THE RESPONSE OF THREE SWEET POTATO CULTIVARS TO INORGANIC FERTILIZERS ON AN ANDISOL IN THE HIGHLANDS OF PAPUA NEW GUINEA

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ABSTRACT

A experiment is reported in which the response of three sweet potato varieties under farmers field conditions to inorganic fertilizer were examined in Gumine, Simbu Province. Fertilizer treatments were 0, 75 and 150 kg N ha^{-1} applied as urea; 0, 50, 100 kg P ha^{-1} applied as triple super phosphate, and 0, 75 and 150 kg K ha^{-1} applied as muriate of potash. Marketable sweet potato yields were substantially increased due to a significant P x K interaction, indicating that these nutrients were limiting sweet potato production. There was greater P-effect than K but the pattern of interactions was related to a significant inter-varietal difference in their response to added nutrients. The magnitude of response by variety Ongi and to an extent, Tripalangi, to added P and K was greater than variety Spagi. Variety adaptation mechanisms developed to offset pest and disease attack and other environmental stress, could reduce variety vigour and responsiveness to fertilizers. The occurrence of such interaction has implications for future on-farm trial work and proper management of fertilizer in subsistence gardens.

Keywords: *Sweet potato, volcanic ash soils, soil fertility, variety x fertilizer interaction.*

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L) Lam) has a diverse role in the highlands of Papua New Guinea. Firstly, it is the staple for the densely populated highlands and is grown under a wide range of soil and climatic conditions (Bourke 1985). Secondly, it is characterized by large numbers of cultivars (Yen 1974; Bourke 1985) of which only a few (about 5-6) may account for >90% of the planting (Wood 1984); thirdly, crop husbandry differ from planting on small round mounds (Kanua and Levett 1990), flat beds (Kanua and Rangaii 1988), raised compost mounds (Waddell 1972), between *gui's* (Wood and Hump-hreys 1982) to sequential planting and harvesting (Rose 1979). Furthermore, sweet potato varieties available to farmers have been selected to suit different soil situations, and are particularly adapted to low levels of soils nutrients (Kanua and Floyd 1988). Some varieties have shown to be adapted to the marginally fertile volcanic soils (Preston 1990; Floyd *et al.* 1988; Goodbody and Humphreys 1986).

However, evidence is scanty on the behaviour or responsiveness of established local cultivars to changing soil conditions; and whether substantial improvements in soil nutrient status is necessary to improve, or increase the yield of these cultivars, as they are often preferred over introduced varieties (Kanua and Floyd 1988). Such information is essential for the improvement of subsistence agriculture. The experiment reported here was conducted to investigate the responsiveness or the response gradient of three local sweet potato cultivars to N, P and K fertilizers, and was conducted on a marginally fertile volcanic ash soil.

METHODS

Experimental Site

The trial was conducted on a gently slopping (15°) farmer's garden at Boromil village, Gumine District, Simbu Province, PNG.

The site was located on an altitude of 1850 m a.s.l. A mean of 10 years rainfall data at the nearby Gumine Station (McAlpine *et al.* 1975) show

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that on an average, the site receives 2,445 mm of rainfall annually; three quarters of which is expected during the months from October to April.

For the Simbu Province, the only published temperature data are for Kundiawa. In an attempt to broaden the data base, Humphreys (1984) used other data from schools in the Province and compared them with data from Kundiawa (1550 m) and Pindaunde (3580 m). He reported mean minimum and maximum monthly temperature range from 13.3 to 26.6°C respectively, with little variation between months. The calculated lapse rate for every 100 m gain in altitude in the Simbu Province is a temperature decline by 7.4 and 5.6°C, mean maximum and mean minimum respectively.

The Soil

The soil was typically volcanic ash in origin. The topsoil was friable and coarse structured, dark brown in color merging into a light brown to yellowish orange subsoil. Two soil samples were collected, one composite sample for the upper and the other for the lower end (Table 1) and sent to the National Chemistry Laboratory in Port Moresby for analysis. The analytical data given in Table 1, indicates that the test soil is strongly acid with P and K being at low levels, whereas P-retention is very high.

Soil fertility is slightly lower on the upper slopes (BS 43%), probably due to erosion of topsoil than the lower slope (BS 51%). Coupled to this, the site had a long history of continuous cultivation with short (12-18 months) fallow breaks. The levels of N are adequate but there is a clear imbalance between Mg and K.

