Soil fertility management options in sweet potato based cropping systems in the highlands of Papua New Guinea

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Abstract
The highlands of Papua New Guinea have one of the highest rates of population growth amongst developing nations, yet the area under agricultural production has not increased accordingly, leading to land use intensification and concomitant soil productivity decline as length of fallow periods decrease. One opportunity to counter soil productivity decline is to extend the use of large composted mounds, or 'Engan' mounds, outside the areas where this method is traditionally practised and has enabled almost continuous Sweet potato based cropping systems. Accordingly, field trials were conducted in 3 highlands provinces to evaluate a range of farmer adoptable soil management practices aimed at combating soil fertility decline. In the first season of these 3-season trials, we observed that large composted mounds containing high value compost materials such was lupines or wild Mexican sunflower, produced substantial yield increases on poorer soils low in N, K and S. The potential of nutrient losses through leaching in these high rainfall areas was also investigated. The results suggested that nitrate losses are negligible as long as compositing material of low nutrient content is used. Hence, the use of organic matter in composted mounds at this stage seems a better soil fertility management option for sweet potato farmers in the highlands of Papua New Guinea.

Key Words
Composted mounding, sweet potato, soil fertility management.

Introduction

Sweet potato based cropping system account for up to 90% of land under cultivation in the Highlands of Papua New Guinea (PNG). Despite very high rates of population growth, the area under agricultural production has remained relatively stable (Bourke 1997, 2001) with concomitant intensification of land use leading primarily to a shortening of fallow periods. Reports on changes in length of fallow periods are variable due to the tremendous variety of land use practises. In some parts of the Highlands, fallow periods may still exceed 20 years, while in others areas, in particular the composting zone of the high altitude areas in the provinces in the west, very little fallowing is done. Overall, length of fallow periods has significantly decreased as the population has expanded. There is now evidence that decreases in soil productivity is impacting Sweet potato yields, the region's main staple food crop. A recent study (Kirchhof *et al*. 2009) has shown that Sweet potato yields decline from around 8 t/ha in gardens that came out of a 2 to 5 year fallow period to 4 t/ha in gardens that were about to go into a fallow period. This decline was linked to inadequate N, K and S nutrition and was more pronounced where small mound tillage was practised. In contrast, soil management practises using Engan (large composted) mounds were the least affected by soil fertility decline. These Engan or large composted mounding systems consist of round or oval mounds, at least 10 m^2 in area and up to 1 m in height (Taraken and Ratsch 2009). Mound productivity is maintained by placing about 30 kg of biomass, cut from the surrounding area, into the inside of the mound before Sweet potato planting. Although these large composted mounds represent an opportunity to minimise soil fertility decline in systems where mineral fertilisers are not used (D'Souza and Bourke 1986; Floyd and Lefroy 1988), they have not been adopted outside their traditional zones in PNG. However, two decades after the work in the 1980s, farmers are now becoming aware of poor Sweet potato yields as a consequence of land use intensification (Kirchhof *et al*. 2009). The objectives of this study were to develop farmer-adoptable soil management practises incorporating compost mounding systems and including different types of fallow vegetation. Results from the first year of field trials are presented in this paper.

Materials and methods

Fields trials were located in Aiyura (Eastern Highlands Province), Kondiu (Simbu Province) and Tambul (Western Highlands Province). Soils were classified as Humult (Aiyura), Aquept (Kondiu) and Aqoll (Tambul). All sites had just come out of a fallow period of at least 2 years. Soil management treatments applied were the same in Aiyura and Kondiu, but different in Tambul where only variants of the large

mounding systems were investigated (Table 1). Besides a simple comparison of individual treatments, the trial was designed to allow the evaluation of different management effects such as addition and management of biomass as mulch or compost, tillage and mound size, by grouping treatments with equal sub-management factors. Sweet potato vines were planted following land preparation and harvested 5 months after planting in Aiyura and Kondiu, and 10 months after planting at the high altitude area in Tambul. Direction of water movement was monitored using tensiometers and calculating hydraulic gradients, and potential leaching of nitrate was measured in soil water extracts using Merckoquant colorimetric test strips for 10 to 500 ppm. Final biomass and tuber yields were measured.

Table 1. Treatments (soil preparation/fallow management/crop rotation used at the 3 trial sites.

