. At the time, it was selected because of its good physical properties, ready availability, known composition, and to establish a principle.

Economic viability was not an issue. This Gromed mulch, available from Gromed Organics at Cramond, KwaZulu-Natal, is widely used in the nursery industry and has the following characteristics:

- thoroughly composted pine bark;
- particle size (graded) 16-24 mm, i.e. cannot compact;
- half-life of 5 years, i.e. very slow decomposition;
- high levels of potassium, calcium and boron.

The mulching trial at Everdon has now run for over 3 years, with no addition to the original mulch and little evidence of decomposition. Originally, 1,5 m^3 was applied under the drip of the seven-year-old trees, in a layer approximately 15 cm thick, to simulate (with the natural leaf mulch) the deep litter layer of an ideal indigenous avocado rainforest habitat. Due to this longevity of the mulch, it is conceivable that when orchards are thinned, the mulch under thinned trees could be transferred to the remaining trees.

An exercise in economic viability of this mulch showed that initial costs per hectare were very high, but that these could be amortized over the life of the mulch, and offset against the gains. Some salient figures are:

Cost of mulch @ 1,5 m^3/tree, 200 trees/ha, delivered from Cramond to Everdon was R26 035/ha in 1994 and R31 265/ha in 1996. Equivalent costs for Cramond to Tzaneen would be R45 673 and R55 340.

However, based on 1994 FOB less export costs supplied by Avodata, Tzaneen, the increased fruit size (ca. 12 %) and greater yield (ca. 42 %) over 2 years resulting from mulching, greatly increased the value of the crop. In 1993/94, extrapolating from the mulching trial, control trees would have grossed R42 377/ha, compared with R78 834 for mulched trees. Figures for 1994/95, a lower crop season, were R15 390 and R38 426. These figures do not take all costs into consideration, nor all benefits such as reduced fertilizer bill and reduced irrigation. Nor is it certain whether these mulching benefits will be as great in a good rainfall season. Nevertheless, they indicate that the 'pay-back' time for Everdon would have been about 11 months, and for Tzaneen 19 months. So even expensive mulches, applied under the tree drip, are not quite as expensive as perceived if their benefits and longevity are taken into account.

IMPORTANT DO'S FOR MULCHING

- Choose suitable, economic mulch.
- The main aim is to *reinforce* the natural leaf and litter mulch under the tree. Avocado trees typically produce spring and summer/autumn growth flushes, but the leaves are short-lived (9-10 months, Whiley & Schaffer, 1994). Therefore a healthy avocado tree will have good, thick natural leaf mulch, with most leaves falling in late spring (or before flowering in stressed trees). The excellent leaf mulch under avocado trees in Israel was a feature of field tours during the recent World Avocado Congress III. In contrast, weak and unhealthy trees will have virtually no natural mulch.
- The best time to apply the mulch, under our climatic conditions, is in autumn — after the summer rains, and in time to tide the trees over the dry, stressful winter and spring. The mulch will also have broken down significantly before the onset of the heavy summer rains (this does not of course apply to chunky composted pine bark, or to large tree prunings which take years to decompose).
- Do not mulch excessively wet soils, or areas of the orchard that become wet after heavy rains — e.g. the lower slopes where drainage water reaches the surface.
- Monitor tree nutrient status (annual leaf and soil analysis) as well as moisture status/irrigation need (tensiometers), both of which are affected by mulches.
- Never remove vegetative material from orchards. Cut up larger limbs and trunks of thinned trees, and place them under the drip — although they have a high C : N ratio, they decompose very slowly so their adverse N draw-down effect is diluted over time. Use a brush-cutter to break down smaller prunings.
- Adjust mulch type, thickness and timing to suit your particular orchard situation. A thickness of 7,5 cm may be quite sufficient in some situations; 10-15 cm in others.

SOME DON'TS FOR MULCHING

- Do not use materials that pack into a water-shedding layer (Handreck & Black, 1994), e.g. green lawn clippings, sawdust. Green grass with little fibre soon turns slimy, due to poor aeration and encouragement of anaerobic organisms. Anaerobic organisms produce organic acids that are toxic to plants (the pH can drop as low as 2), and nitrogen loss can be high (Handreck & Black, 1994).
- Avoid materials with very high C: N ratios (> 100: 1, unless they decompose very slowly and have good physical properties), or very low C: N ratios (< 20: 1). The latter supply considerable nutrients as they decompose, and must be considered as organic fertilizers rather than mulches.
- Don't mulch already wet areas (lower slopes) or during very wet periods.
- If tree barks are used, they should be composted or aged, especially pine bark which contains resins.
- Do not apply thick, poorly aerated mulches just before the summer rains.
- Do not use wet, unleached composts or manures from, for example, kraals or piggeries — they may have a high salt content if they have not been thoroughly leached.
- Do not place mulches right up against the tree trunk — they can encourage *Phytophthora* collar rot.

CONCLUSIONS

Under South African and Australian conditions, with warm to cool climates and summer rainfall, mulching under and sometimes slightly beyond the drip of the tree has proven highly beneficial on well-drained soils. It simulates the rainforest floor conditions of the indigenous habitat, and benefits the rather shallow feeder root system of this 'litter feeder'. Root growth and root health are promoted, reducing the tree stress syndrome, especially at critical periods. This has led to larger fruit size and increased yield in Hass. Suppressive soils are also encouraged.

However, the choice of mulch must take into account factors such as C : N ratio, cost and availability, and speed of breakdown. Mulches must be applied correctly, and avoided where soil wetness is a problem. Composted pine bark has proved highly beneficial, and its initial expense is offset by a long life and greatly improved tree performance. The do's and don'ts of mulching are discussed. Overall, advantages outweigh disadvantages, and growers are strongly advised to use suitable mulches to their advantage, especially where water conservation is important. Moreover, mulching is environmentally friendly in a world increasingly conscious of 'clean and green' issues.

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