EFFECT OF SHEEP MANURE AND PHOSPHORUS FERTILIZER ON POTATO AND SUCCEEDING MAIZE AND CASSAVA CROPS

S. Sivasupiramaniam[1], A. K Benjamin[1] and J.A Pitala[1,2]

ABSTRACT

A trial was conducted at the Menifo Sheep Research Centre located in the Eastern Highlands to examine the responses of potato, maize and cassava to application of sheep manure and inorganic phosphorus(P). Potato, maize and cassava were grown sequentially after the application of sheep manure and P fertiliser. Potato tuber yield increased with increasing rates of sheep manure. When manure was applied either at 10 or 20 t ha^{-1}, inorganic P significantly (P< 0.05) increased tuber yield but had no effect when either 0 or 40 t ha^{-1} of manure was applied. At the same level of manure application, yield response to band application was significantly (P< 0.05) higher. Inorganic P failed to influence tuber yield significantly (P< 0,05) when manure was applied in bands. Residual effect of manure was observed in both maize and cassava. Manure significantly (P< 0.05) increased the number and size of the marketable ears of maize , and the fresh tuber yield of cassava. Residual P increased the number and size of marketable ears of maize significantly (P< 0.05) at 10 t ha^{-1} of manure application only, and had no effect on cassava yield.

Key words: *cassava, central highlands, cropping sequence, inorganic phosphorus, maize, potato, residual effects, sheep manure.*

INTRODUCTION

In many parts of the central highlands of Papua New Guinea, soil fertility is a major factor limiting intensive cropping (Humphreys 1984, Bourke and D'Souza 1982). Crop responses to application of organic fertilisers like cattle manure, chicken manure, pig manure, compost and coffee pulp have been reported (Kimber 1982; Thiagalingam and Bourke 1982; D'Souza and Bourke 1986; Floyd *et al.* 1988). However, most of these studies were restricted to food crops which can tolerate relatively low soil fertility. Potato yield response to application of compost on volcanic ash soils have been observed (Preston and Kowor 1987). Preliminary studies indicated that potato and maize respond to sheep manure (Sivasupiramaniam 1989). However, long term effects of sheep manure on different crops planted in sequence have not been studied.

Most soils in the highlands are deficient in available phosphorus (P). While the traditional highlands crops like sweet potato are tolerant to low soil P, recently introduced crops like potato and maize are not (Radcliffe 1985) and require P fertiliser. Organic manures improve P availability by reducing its fixation (Tripathi and Hazara 1987) and also by providing P directly to the crops through the soil (*Biswas et al.* 1970, Mugwura 1984).

This paper reports the results of a field trial conducted to examine the effects of sheep manure and inorganic P on the yields of potato, maize and cassava planted sequentially on a sandy clay soil in the Eastern Highlands.

MATERIALS AND METHODS

The trial was conducted at Menifo Sheep Research Centre farm in the Eastern Highlands Province (1405 m a.s.l). It was initiated in October 1988 and ended in April 1990. The soil is a sandy clay of mixed sedimentary origin which was deficient in nitrogen (N) and Phosphorus (P), low in potassium (K) and organic matter (OM) and the soil has a high P retention. The site was an old sweet potato garden fallowed for two years.

[1] Department of Agriculture and Livestock, P.O Box 1075, Goroka, Eastern Highlands Province, Papua New Guinea.

[2] Department of Agriculture and Livestock, P.O Box 1984, Lae, Morobe Province, Papua New Guniea.

The treatments included four levels of manure (0, 10, 20 and 40 t ha^{-1}) broadcasted and also two levels (10 and 20 t ha^{-1}) applied in narrow bands. All manure levels were applied in combination with 50 kg P ha^{-1} (P50) in the form of triple superphosphate (TSP).

The experiment was laid out as a randomised block design with three replicates. The plots were raised beds of 5 m^2 in size. Manure was applied four weeks before planting of the first crop (potato) and mixed with the soil. For band application, manure was applied in 35 cm wide rows which were 35 cm apart. The sheep manure applied contained 1.2% N, 0.5% P and 1% K on a dry matter basis.

Four weeks after application of manure, Potato (*Solanum tuberosum* Linn cv. Sequoia) was planted in furrows (70 cm x 30 cm). For band application of manure treatments, the planting rows were positioned at the centre of the band. TSP was furrow applied just prior to planting and normal cultural practises were maintained. Plant emergence count was taken 30 days after planting (DAP) and samples of the third compound leaf from the top of the plant from all plots were collected 60 DAP for N, P and K determination. Potato tuber yields and total marketable tuber numbers were recorded at full maturity. Tubers less than 3cm in diameter were considered nonmarketable.

