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Soil Nutrient Concentrations and Crop Yields under Sweet Potato (*Ipomoea batatas*) and Groundnut (*Arachis hypogaea*) Intercropping in Swaziland

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ABSTRACT

A field experiment was conducted in 2007/2008 cropping season to assess the effects of interplanting a fixed population of groundnut (*Arachis hypogaea* L.) through a varied population of sweet potato [*Ipomoea batatas* (L.) Lam.] on soil nutrient concentrations and crop yields. Results showed significant ($P < 0.05$) differences in the concentrations of potassium (161.5-239.0 mg kg^{-1}), nitrate nitrogen (3.0-4.8 mg kg^{-1}) and total nitrogen (0.14-0.19%). There were non-significant differences in marketable tuber yields (25.2-28.6 tonnes ha^{-1}). There were non-significant differences in groundnut pod yield, though the sole crop yielded higher (2,001.0 kg ha^{-1}) than the intercrops (1,382.0-1,366.9 kg ha^{-1}). Land equivalent ratio showed greater benefit (LER, 1.67) in the lower sweet potato population of 16,667 plants ha^{-1} than in the higher sweet potato population of 33,333 plants ha^{-1} (LER, 1.62). It is recommended that small-scale farmers intercrop sweet potato at 16,667 plants ha^{-1}, with groundnut at 200,000 plants ha^{-1}.

Key Words: Crop yields; Groundnut; Intercropping; Land equivalent ratio; Soil nutrient concentrations; Sweet potato

INTRODUCTION

The most important storage root crop grown and eaten in Swaziland is sweet potato [*Ipomoea batatas* (L.) Lam.] (Ossom *et al*., 2004). It is a short-season crop, which reliably provides food on marginal and degraded soils, with little labour and few or no inputs from outside the farm (Ewell & Mutuura, 2004). Sweet potato is a strategic, drought-tolerant crop that grows well even in areas with low and un-reliable rainfall (Acland, 1991; Onwueme & Sinha, 1991). Among the grain legumes that are cultivated in Swaziland, that which features most commonly in Swazi cuisine is groundnut (*Arachis hypogaea* L.); others are field bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* Walp).

Between 1990 and 1992, Swaziland was estimated to have 10% of its population being undernourished. However, between 1997 and 1999, this figure rose to 12% (FAO, 2002). It has now gone beyond 15%. Swaziland needs to address this bleak scenario. In agreement with two of the seven 2002 World Food Summit commitments (FAO, 2002) the country should implement policies aimed at "eradicating poverty and inequality and improving physical and economic access by all at all times, to sufficient, nutritionally adequate and safe food and its effective utilization". The country should also address the problem of making available reliable food supplies at the household and national levels (FAO, 2002).

One of the ways of addressing the problem of food insecurity in Swaziland is to maximize the use of farmland through intercropping involving grain legumes. Intercropping (Ruthernberg, 1980) is the agricultural practice of cultivating two or more crops in the same space at the same time (Andrews & Kassam, 1976). It is commonly used in tropical regions of the world and by various indigenous peoples (Altieri, 1991) but in the mechanized agriculture of Europe, North America and parts of Asia it is far less widespread. Given the biological value of the proteins found in grain legumes, they are very good complements to cereals and tubers (Summerfield & Hunting, 1980). Edje and Semoka (1990) noted the use of beans in maintaining soil fertility in Tanzania. Similar results have been reported by other workers (Ofori & Stern, 1987; Hoshikawa, 1991).

Legume-based cropping systems including crop rotation have been shown to be generally beneficial to the soil by preservation of organic matter, increasing soil nitrogen, improving soil physical properties and could also break the cycle of soil-borne diseases (Imai *et al*., 1989a & b; Imai, 1990). Borin and Frankow-Lindberg (2005)

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reported that intercropping increased cassava total dry matter and crude protein yields in cassava-legume mixtures. Richards (1983) cited data from intercropping studies that suggested that small-scale farmers' returns tended to be more reliable with intercropping. He emphasized that intercropping could be regarded as one of the great glories of African agricultural practice. He observed that intercropping is capable of producing remarkable results such as labour productivities that might perhaps equal to, if not better than, improved, small-scale farming practised in Europe. However, Makeno and Doto (1982) and Semu and Jana (1975) showed that there was usually a reduction in the yield of one or both crops in the mixture compared to the higher yield in the respective pure stands of the same crops. Stressing the importance and research needs of intercropping Willey (1979) considered both crop competition and yield advantages. It was reported that intercropping two or more crops maximized output per hectare compared to mono-cropping (Ruthernberg, 1980; Mortimore *et al.*, 1997; Ossom & Nxumalo, 2003). Apart from the physical yields, there are also socio-economic benefits of intercropping, including insurance against crop failure, regular availability of different types of food to the farming family and increased stability of farm productivity (Ruthernberg, 1980; Gomez & Gomez, 1983).