Although interpretation of soils data is often difficult due to large soil variability, the present data indicate that:

***Table 1.* Soil physical and chemical data with climatic and environmental descriptions of the experiment site.**

Location		Gumine	
Altitude (m)		1850	
Mean annual rainfall (mm)		2445	
Mean temp (°C)	max.	26.6	
	min.	13.3	
Site history		Continuous cultivation with short grass fallow previous <1y	
Soil type		Airfall volcanic ash	
		Lower slope	Upper slope
pH H_2O		5.2	5.2
P (mg/kg)		3	1
exchangeable cations (cmol/kg)			
Ca		4.6	4.1
Mg		3.65	3.35
K		0.20	0.20
Na		0.10	0.10
CEC		16.9	17.9
B.S. %		51	43
Org. Carbon (%)		7.3	7.9
N%		0.52	0.58
C/N Ratio		14	14
P Retention %		96	93

Methods used: Organic matter - Dichromate oxidation; Extractable phosphate - Saunders method, Extractable cations - Neutral, 1 M ammonium acetate; CEC - sum of exchangeable bases and acidity.

1) due to the acid nature of the soil, the availability of micro-nutrients, especially Boron and Molybdenum may be below.

2) The problem of K deficiency is partially induced by the high Mg/K imbalance (ratio > 18) in the soil exchange complex, and partially by K fixation (Kanua 1995). The application of K is only necessary to offset the imbal ance (Mg/K) for a response.

3) The high phosphate fixation (>90%) is a characteristic of soils with volcanic ash influence. This means that the application of this nutrient together with other cations in low supply are highly likely to give a response.

Experimental Design

The experimental areas were cleared of vegetation, cultivated by hand to produce suitable tilth before the plots were marked out.

A split-plot design was used in which three (3) levels of nitrogen, phosphorus and potassium were randomly applied to the main plots which measured 27 m^2. The fertilizer rates were:

N 0, 75 and 150 kg ha^{-1}
P 0, 50 and 100 kg ha^{-1} applied as triple super phosphate,
K 0, 75 and 150 kg ha^{-1} applied as muriate of potash.

The sub-plots measured 9 m^2, and they were randomly allocated to three local sweet potato cultivars, namely Ongi, Tripalangi and Spagi.

The 27 treatments were arranged in randomized complete blocks and replicated three times. The plots were marked out and fertilized before small round mounds (1 m^2) were made in the traditional manner. Immediately after mounding, three sweet potato cuttings of the respective cultivars, approximately 30 cm in length were planted on the mounds at a plant population of 30,000 ha^{-1}. The sweet potato cuttings were collected from gardens in the vicinity of the experiment site. During growth, no plant protection measures were taken other than keeping the crop relatively weed free.

At harvest, mounds were broken up and the yields separated as fresh weight of vines, stockfeed tubers (tubers <100 g) and marketable tubers (>100 g) were recorded for each treatment. Numbers of vines, stockfeed and marketable tubers were also recorded. The trial was planted on the 23rd of January 1987 and harvested after eight months.

Statistical Analysis

The data collected were analyzed by the analysis of variance method after Little and Hills (1978), and treatment means compared by the Duncan's Multiple Range Tests (DMRT).

Table 2. **Fertilizer effect on the fresh weight yield of marketable tubers averaged over the three sweet potato varieties tested.**

	Mean yields (t ha^{-1})[1]					
	N (kg ha^{-1}) fertilizer			K (kg ha^{-1}) fertilizer		
P (kg ha^{-1}) fertilizer	0	75	150	0	75	150
0	4.4b	2.0b	1.9c	1.4b	3.4c	5.3b
50	9.5a	15.0a	16.6b	5.2a	12.9b	17.0a
100	11.6a	13.1a	14.9b	5.1a	16.7a	17.7a

[1] Average of 3 replicates. Means in any column followed by the same letter are not significantly different (P<0.05) from each other according to DMRT. LSD (0.05) value for comparing fertilizer (N and K) means in a row is 3.4 t ha^{-1}.

Table 3. **Variety x fertilizer (N, P) effects on marketable tuber yield of sweet potato varieties Ongi, Tripalangi and Spagi.**

Mean yields (t ha^{-1})[1]						
Variety	P (kg ha^{-1}) fertilizer			K (kg ha^{-1}) fertilizer		
	0	50	100	0	75	150
Ongi	5.5a	15.5a	16.5a	5.6a	15.1a	16.8a
Tripalangi	2.0b	12.9a	14.5a	3.8a	11.5b	14.2a
Spagi	0.9b	6.7b	8.5b	2.4a	6.4c	7.2b

[1] Average of 3 replicates. Means in any column followed by the same letter are not significantly different ($P<0.05$) from each other according to DMRT. LSD (0.05) value for comparing fertilizer (P and K) means in a row is 2.4 t ha^{-1}.

