

Macadamia husk compost improves soil health in sub-tropical horticulture

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Abstract

The macadamia industry has acknowledged that bare soil under mature trees with mechanical harvesting from the orchard floor has resulted in soil loss from erosion. Macadamia husk and poultry manure were composted to provide a surface cover and the effects of compost on soil health assessed. A green waste compost was also included for comparison. Both composts and a compost treatment with a fibre mat on top were applied to three tree plots of macadamias, and soil health indicators were measured for 18 months. Microbial activity increased in the 0-2cm and 2-10cm soil layers under compost over time, and was significantly greater than the bare soil control. The soil pH under the husk compost increased from 4.15 to 5.0 after 18 months in the 0-2cm layer. The green waste compost did not improve these soil properties as much, but was greater than the bare soil. Water holding capacity was only increased by the husk compost. The green waste compost had a much larger particle size and different source material which may explain the differences. By 18 months, the microbial biomass carbon in the 0-2cm layer under the husk compost showed that the population was 300% more than bare soil, while the green waste compost was only 50% greater. The benefits of husk compost under macadamia trees were substantial as it improved soil fertility and may reduce soil loss in the long term.

Key Words

Microbial activity, soil health, biological indicator

Introduction

The macadamia industry currently produces 29,000 tonnes of raw nut from more than 1.25 million hectares of orchards in northern NSW and south eastern Qld. The management of these orchards is to harvest the nut from the bare soil floor with mechanical finger wheel harvesters. Due to the large size of mature trees, inadequate light reaches the floor to maintain a permanent groundcover. Leaves and other refuse are mechanically swept or blown from this bare earth prior to “nut-fall”. The harvest period can range from late February to September, depending on variety, and pick up occurs approximately monthly. These management practices utilised over the last 30 years have lead to concern about soil degradation such as erosion in this sub-tropical environment. Tree roots are commonly exposed and flood events leave visible evidence of soil movement down slopes. Other intensive cropping systems with exposed soil on slopes have led to considerable soil erosion and degradation, which resulted in community concern (Edwards *et al.* 2000).

In 1999 soil extension staff established an erosion demonstration site with Gerlach troughs in a macadamia orchard to quantify runoff and sediment loss over several years. Bare soil was compared to a mulched plot, mechanically drained plot and a planted groundcover plot (shade tolerant sweet smother grass *Dactyloctenium australe*). After three years the average soil loss in the bare plot was 2 tonne/ha/yr, with two major rainfall events responsible for 88% of runoff and 76% of sediment loss (Reid 2002). The smothergrass reduced soil loss by a staggering 99.9%. At the same time a project was undertaken by NSW Primary Industries and a local Landcare group to evaluate the soil health in a variety of horticultural industries. It found that macadamia orchards had a significant loss of microbial activity and microbial biomass carbon in the tree row compared to the inter-row and undisturbed sites (Van Zwieten *et al.* 2001). There was also compaction in the inter-row. These studies, along with anecdotal farmer evidence, link the management of macadamias with degraded topsoil with reduced biological activity and organic carbon, indicating diminished soil health.

The search for a solution congruent with current management practices led to the use of compost for improving soil stability, microbial activity, nutrient status and organic carbon. Application of compost to

agricultural land has proven very beneficial to soil quality, crop yield and quality. Compost has been shown to improve soil texture and aggregation from the contribution of polysaccharides, humic acid, and other organic matter (Raviv 1998). It also assists nutrient cycling through increased microbial activity and contains fertiliser value for plant nutrition (Raviv 1998). Another benefit lies in the increased water holding capacity and better infiltration rates, as shown by Buckerfield and Webster (2000) in vineyard soils. They also found reduced soil resistance and increased earthworm biomass under composted mulch. Improvement in soil quality resulting in improved crop yields and quality has been demonstrated with barley (Cook *et al.* 1998), and a range of vegetables (Warman 1998). The role of compost in Australian extensive horticulture has not been fully exploited. Barriers to the widespread and effective use of compost include cost of production and transport, commercial availability, and reliability in quality. However, the increase in number of quality compost suppliers and the release of the latest standard (AS 4454-2003) have improved compost quality recently.