Plant population is of great importance in the production of any crop, especially when yield is of great concern. Attempts have been made by farmers to maximize field bean seed yield (Leakey, 1972). One likely reason for the advantageous effects of grain legumes in a cropping system could be nitrogen fixation through beneficial symbiotic bacteria that reside in legume root nodules. However, it could be pointed out that some grain legumes do not substantially increase soil nitrogen. Investigations on soybean (Glycine max L.) and Mucuna (*Mucuna puriens var utilis*) has shown that different grain legumes contribute varying amounts of nitrogen, depending on the legume as well as the bacterium used in the inoculation (Kumaga & Ofori, 2004; Kumaga *et al*., 2006). The beneficial effect of legumes on succeeding crops is normally attributed to the increased soil nitrogen fertility, because of nitrogen fixation (Hoshikawa, 1991). Legume crops are also known to have a beneficial effect on succeeding crops (Edwards *et al*., 1988). Soil nutrient concentrations and crop yields under sweet potato-groundnut association are not known. It would be beneficial to determine the effects, which different sweet potato populations could have on crop yield under intercropping. Therefore the objective of this investigation was to assess the effects of two populations of sweet potato and groundnut in a fixed population of groundnut on soil nutrient concentrations, crop yields and land equivalent ratio in a sweet potato-groundnut mixture.

MATERIALS AND METHODS

Site and experimental design. The field investigation was conducted at the Crop Production Department Experiment Farm in the Faculty of Agriculture, University of Swaziland, Luyengo (26.34^{o}S, 31.10^{o}E; 732.5 m above sea level; mean annual rainfall range, 850-1000 mm; mean annual temperature, 18^{o}C) in the Middleveld agro-ecological zone of Swaziland (Ossom & Rhykerd, 2007). The soil was an Oxisol of the Malkerns soil series, which are dark loams to sandy loams (Murdoch, 1968). The experimental design was a randomized complete block of five cropping system treatments, replicated four times. The treatments were: (1), pure sweet potato at 33,333 plants ha^{-1} (recommended plant population)–30 cm x 100 cm, one cutting (30 cm long) per stand; (2) pure groundnut at 200,000 plants ha^{-1}–10 cm x 100 cm, 2 grains per hill; (3), pure sweet potato at 16,667 plants ha^{-1}; (4) sweet potato at 33,333 plants ha^{-1} interplanted with groundnut at 200,000 plants ha^{-1}; and (5), sweet potato at 16,667 plants ha^{-1} interplanted with groundnut at 200,000 plants ha^{-1}. Plots were 7.2 m x 8.0 m, with 1.0 m distance between ridges, thus giving nine ridges per plot. Each plot and each replicate was separated from others by a 100-cm border; a 100-cm perimeter space also surrounded the layout as non-experimental area.

Land preparation, planting and fertilization. The land was prepared using a tractor-mounted mouldboard plough and a tractor-mounted disc harrow was used to make a fine tilth and suitable seedbed for planting. The soil was sampled at 15-cm depth using a soil probe and a composite sample of the soil was analysed at Malkerns Research Station Soils laboratory for pH, exchangeable acidity, P, K, Mg and Ca concentrations. Using a tractor-mounted ridger, 1-metre ridges were made; these were later moulded manually, using a hand hoe, to make them more uniform. The variety of sweet potato planted was ‘Kenya’, whilst the groundnut variety was ICG 10478. Both crop varieties were originally obtained from Malkerns Research Station. Planting both sweet potato and groundnut was done on 22 and 23 October 2007. After planting was completed, supplementary irrigation was administered the same day using a sprinkler irrigation system. Irrigation was done once a week only in the first month after planting to enable good crop establishment. Each time irrigation was performed the soil was watered to field capacity, allowing as much water as possible into the soil profile, but without flooding the plots with excess water. Gap filling was done at 2 weeks after planting (WAP).

