Nutrient deficiencies limiting the growth of sweetpotato vines on important soil types in the highlands of Papua New Guinea

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Abstract

Declining soil fertility is threatening the productivity of sweetpotato in the highlands of Papua New Guinea (PNG). A survey of sweetpotato gardens (SMCN/2005/043) identified K, S and P deficiencies as the main nutritional limitations on tuber production in the region. A pot experiment was conducted to evaluate how sweetpotato vines, propagated on three important soil types (Humult, Aquept and Aqoll), are affected by sequentially omitting 13 nutrients (N, P, K, Ca, Mg, S, Fe, Bo, Zn, Mn, Cu, Mo, Ni) from fertiliser applications. On the Humult, only the minus Mo treatment produced significantly less shoot yield than the all nutrient control (ALL), but symptoms of S deficiency were also present in plants on the minus S treatment. On the Aquept, the minus N, P, Ca, S, B and Mn treatments had significantly less shoot yields than the control, but the minus S and N treatments were lowest yielding, and the S deficiency being clearly manifest. On the Aqoll, the minus N, P, S, Mn, Zn, Mo and Ni treatments had significantly lower shoot yields than the control, and again the minus S treatment produced the lowest yield. On all three soils, vine yields in the minus K treatments were not significantly less than those in the ALL, even though the concentrations of K in soil were very low (0.02 meq/100g). It was concluded that the early stage of vine propagation is probably less K-demanding than the tuber production stage in mature crops.

Key Words

Sweetpotato, nutrient deficiencies, vine production, sulfur, potassium, molybdenum

Introduction

Sweetpotato (*Ipomoea batatas*) is the staple food crop in the PNG highlands. Declining crop productivity, however, appears to be threatening the sustainability of sweetpotato-based farming systems within the region, a probable cause being the exhaustion of soil nutrient reserves in continuously cultivated sweetpotato gardens. To assess the extent of the problem, an ACIAR funded survey of sweetpotato gardens (SMCN/2005/043) was conducted across four highlands provinces and information on soil and crop variables was obtained for old gardens (cultivated over many seasons) and new gardens (newly brought into cultivation) on soils of volcanic and non-volcanic origin (Kirchhof 2009). Crop leaf nutrient data collected in the survey suggested that K deficiency was the primary cause of poor crop production in almost a third of sweetpotato gardens. Phosphorus deficiency was also a problem on volcanic soils, and S deficiency on non-volcanic soils (Bailey *et al*. 2009). A follow-up study was planned to acquire more detailed information on nutrient dynamic processes in sweetpotato cultivation systems, and to use this information to develop optimal nutrient management regimes capable of sustaining sweetpotato production on three key soil types. The preliminary phase of the follow-up study involved nutrient omission trials. These were used to evaluate how the growth of sweetpotato vines, propagated on three important soil types were affected by sequentially omitting a range of macro and micronutrients from fertiliser applications.

Methods

Soils

Soils were collected from the A horizon at three sites: (**1**) Aiyura, (**2**) Kondiu, and (**3**) Tambul. The locations of these sites are denoted by stars in Figure 1. The soil types were classified according the 1975 USDA scheme of soil taxonomy as: (**1**) Humult, (**2**), Aquept, and (**3**) Aqoll.