Indicators are currently used to assess soil health in agriculture as there is no one measure which will provide soil health condition. Usually a suite of soil physical, chemical and biological parameters are chosen to represent the status of the soil. As there are also no benchmarks in Australia that represent adequate values for these indicators, the trend over time is tracked or comparisons made of different experimental treatments. Many studies using a minimum data set approach have identified that carbon amounts (e.g. total, organic, labile carbon) as very informative (Sparling and Schipper 2002). Most have recommended that all soil health indicators include this measure. Elliott (1997) reported that the biological measures were the first to respond and as such provided a good early detection system for soil change. Biological parameters used as indicators of soil health include soil enzyme activity, microbial activity and biomass, earthworm biomass, nematode community structure and biodiversity. This study chose microbial activity and biomass carbon, total carbon and nitrogen, pH, water holding capacity and bulk density as indicators of soil health under two different composts.

The location

The climate in the northern rivers region of NSW is sub-tropical with a mean temperature range of 19.3-27.2°C January and 9.3-18.3°C in July, with summer dominant annual rainfall averaging 1867mm (anon 1988). The sites vary from flat to mildly sloping (< 8°) with Ferrosol soil (Australian Soil Classification) of volcanic origin (basalt) (Lines-Kelly 2000). These acidic soils are composed mainly of kaolinitic clay minerals, as well as large amounts of iron and aluminium oxide (Nicolls and Tucker 1956).

Compost development

Macadamia husks are the outer coating of the nut-in-shell and usually accumulate in stockpiles on the farm as a result of de-husking processes. Volumes of 40-50m³ per orchard/year are not uncommon. Several growers currently spread this husk under their trees after harvesting has finished, as a mulch layer. The C:N ratio is typically 40:1 and the husks degrade very slowly by themselves. To compost this material another waste with high nitrogen was required and broiler chicken manure (with sawdust) was available and economic. With the valuable assistance of a local grower and farm resources, a composting operation was established on the farm. Macadamia husk and chicken litter (from a local poultry producer) was incorporated with a front-end loader in a windrow at the end of September 2000. Husk (40 m³) was used with the addition of 40m³ of chicken litter to create a pile approximately 2m high x 3m wide x 20m long. The proportion of materials was calculated from analysis of carbon and nitrogen values of the materials. The compost was adjusted to approximately 50% moisture, using on-farm stored rainwater. Availability of water proved to be limiting due to the unseasonably dry conditions. The temperature was measured with several data loggers (Tiny tags, Hastings Data Loggers) so that turning times could be determined. The pile was turned with a front-end loader when the temperature maintained or exceeded 55°C for 3 days. This resulted in approximately fortnightly turnings. The pile was watered several times during the 8-week composting process. The final C:N ratio was very low at 14:1. The commercial green waste compost was purchased from a company sourcing council green waste as the base material, with no information provided.

Compost experiment design

Three year old macadamia trees (variety 246) were used on the research station site when the experiment was established in May 2001. Three consecutive trees (within four rows) were designated a plot unit (15m long). The treatments included macadamia husk compost (MHC), a commercial green waste compost

(GWC), the commercial green waste compost with a layer of coconut fibre matting, and bare soil control. Compost was spread uniformly over the length of the plot to 10 cm depth and 3 m width, by hand raking. The fibre mat was rolled over the green waste compost in 2 sheets on either side of the tree, and pinned with plastic stakes. As the experiment was set up to also include a cover crop treatment which didn't eventuate, there is uneven replication of plots (2 or 4).