Fertilizer application and weeding. Because the soil was at pH of 5.3 dolomitic lime, $CaMg(CO_3)_2$ (1.0 tonne ha^{-1}) was applied to all plots before planting (Anonymous, 1991). The lime was broadcast on the ridges and incorporated into the soil, using a rake, on the same day. For basal dressing, a compound fertilizer, N: P: K, 2: 3: 2 (38) + 5% zinc was applied at 350 kg ha^{-1} (Anonymous, 1991). Single superphosphate (10.5% P_2O_5) at 50 kg ha^{-1} was applied to all plots except for pure groundnut plots at planting. At 6 WAP, side dressing with 10 parts of urea (45% N) and 50 parts muriate of potash (KCl, 50% K) at the rate of 120 kg ha^{-1} was applied to all plots except for sole groundnuts. In all applications the banding and incorporation method was used. Weeding was manually done using a hand hoe at 4 and 8 WAP. After each weeding, ridges were re-moulded.

Recording and analysis of data. At harvest, sweet potato tubers were sorted according to the criteria used by Ossom (2007) in which marketable tubers were whole or complete tubers that had no harvest wounds and did not weigh less than 100 g or more than 1.4 kg. Non-marketable tubers were tubers that had harvest wounds, or were outside the mass range for marketable tubers. The land equivalent ratio (LER) compared the yield in intercropping with that of the pure stand, using the relationship (Andrews & Kassam, 1976; Yancey, 1994):

$$\text{Land equivalent ratio} = \frac{\text{yield of groundnut+sweetpotato}}{\text{yield of pure groundnut}} + \frac{\text{yield of sweetpotato+groundnut}}{\text{yield of pure sweetpotato}}$$

Soil samples were collected (15 cm depth) from each plot, air-dried in the laboratory, sifted and shipped for analysis using standard analytical procedures (AOAC, 1990). The parameters analyzed for included soil organic matter, pH, N, P, K, Ca, Mg, nitrate N, total N and micronutrients. Statistical analysis was done by the use of MSTAT-C, version 1.3 statistical package (Nissen, 1983); the least significant difference test (Steel *et al*., 1997) was used for mean comparisons at $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Soil chemical properties. The initial chemical properties of the soil were: pH, 5.3; exchangeable acidity, 0.15 cmol kg^{-1}; P, 122.0 mg kg^{-1}; K, 255 mg kg^{-1}; Mg, 18.45 mg kg^{-1}; Ca, 2.49 mg kg^{-1}. Because the pH was 5.3, it was necessary to lime the soil such that the pH would be above 5.3 (Anonymous, 1991; Onwueme & Sinha, 1991). In Swaziland, it is recommended that whenever the soil pH is 5.3 or less, liming should be done to raise the pH above 5.3 (Anonymous, 1991). Table I shows that only the K, nitrate nitrogen and total N concentrations were significantly different among the treatments (cropping systems). Potassium concentration was significantly ($P < 0.05$) higher (239.0 mg kg^{-1}) in soil planted to groundnut intercropped with a low population of sweet potato (16,667 plants ha^{-1}) than in soil planted to pure sweet potato at a high population (33,333 plants ha^{-1}, 161.5 mg kg^{-1}) and also significantly ($P < 0.05$) higher in soil planted to a low population of pure sweet potato (16,667 plants per ha, 197.3 mg kg^{-1}). There was no significant difference in K concentration between soils planted to pure groundnut (225.0 mg kg^{-1}), groundnut intercropped with 33,333 plants per ha of sweet potato (205.5 mg kg^{-1}) and groundnut intercropped with 16,667 plants per ha of sweet potato (239.0 mg kg^{-1}). Ossom and Rhykerd (2007), comparing soil nutrient concentrations under different lime regimes in mono-cropped sweet potato, reported non-significant concentrations of soil P, K, Ca, cation exchange capacity, nitrate nitrogen and total N levels.

However, the significantly ($P < 0.05$) higher levels of nitrate N and total N recorded in the present experiment could be interpreted to signify improved soil fertility associated with nitrogen fixation in groundnut root nodules in agreement with earlier reports of Chandrapanya *et al*. (1982) and Haynes (1980), who observed that grain legumes do improve soil fertility status. The higher levels of N observed could also have been a contribution from the N applied as fertilizer.

As shown in Table II, there were non-significant differences among micronutrient concentrations, exchangeable aluminum concentrations and base saturation in the different cropping systems investigated.