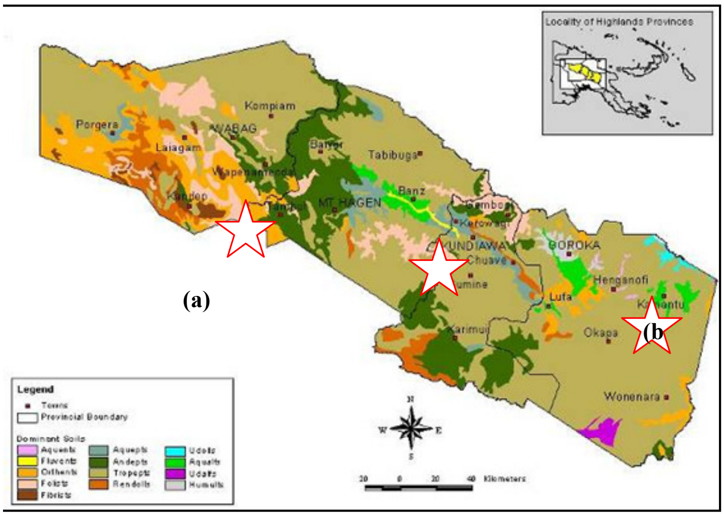

Figure 1. Map of four of PNG's highlands provinces showing dominant soil types according to the 1975 USDA soil taxonomy and locations of soils (stars) used in the nutrient omission trials.

Experimental protocol

Set weights of each soil were weighed into black polythene grow bags. The weight of soil plus bag and water needed to achieve 80% field water capacity was then determined. Nutrients (N, P, K, Ca, Mg, S, Fe, B, Mn, Cu, Zn, Mo and Ni) were added at rates given in Table 1 to give an ALL treatment plus 13 other treatments, each with one nutrient sequentially omitted. For example, the minus N treatment comprised all nutrients except for N, and the minus S treatment comprised all nutrients except for S. Sweetpotato vines, of similar weight and length were then planted, three per pot: Wahgi besta in Aiyura (**1**) and Kondiu (**2**) soils and Mae in Tambul (**3**) soil. Each treatment had 4 replicates, and these were laid out in a randomised block design in a screen house. After two weeks growth, the plants were thinned to two per pot, grown for a further four weeks and then harvested and total dry weight per pot determined. Leaf samples were collected at harvest from each pot for chemical analysis. Vine yield data were subjected to analysis of variance.

Table 1. Rates of nutrient application (kg/ha)

Nutrient	N	P	K	Ca	Mg	S	Fe	B	Zn	Mn	Cu	Mo	Ni
Rate (kg/ha)	190	112	160	68	56	48	10	4	8	8	6	0.8	0.2

Results and discussions

For the Aiyura soil, only the minus Mo treatment produced significantly less shoot yield than all nutrient control (Figure 2a). However, the concentration of Mo in shoots on the minus Mo treatment was considerably greater than the critical concentration (O'Sullivan *et al*. 1997). Clear symptoms of S deficiency, i.e. pale green/yellow coloration of leaves were present in plants grown on the minus S treatment (Figure 2b) even though vine yield on this treatment was not significantly less than that on the ALL control (Figure 2a). Leaf S concentration in the minus S treatment, however, was also appreciably less than the critical S concentration (Table 2) suggesting that S deficiency is potentially a problem in this soil.

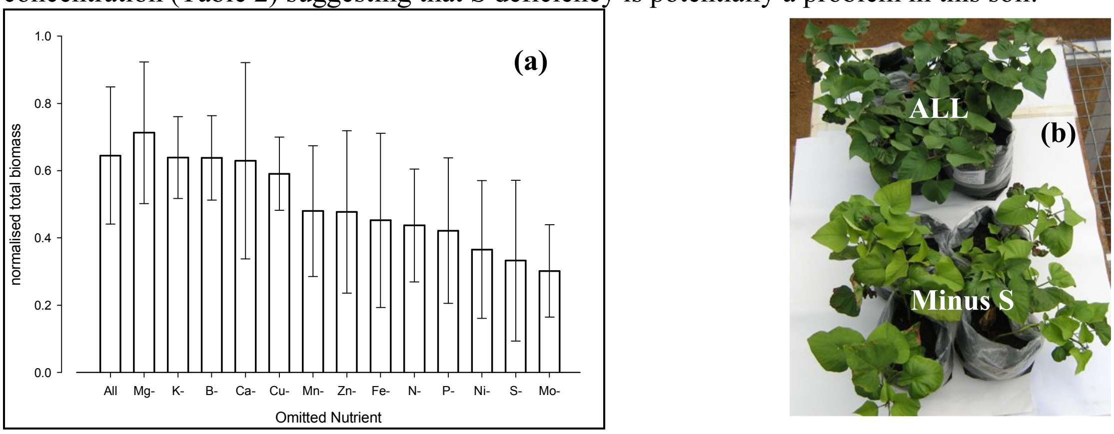

Figure 2 (a) Normalized DM yields of vines grown on soil from Aiyura and (b) photograph of S deficient vines on the minus S treatment against the All nutrient control just prior to harvest.