Soil sampling and analytical methods

Soil samples were taken at the start then after 3, 6, 9 and 18 months. The compost layer and the 0-2cm and 2-10cm soil layers were sub-sampled and composited. Microbial activity was measured using the FDA hydrolysis method described by Alef and Nannipieri (1995). This method is based on the ability of several enzymes (e.g. esterases, lipases, and proteases) produced by bacteria and fungi to split the fluorescein diacetate molecule. The byproduct is fluorescent which was measured on a fluorescent plate reader. Microbial biomass carbon was calculated using the microwave and extraction technique (Islam and Weil 1998) and carbon measured using a TOC analyser. Water holding capacity was measured by water content of free draining soil in funnels after 24 hours. The soil pH (CaCl_2) was measured using a 1:5 soil/water extract (Rayment and Higginson 1992). Total carbon and nitrogen were determined by LECO combustion. Moisture content was measured by oven drying to constant weight, and expressed as dry matter. Bulk density was measured underneath the compost layer by driving a steel ring of known volume, 6cm deep into the soil and calculating the core's dry weight. The data were analysed by linear regression.

Results

Microbial activity of the macadamia husk compost (MHC) was initially very high (25 mg fluorescein/ g soil/ 45 min) and three times the activity of the commercial green waste compost (GWC) (7 mg fluorescein/ g soil/ 45 min). Activity of the MHC decreased over 18 months to 8.5 mg fluorescein/g soil/ 45 min while the GWC remained the same. In the 0-2cm soil layer, however, the microbial activity increased under both composts and was double the level of the bare soil control (fig 1). Seasonal conditions influenced activity levels as the variation in the data shows. In the 2-10cm layer, the overall trend showed that the bare soil remained at the same activity level, while the layers under the compost increased, and the MHC always performed better.

By 18 months, the microbial biomass carbon in the 0-2cm layer showed that population under MHC had built up to more than 300% of bare soil (fig 2). The GWC was only 50% greater than the control. The fibre matting over the GWC seemed to have improved the result over the GWC alone. The only influence compost had on the 2-10cm layer was under the MHC treatment. The microbial population of the composts themselves were quite low.

MHC significantly and substantially increased soil pH. Over time, the originally acidic pH of the 0-2cm layer (4.15) increased to 5.0 after 18 months, while the bare soil control remained at 4.0 (fig 3). The GWC also increased the pH (to 4.6 and 4.8) in the 0-2cm layer. The pH of the 2-10cm layer under both composts increased slightly from 4.2 to 4.35.

The MHC also increased the water holding capacity of the 0-2cm layer compared with the control (fig 4). The green waste compost WHC remained the same over the study while ending only slightly greater than the bare soil control. The WHC of the MHC itself decreased dramatically from the high initial state of 300%, down to 150% by 18 months. The GWC had only 170% WHC at the start and reduced to 115%. This was supported by moisture content measurements, where the MHC was always wetter than the GWC at each sampling time (data not shown).

The MHC contained nearly twice the organic carbon (28% carbon) of the GWC (17% carbon) at the start. The carbon content of the 0-2cm layer increased under both composts while the control remained the same over time (fig 5). The surface soil under MHC after 9 months had a carbon content of 6.2% while the GWC had 5.75%. The GWC+fibre mat had the highest carbon content throughout the experiment and the 0-2cm layer also had 6.2% carbon at 9 months. In the 2-10cm layer there was also an increase under MHC and GWC+fibre mat over time, but the GWC carbon content decreased slightly (data not shown). This same pattern was also shown with total nitrogen.