	Soil preparation	Fallow/biomass management	Crop rotation	Aiyura Kondiu*	Tambul
1	Large mounds	20t/ha grass compost buried in mounds	Sweet potato – fallow – sweet potato	√	√
2	Large mounds	50t/ha grass compost buried in mounds	Sweet potato – fallow – sweet potato		√
3	Large mounds	50t/ha Wild mexican sunflower compost buried in mounds	Sweet potato – fallow – sweet potato		√
4	Large mounds	50t/ha Lupine compost buried in mounds	Sweet potato – fallow – sweet potato		√
5	Large mounds	No compost	Sweet potato – fallow – sweet potato		√
6	Large mounds	Fallow vegetation slashed and burnt – ash enriching the soil	Sweet potato – fallow – sweet potato		√
7	Small mounds	Fallow vegetation slashed and burnt – ash enriching the soil	Sweet potato – fallow – sweet potato	√	
8	Small mounds	Fallow vegetation slashed and burnt, and extra compost added to mounds from surrounding area	Sweet potato – fallow – sweet potato	√	
9	Small mounds	Fallow slashed but not burnt and used a mulch	Sweet potato – fallow – sweet potato	√	
10	Small mounds	Fallow vegetation slashed and burnt – ash enriching the soil	Sweet potato – peanut – sweet potato	√	
11	Small mounds	Fallow vegetation slashed and burnt – ash enriching the soil	Sweet potato – sweet potato – sweet potato	√	
12	Flat beds	Fallow vegetation slashed and burnt – ash enriching the soil	Sweet potato – peanut – fallow – sweet potato	√	√

*Treatments 7, 10 and 11 are identical in the first cropping phase

Results and discussion

Water movement and Nitrate leaching

As expected, due to the high rainfall in the PNG Highlands, hydraulic gradients were mainly positive showing a leaching environment. Average gradients downwards were largest in Tambul, followed by Aiyura and Kondiu. However, despite a net water movement down the profile, leaching of nitrate was only observed at the start of the cropping phase in Tambul. This may indicate that nutrient losses through leaching in a system without mineral fertiliser application are of little importance, except in very high rainfall areas where large amounts of compost or high value compost are added. However, these preliminary finding should not distract from the possibility of nutrient leaching if mineral fertilisers are added to the large mounding systems.

Sweet potato yields

Sweet potato yields at Aiyura ranged from 17 t/ha to 30 t/ha, with Treatment 1, the Engan mounds, having the lowest yield ($p=0.052$). However, compared to all other treatments, the Engan mounds had no large tubers and significantly more medium and small size tubers ($p=0.04$). This suggested that the yield potential using Engan mounds had not been realised and that sequential harvesting, as practised by farmers, might improve yield substantially. Statistical analysis of sub-factors (management of biomass as mulch or compost, tillage and mound size) was not significant. The general lack of treatment impact on yield was attributed to the fact that the site had come out of a long 5-year fallow period. The range of yields at the Kondiu site was similar to the Aiyura site (15 to 30 t/ha). However, in contrast to the Aiyura site, Treatment 1 (Engan mounds) out-yielded all other treatments with a yield of 29.9 t/ha ($p=0.001$). The higher yield was due to more tubers in all size classes compared to the other treatments. There was no tillage effect on tuber

yield, but composting, even in small mounds, improved yield compared to the conventional practise of burning. The most striking difference between the Aiyura and Kondiu sites was the yield on Engan mounds. Again we contributed this difference to past land use where Kondiu only had 2 years of fallow and had an overall poorer quality soil, being particularly low in S and exchangeable K. However, yield monitoring for the following years is needed to support the hypothesis that Engan mounds are a suitable alternative to land management outside the traditional mounding zone.

Yields at the Tambul site were tremendously low ranging from below 1 t/ha to 10 t/ha. The relatively poor yields on this site were attributed to the site history. The area is an old lake that and had partly been filled with tephra about 90,000 ago. The lake subsequently dried and formed a swamp. Organic carbon content of the soil now is more then 20% in the topsoils and bulk densities range from 0.22 to 0.37 g/cm^3. The site was drained for grazing about 3 decades ago, but has never been cultivated. In the first year of cultivation and cropping there was insufficient mineralisation, rendering this a very unproductive soil. However, productivity is expected to increase as organic matter mineralises over time. The highest tuber yields of 10.1 and 8.8 t/ha ($p<0.001$) were recorded in the treatments where high value compost, wild Mexican Sunflower (*Tithonia diversifolia*) and Lupines (*Lupinus perennis*), respectively, had been added. This treatment effect supported our assumption that easily mineralisable material needs to be added to this poor soil to get any appreciable amount of tuber yield.

Conclusion

Results from the 1st year of a 3 year study on Sweet potato productivity showed that the large Engan compost mounding systems has the potential to overcome soil productivity decline on soils outside the traditional mounding zone in the Highlands of PNG. Yield improvements at this stage are most pronounced on soils with inherently low soil fertility. Composting, rather than burning could be the first step countering soil fertility decline. Preliminary results also showed that, even though the areas are in a strong leaching environment, nutrient losses were negligible. While at this stage there is little indication that leaching may be a problem in systems where only organic fertilisers are applied, we advise caution in the use of soluble mineral fertiliser.

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