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Table 2. Comparison of critical leaf nutrient concentrations (%) with leaf nutrient concentrations for the ALL, minus N, minus S and minus K treatments on each of the three sites/soil types.

Site/Soil	Aiyura/Humult			Kondiu/Aquept			Tambul/Aqoll		
	N	S	K	N	S	K	N	S	K
Critical nutrient concentration [a]	4.0	0.34	2.6	4.0	0.34	2.6	4.0	0.34	2.6
Concentration in ALL treatment	3.1	0.14	2.1	2.7	0.21	1.9	3.5	0.25	2.7
Concentration in Minus treatment	2.0	0.11	2.1	1.5	0.10	1.4	2.3	0.12	2.2

[a] (O'Sullivan *et al*. 1997)

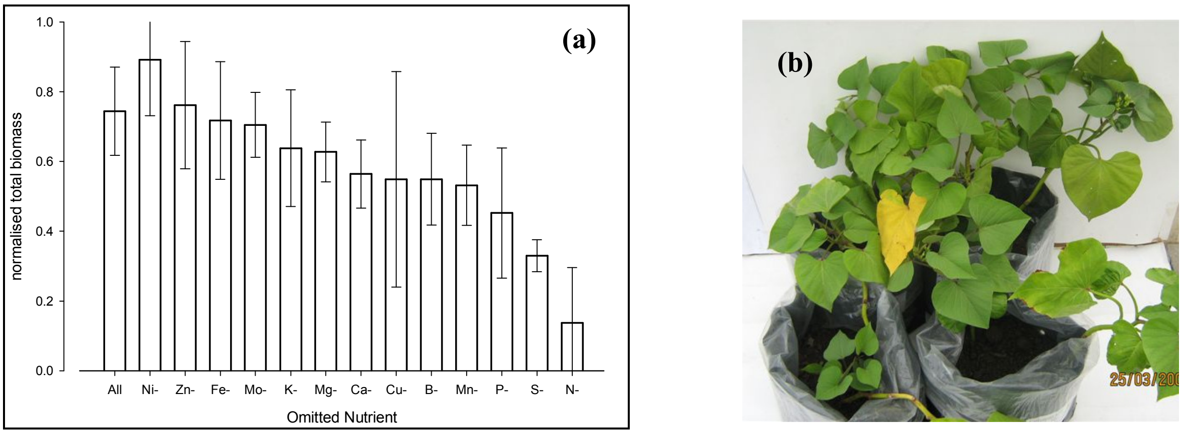

Figure 3 (a) Normalized DM yields of vines grown on soil from Kondiu and (b) photographs of vines on the minus S treatment showing pale green/yellow coloration typical of S deficiency.

Although the sweetpotato garden survey identified K deficiency as the major nutrient limitation on sweetpotato production, in this study, vine yield on the minus K treatment was not significantly different to that on the ALL treatment (Figure 2a). Likewise leaf K concentrations did not differ between the ALL and minus K treatments even though the concentration of K in soil was very low (0.02 meq/100g).

For the Simbu soil, the minus N, P, Ca, S, B and Mn treatments all had significantly less shoot yields than the control (Figure 3a), but the minus S and minus N treatments were lowest yielding, and the S deficiency was clearly manifest in the leaves, which were pale green/yellow in colour (Figure 3b). Leaf N and leaf S concentrations on the minus N and minus S treatments, respectively, were also appreciably less than the critical concentrations of these nutrients as determined by O'Sullivan *et al*. (1997). Vine yield on the minus K treatment was not significantly less than that on the ALL treatment even though the concentration on K in this soil was low (0.02 meq/100g). However, leaf K concentrations on both the ALL and minus K treatments differed little, although both were also appreciably lower than the critical K concentration.