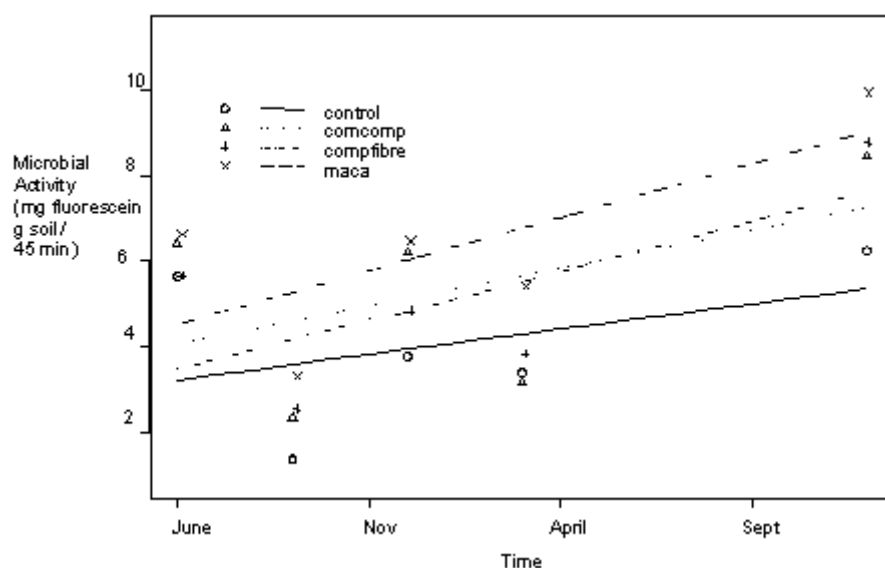


Figure 1. Microbial activity (mg fluorescein/ g soil/ 45 min) of the 0-2cm soil layers from the treatments over 18 months from June 2001. Control (bare soil), comcomp (commercial green waste compost) comp fibre (green waste compost + coconut fibre mat), maca (macadamia husk compost).

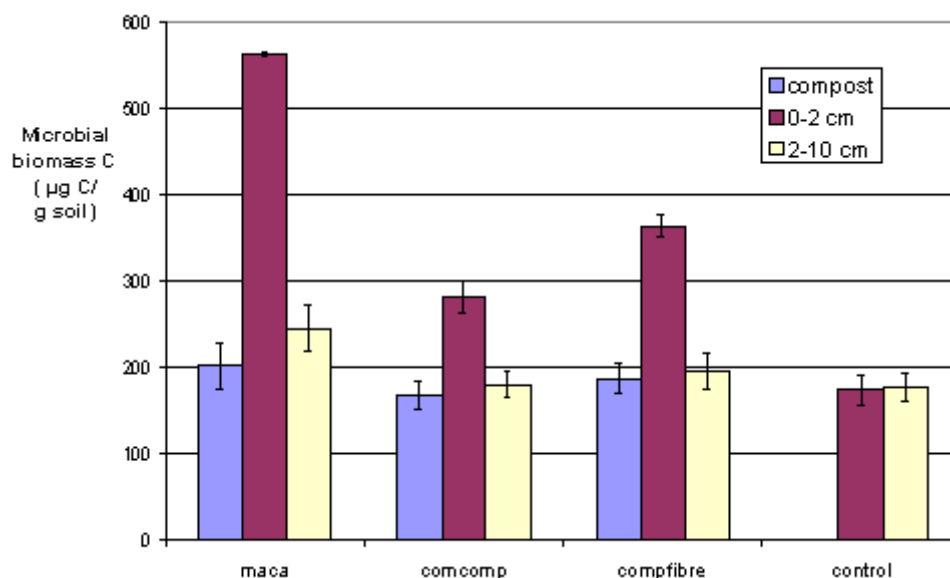


Figure 2. Microbial biomass carbon (µg C/ g soil) of the compost, 0-2cm and 2-10cm layers of the treatments at 18 months. Control (bare soil), comcomp (commercial green waste compost) comp fibre (green waste compost + coconut fibre mat), maca (macadamia husk compost).