RESULTS

Marketable tuber yield was considered sufficient to use as the single relevant indicator of variety response to inorganic fertilizer in this trial. Table 2 gives N x P and P x K effects on mean fresh weight yield of marketable tubers of the three sweet potato varieties tested.

Application of N in the absence of applied P decreased yield. Similarly, increasing K-levels in the absence of P, there was no significant increase on yields above the control. Application of P in the absence of both N and K significantly increased yields.

In general, increasing P with a corresponding increase in K rates gave better yields; hence highest yields were achieved at the highest P and K levels. The variety x fertilizer (P and K) main effects on the marketable tuber yield is given in Table 3. The results indicated significant inter-variety differences in their response to different levels of fertilizer application. Overall, cultivars Ongi and Tripalangi responded more to inorganic fertilizer than Spagi. Cultivar Ongi was the better variety, but its yield was not significantly different from the yields of Tripalangi at the 50 and 100 kg P ha^{-1} and 150 kg K ha^{-1} (Table 3). Ongi out yielded Spagi but at no level of P and/or K (except at zero K) was the yield of Ongi not significant or similar to the yield of Spagi. Cultivar Tripalangi's yield was only significantly different from Spagi's at the 50 and 100 kg P ha^{-1} and 75 and 150 kg K ha^{-1}.

Overall, variety yields were significantly improved due to P fertilizer. The application of P significantly improved yields of cultivars Ongi and Tripalangi but had limited effect on variety Spagi. The statistical analysis did not reveal a variety effect due to nitrogen fertilization. This is probably because of the high levels of organic matter, which provides ample mineralised N to the soil during the cropping period.

DISCUSSION

The significant yield response to added fertilizer suggests that inadequate levels of major elements in the Gumine soils are a constraint to sweet potato production. In particular, inadequate P and K seem to be the critical limiting factors. This results agree with the findings of Floyd *et al.* (1988) on volcanic soils in the Southern Highlands. Furthermore, the evidence for N x P and P x K interaction on the yield of sweet potato is of practical significance. The evidence for a limited N x P interaction is attributed largely to P being probably more limiting on this soil than N as indicated by the soil analytical data (Table 1). This is clearly demonstrated at the highest level of P and altering N levels, there are no significant yield increases due to increasing N levels (Table 2).

In general, the significant P x K interaction is of practical importance, implying that applying P without K can be wasteful resulting in lower yields.

The results indicate that there can be significant differences in variety responses to added fertilizer. The experimental data showed that the yield of cultivar Ongi, followed by that of Tripalangi were significantly improved due to increasing P and K levels. Cultivar Spagi showed some response to P, but was generally inefficient in utilizing added fertilizer.

No explanation for the differences in variety responses to fertilizer can be offered by the experimental data. The reduced response of variety Spagi to fertilizers represents an example of cultivars that are prevalent in farmers fields. A number of factors could be causing this, one of which is probably an adaptation mechanism developed by certain cultivars in this environment which have been continuously used in marginal soils (e.g. Kanua and Floyd 1988) and overly stressed agricultural systems (e.g. Wood 1984). The other reasons could be due to the involvement of diseases, especially viruses (Waller 1985) and nematodes (Bridge and Page 1984). These interacting factors in the ecosystem, coupled with the longer history of domestication of variety Spagi, will act as agents of natural selection pressure on the variety, and consequently reduce the variety vigor. On similar soil types elsewhere in the highlands, Kanua and Floyd (1988) reported that established local varieties of sweet potato were less responsive to differences in yield potential between sites than newly introduced cultivars.

CONCLUSION

Some care is needed in deriving conclusions as the involvement of pests and diseases including nematodes could play a part in these experiments. It is concluded that volcanic soils in Gumine cannot sustain heavy sweet potato yields due to low nutrients, particularly deficient P and K. However, results from this study showed that the deficiencies can be corrected, and sweet potato yields can be increased significantly by applying small amounts of fertilizer.

In this soil, the application of N, P, or K alone is unlikely to bring about a significant response. Results show that these elements must be applied together. There was a greater P effect, which suggests that the inter-play of local mycorrhiza (Floyd *et al.* 1988) in the nutrition of sweet potato cannot be ruled out. Further research is required to strike the right balance between fertilizer and local mycorrhiza interactions to achieve maximum yields. Experimental evidence also showed that sweet potato varieties differ in their responsiveness to increased soil fertility.

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