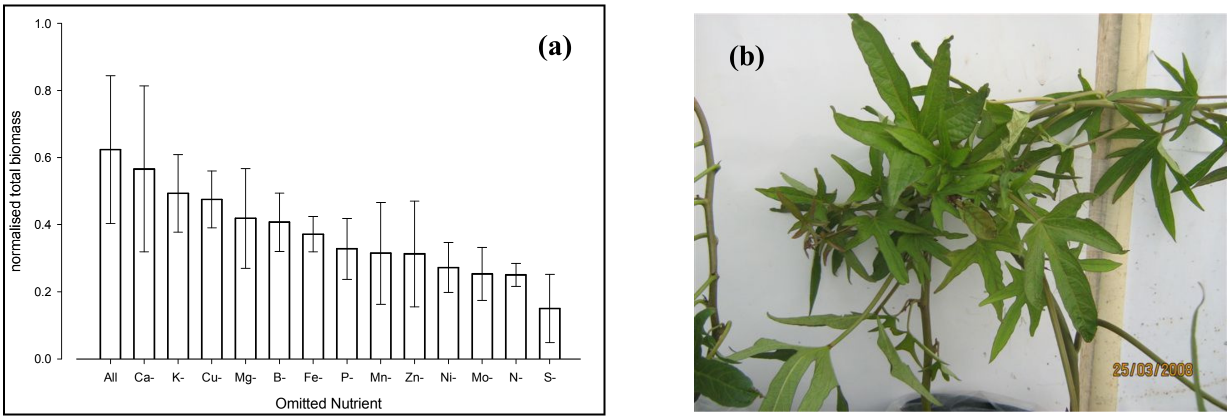

Figure 4 (a) Normalized DM yields of vines grown on soil from Tambul and (b) photographs of vines on the minus S treatment showing pale green/yellow coloration typical of S deficiency.

For the Tambul soil, the minus N, P, S, Mn, Zn, Mo and Ni treatments all had significantly lower vine yields than the ALL treatment (Figure 4a). Here again the minus S treatment produced the lowest yield, and the leaves were pale green/yellow in coloration (Figure 4b). Leaf S concentration was also appreciably lower than the critical concentration indicating that S deficiency is definitely a problem on this soil. The next lowest yielding treatments were the minus N and minus Mo treatments. However, while the concentration of

N in leaves on the minus N treatment was appreciably lower than either the critical N concentration or the N concentration in leaves on the ALL treatment (Table 2), the concentration of Mo in leaves on the minus Mo treatment was actually greater than the critical Mo concentration. Vine yield on the minus K treatment was not significantly less than that on the ALL treatment even though the concentration of K in soil was very low (0.02 meq/100g). Leaf K concentrations on both the ALL and minus K treatments differed little and were not appreciably lower than the critical K concentration (O'Sullivan *et al*. 1997).

Conclusions

For all three sites, S limitations appear to be affecting vine production potential, which is in keeping with the results from the sweetpotato garden survey. However, in contrast to the findings from this survey, which showed that K deficiency was the main nutritional limitation on sweetpotato production, K deficiency was not a problem for vine production on the three soils examined in this study, even though the levels of K in soil were very low. It should be noted though that the K requirement of sweetpotato is greatest during tuber formation and that this process does not commence until three months after vine planting, whereas in the present study vine cuttings were only propagated for 6 weeks. It is likely therefore that the K needs of the plants were adequately met from soil supplies plus existing K in vine tissue during this early stage of propagation. Based on the results, there seems to be scope for further trace nutrient studies on these soils focusing particularly on Mo, Ni and Mn limitations to sweetpotato production.

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