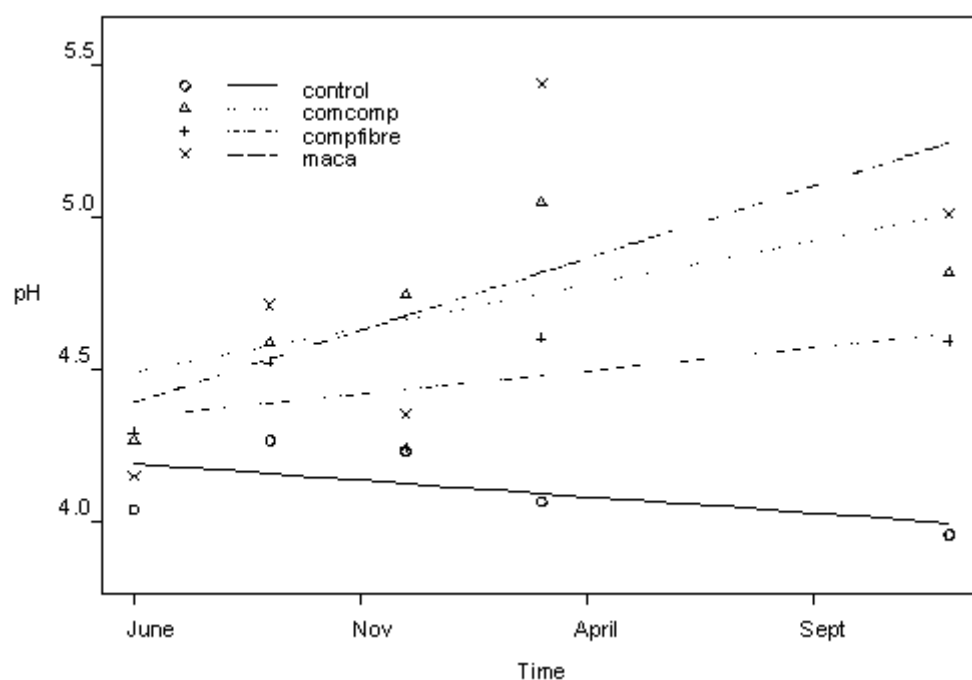


Figure 3. Soil pH of the 0-2cm soil layers from the treatments over 18 months from June 2001. Control (bare soil), comcomp (commercial green waste compost) comp fibre (green waste compost + coconut fibre mat), maca (macadamia husk compost).

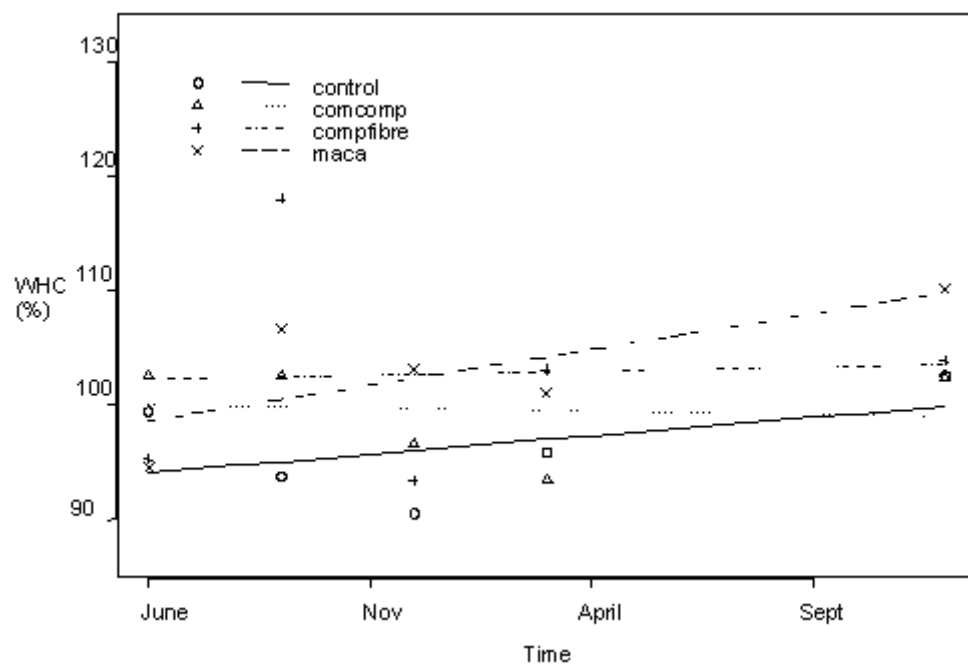


Figure 4. Water holding capacity (%) of the 0-2cm soil layers from the treatments over 18 months from June 2001. Control (bare soil), comcomp (commercial green waste compost) comp fibre (green waste compost + coconut fibre mat), maca (macadamia husk compost).