A local variety of maize (*Zea mays* Linn.) was planted immediately after harvesting the potato, at a spacing of 70 cm x 20 cm. Ears were harvested at the stage suitable for direct consumption and the number and weight of the marketable ears recorded. The maize stover was cut and used as mulch and a local variety of cassava (*Manihot esculenta* Crantz) was planted at 4 plants per plot. The cassava crop was harvested 12 months later and the shoot and tuber fresh weights and tuber numbers were recorded.

RESULTS AND DISCUSSION

Marketable potato tuber yield

Application of sheep manure up to 40 t ha^{-1} significantly ($P< 0.05$) increased the marketable potato tuber yield. At the same level of manure, band application produced significantly ($P< 0.05$) higher yield (Table 1). Neither the manure rate nor method of application influenced the non-marketable (< 3 cm) tuber yield (data not presented).

P alone failed to influence marketable tuber yield but at lower manure rates (10 or 20 t ha^{-1}), P significantly ($P <0.01$) increased marketable tuber yield. There was no yield response to P when manure was applied either in bands or at 40 t ha^{-1} (Table 1).

Total and marketable tuber numbers

The total tuber numbers per plant was significantly ($P< 0.01$) increased when manure was applied at 10 t ha^{-1}, but further increases to higher manure levels were either small or negligible (Table 2). Neither method of application of manure nor inorganic P influenced total tuber numbers markedly. Manure significantly ($P< 0.05$) increased the number of marketable tubers except when applied at 10 t ha^{-1} and spread evenly. Inorganic P had no effect on marketable tubers.

Mean tuber weight of marketable tubers was significantly ($P< 0.01$) increased by manure and the response varied with the rate and method of application (Table 2). In the presence of manure, inorganic P additively increased the mean tuber weight of marketable tubers. Higher tuber yield to manure application has been achieved mainly through increased tuber number at the lower manure levels and through increased tuber number and size at the highest manure level. The relatively higher response to band application may be explained by greater availability of nutrients from the manure concentrated near the root zone.

The lack of response to P in the absence of manure may possibly be attributed to K deficiency. This is reflected in the K concentration in the third compound leaf (Table 3). It appears that when sufficient K was available from the manure there were responses to applied P. However, at 40 t ha^{-1}, it appears that P supply from manure alone was adequate to meet the crop demand.

N, P and K concentrations in the leaf were found to show high correlations with tuber yields in potato. The critical concentrations used to define deficiency limits of N, P and K in the leaf 50 DAP were 3.8, 0.3 and 3.8% respectively (Singh and Brar 1983, Singh 1987). In the present study, the relative sufficiency levels of leaf N, P and K for maximum tuber yield were observed in the 40 t ha^{-1} treatment which produced the maximum tuber yield.

Residual effect of manure and phosphorus

Residual effect of manure was apparent on both maize and cassava, particularly at the high rates (Tables 4 and 5). In another experiment, manure

Table 1: **Effect of sheep manure and inorganic phosphorus on marketable tuber yield of potato.**

Manure level (t ha^{-1})	Marketable tuber yield (t ha^{-1})		
	No phosphorus	phosphorus (50 kg ha^{-1})	Mean
0	5.60	6.14	5.87
10	8.95	15.16	12.05
20	10.64	15.05	12.84
40	20.04	20.89	20.46
10 (banded)	13.65	15.45	14.55
20 (banded)	16.15	18.28	17.21
Mean	12.50	15.16	

ANOVA: Manure **
P **
M x P *

** - Significant at 1% level
* - Significant at 5% level

LSD to compare treatment means: 2.79 (5%); 4.26 (1%). CV (%) = 11.9

Table 2: **Effect of sheep manure and inorganic phosphorus on total and marketable tubers and mean tuber weight of marketable tubers**