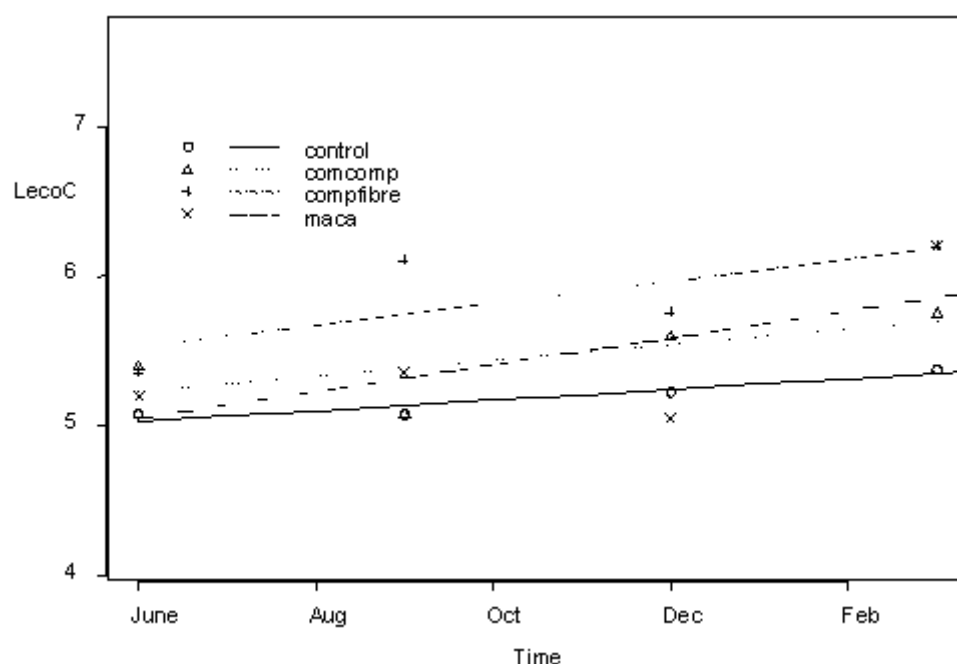


Figure 5. LECO (total) carbon (%) of the 0-2cm soil layers from the treatments over 9 months from June 2001.

Discussion

Overall the effects of both composts were beneficial to the soil, especially in the surface 0-2cm layer. The husk compost out performed the GWC in every indicator. The MHC improved the microbial activity, biomass, water holding capacity, pH, organic matter and bulk density of the soil compared with the bare soil control over 18 months. The microbial biomass carbon in the 0-2cm layer of 562 $\mu\text{g C/g soil}$ and 245 $\mu\text{g C/g soil}$ in the 2-10cm layer under husk compost were similar to that of Borken *et al.* (2002) who applied compost to spruce forest. The difference between compost treatment and the control in the forest was only a 50% increase, while underneath the macadamias a 320% increase was measured. Many studies have shown a build up of diverse and active microbial populations with compost addition in agricultural industries. Compost is a source of both diverse organic compounds (like humic, fulvic acids) and a suite of micro and macro organisms, in a media that potentially holds a great deal of water. When applied to the surface or incorporated into the soil, compost organisms such as bacteria, fungi and protozoa use the food available and develop a new community/food web structure for their environment.

The higher microbial activity in the soil under MHC compared with bare soil was expected given the organic matter and microorganism addition from the composts. The variability over the study time was also expected, given that biological properties are more variable and susceptible to seasonal influences (Elliott 1997). The reduced microbial activity in the GWC compared to the MHC is likely to be related to the physical characteristics of the material. The GWC had very large average particle size, ranging from sand grain size to timber pieces 30cm long x 10cm wide. A large fraction of the GWC would not actually be composted material at all. It also contained a large proportion of contamination (plastic, concrete, rubber). This would have contributed to a reduced water holding capacity, and therefore a diminished habitat for microorganisms. The fibre matting over the GWC seemed to have no effect on the microbial activity, even under the drought conditions the experiment ran under. Wilkinson *et al.* (2002) have identified highly variable compost quality in Australia (even with consistent tree species as a source) as a problem the industry needs to address before its successful use in horticulture.