Manure rates (t ha^{-1})	Total no. tubers plant^{-1}			No. of marketable tubers plant^{-1}			Mean marketable tuber wt. (g)		
	P0	P50	Mean	P0	P50	Mean	P0	P50	Mean
0	3.85	5.10	4.47	1.82	2.12	1.97	80.7	72.5	76.6
10	6.78	6.72	6.75	2.88	3.73	3.30	77.7	103.3	90.5
20	6.92	7.37	7.14	3.12	4.07	3.59	85.4	92.9	89.1
40	7.49	7.43	7.45	4.25	4.02	4.13	112.8	136.4	124.6
10 (banded)	6.80	7.28	7.04	3.97	4.05	4.01	85.3	95.4	90.3
20 (banded)	7.70	7.43	7.66	4.35	4.25	4.30	93.0	111.6	102.3
Mean	6.59	6.89	3.40	3.03	89.1	102.0			
ANOVA: Manure		**			*			**	
P		NS			NS			**	
M x P		NS			NS			**	
CV (%)		13.3			33.9			14.3	
LSD Manure 5%		1.12			1.45			12.8	
1%		1.52			-			17.2	
LSD P 5%		-			-			9.5	
1%		-			-			9.5	

applied at 15 t ha^{-1} on the same soil failed to have any effect on sweet potato planted in the following year (Sivasupiramaniam 1989). The significant residual response to manure in the present study may be attributed to the shorter planting cycle, higher manure levels used and the types of crops planted.

The lack of residual response to applied P in maize, except at the lowest level of manure rate of 10 t ha^{-1} (Table 4) indicates that at higher manure rates, sufficient P has become available to maize from decomposing manure and perhaps may have reduced fixation.

Lack of residual response of cassava to applied phosphate (data not presented) may partly be due to the inherent capacity of the crop to tolerate low soil P.

CONCLUSION

This experiment demonstrates that sheep manure is a potentially useful organic fertiliser. High yields of potato and maize can be realised by using high rates or moderate rates by band application. Relay cropping of the land would be a good strategy to maximise

Table 3: **Effect of sheep manure and inorganic phosphorus on the nitrogen, phosphorus and potassium concentration (%) in the third compound leaf at 50 days after planting.**

Manure (t ha^{-1})	N			P			K		
	P0	P50	Mean	P0	P50	Mean	P0	P50	Mean
0	4.86	4.14	4.50	0.22	0.28	0.25	2.98	2.92	2.95
10	4.29	3.72	4.00	0.25	0.29	0.27	4.09	3.72	3.90
20	4.14	4.02	4.08	0.30	0.30	0.30	3.60	3.82	3.71
40	4.04	4.24	4.14	0.30	0.34	0.32	4.24	4.26	4.25
10 (banded)	4.20	4.08	4.14	0.28	0.32	0.30	3.80	3.51	3.65
20 (banded)	4.16	4.16	4.16	0.27	0.29	0.28	3.58	3.54	3.56
Mean	4.28	4.06		0.27	0.31		3.72	3.63	
ANOVA: Manure		NS			*			**	
P		NS			**			NS	
M x P		NS			NS			NS	
CV (%)		9.1			12.3			10.5	
LSD Manure 5%		-			0.042			0.65	
P 5%					0.024				
1%					0.032				

Table 4: Residual effect of sheep manure and inorganic phosphorus on the productivity of maize.

Manure (t ha^{-1})	No. marketable ears ha^{-1}			Marketable ear size (g ear^{-1})		
	P0	P50	Mean	P0	P50	Mean
0	14,650	15,600	15,125	156	152	154
10	21,340	25,000	23,170	168	186	177
20	25,340	27,340	26,340	181	179	180
40	32,000	37,340	34,670	190	194	192
10 (banded)	17,340	31,340	24,340	167	165	166
20 (banded)	30,660	27,340	29,000	181	191	186
Mean	23,555	27,327			174	179
ANOVA: Manure		**			**	
P		**			NS	
M x P		**			**	
CV (%)		14.1			8.6	
LSD M x P 5%		4800			6.6	
1%		6520			8.9	

Table 5: **Residual effect of sheep manure on cassava fresh tuber and shoot yields***

Manure (t ha^{-1})	Fresh tuber (t ha^{-1})	Fresh shoot (t ha^{-1})
0	23.7	6.4
10	30.1	7.4
20	38.7	9.3
40	51.8	10.7
10 (banded)	34.8	7.3
20 (banded)	37.9	10.4
ANOVA:	**	NS
CV (%)	38.7	53.8
LSD 5%	9.14	
1%	12.42	

* As there was no response to inorganic P, data for P levels were pooled.

benefits from sheep manure. At lower manure rates, application of P fertiliser would enhance potato tuber yield.

ACKNOWLEDGEMENTS

We are grateful to G. Wiles and R.D. Ghodake for their comments on the manuscript. V. Bidi helped with the field work and the Department of Agriculture and Livestock for providing the resources.

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