Another benefit of the MHC was that it raised the pH from 4.15 to 5.0 in the surface soil layer. In this highly buffered ferrosol, the equivalent amount of lime to achieve this increase would be 4.5-9 tonne/ha (Hockman *et al.* 1995). Macadamias require acidic soil, but growers are wary of letting soil get too acid as it can lead to aluminium toxicity, nutrient unavailability and can deter some organisms. Macadamia husk compost from Hawaii also increased the pH compared to fertiliser addition (control) but only maximum of 0.2 units (Bittendender *et al.* 1998).

The MHC increased the water holding capacity of the soil as expected, but the GWC did not to any extent. It is understandable when the WHC of both composts are compared. The MHC was far superior in moisture holding ability. The increase in WHC was not large, as surface applied organic matter does not improve soil conditions as well (or as quickly) as incorporated matter (Buckerfield and Webster 2000). The incorporation of surface compost into the soil profile relies on earthmoving and tunnelling invertebrates, and as earthworm numbers are depleted in macadamia orchards (Van Zwieten *et al.* 2001) this may explain a lack of incorporation.

The carbon level increase under compost was anticipated given that most studies report this result. The higher carbon in the MHC than GWC may have contributed to the better performance of the husk compost. The source material for compost plays a determining role in its eventual quality and characteristics (Wilkinson *et al.* 2002). The fibre mat added extra carbon to the system of a different form (and C:N ratio) which may have explained the improved C, N (especially at depth) and WHC compared with the GWC. The addition of carbon (in compost) to the soil has been shown to improve soil structure, water holding characteristics, nutrient turnover and microbial populations (Wells *et al.* 2000). Even though the natural carbon content of the Ferrosols is high, the loss of soil through current management techniques has significantly reduced the carbon levels (Van Zwieten *et al.* 2002) which may lead to reduced soil fertility.

Another possible explanation for compost differences is that the MHC is returning to macadamia orchards and therefore may possess the beneficial suite of microorganisms for that tree species. The GWC could have been a mixture of any local council plants, exotic and native. The return of farm organic matter back to the soil is both beneficial to the soil biota and soil structure, but is also an excellent waste management option.

There are many local orchardists undertaking composting in this region for use on farm. Although they realise the benefits and our laboratory studies have shown improvements, there is a need for a tool for farmers to measure the biological impacts of these and other newer commercial biological additions. It is not as easy to determine compost effects on fruit or nut yield on these perennial tree crops compared with vegetables or cropping, so other measures of soil benefit are required. Techniques that may be followed up in future include the calico strip test (Correll *et al.* 1997), litterbags, a soil respiration kit from the USA (www.solvita.com) and commercially available soil biology tests.

Conclusion

Macadamia husk compost improved the soil health of the orchard soil by increasing microbial activity, water holding capacity, pH, carbon and nitrogen. The large increase in pH was particularly beneficial in this acidic soil. MHC also physically protected the soil surface from rainfall erosion and machinery disturbance. The green waste compost improved microbial activity and pH but not as much as MHC and did not influence WHC or C greatly. This is likely to be due to the very large particle size of the GWC, the source material and the rubber, concrete and timber pieces contamination. Many orchardists are now making their own compost to harness the beneficial properties to their soil, even though yield increases will be very hard to quantify. There is a need for a tool that farmers can use to monitor the soil biological properties, so that they can test the effects of different soil biological additions.

Acknowledgments

This project was co-funded by the Natural Heritage Trust, Tuckombil Landcare and NSW Agriculture. Thanks go to the Tuckombil Landcare group for their enthusiasm, input and access to their properties, especially Ian and Beth Hotson (Balcarres). Thanks to Steve Pepper and Tamara Collins for assistance with field and lab work and Colin Rucker for valuable farm assistance.

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