Marketable and non-marketable tuber yields. As shown in Table III, sweetpotato at the lower population of 16,667 plants ha^{-1} had the highest marketable tuber yield (28.6 tonnes ha^{-1}), whilst intercropped sweet potato (16,667 plants ha^{-1}) associated with groundnut had a lower yield (28.1 tonnes ha^{-1}). Sweet potato at the higher population (33,333 plants ha^{-1}) associated with groundnut resulted in the lowest marketable tuber yield (25.2 tonnes ha^{-1}). There were non-significant differences in yield among the cropping systems. In a liming experiment, Ossom and Rhykerd (2007) reported a range of non-significant marketable tuber yields of 19.5-24.6 tonnes ha^{-1} in mono-cropped sweet potato. Ossom and Rhykerd (2007) suggested that a likely factor, which could adversely affect marketable tuber yield, was the care at harvest. Careless harvesting could result in wounds on the tubers as could reduce the amount of marketable tubers.

Sole sweet potato at the lower population of 16,667 plants ha^{-1} resulted in the highest (717.0 kg ha^{-1}) tuber yield of non-marketable tubers, whereas sweet potato at the higher population of 33,333 plants ha^{-1} and associated with groundnut had the lowest (588.5 kg ha^{-1}) yield of non-marketable storage roots. However, these yield differences were non-significantly different among the cropping systems.

Groundnut pod yields. Table IV shows groundnut pod yield under intercropping with a varied population of sweet potato. Mono-cropped groundnut had the highest pod yield (2,001.0 kg ha^{-1}), whilst groundnut associated with sweet potato at the higher sweet potato population of 33,333 plants ha^{-1} had a pod yield of 1,382.0 kg ha^{-1}. Groundnut interplanted with sweet potato at 16,667 plants ha^{-1} had the lowest pod yield (1,366.9 kg ha^{-1}). There was a non-significant difference in pod yield among the cropping systems.

Land equivalent ratio. The LER of the cropping systems was higher in the lower sweet potato population (wider spacing) of sweet potato at 16,667 plants ha^{-1} than under the higher sweet potato population of 33,333 plants ha^{-1}. Thus, sweet potato at 16,667 plants ha^{-1} (60 cm x 100 cm) resulted in an LER of 1.67, whereas sweet potato at 33,333 plants ha^{-1} (30 x 100 cm) gave an LER of 1.62.

Table I. Soil chemical properties under a fixed groundnut population and a varied sweet potato population in Swaziland

Cropping systems	Organic matter (%)	mg kg^{-1} P	K	Mg	Ca	Nitrate N (mg kg^{-1})	Total N (%)	Cation exchange capacity (cmol kg^{-1})	pH
Pure sweetpotato (33,333 plants ha^{-1})	4.1	40.2	161.5	225.0	575.0	3.5	0.16	6.4	6.2
Pure groundnut (200,000 plants ha^{-1})	4.1	43.5	225.3	231.3	575.0	4.0	0.18	6.6	6.3
Pure sweetpotato (16,667 plants ha^{-1})	4.1	52.5	197.3	250.0	700.0	3.0	0.14	7.3	6.3
Groundnut (200,000 plants ha^{-1}) + (33,333 sweetpotato plants ha^{-1})	4.0	46.0	205.5	233.8	700.0	4.5	0.19	7.2	6.4
Groundnut (200,000 plants ha^{-1}) + sweetpotato (16,667 plants ha^{-1})	4.3	46.5	239.0	246.3	700.0	4.8	0.17	7.4	6.4
Means	4.1	45.8	205.7	237.3	650.0	4.0	0.17	7.0	6.3
[1]LSD $_{(0.05)}$	0.38	19.43	39.77	64.43	218.79	1.55	0.04	1.49	0.44
Significance	NS	NS	*	NS	NS	*	*	NS	NS

[1]Least significant difference
*, significant at P < 0.05
NS, non-significant at P > 0.05

Table II. Soil micronutrient, exchangeable aluminum concentrations and base saturation under intercropping with different sweet potato populations and a fixed groundnut population

Cropping systems	mg kg^{-1}					Base saturation (%)			
	S	Zn	Mn	Cu	B	K	Mg	Ca	H
Pure sweetpotato (33,333 plants ha^{-1})	14.5	4.7	27.0	1.2	0.3	6.8	29.3	44.6	19.3
Pure groundnut (200,000 plants ha^{-1})	10.8	4.1	28.3	1.3	0.2	8.8	29.3	43.4	18.6
Pure sweetpotato (16,667 plants ha^{-1})	13.3	4.8	27.5	1.5	0.3	7.3	28.5	47.2	17.1
Groundnut (200,000 plants ha) + (33,333 plants ha^{-1})	11.3	4.9	29.3	1.5	0.2	7.4	27.1	48.7	16.8
Groundnut (200,000 plants ha^{-1}) + sweetpotato (16,667 plants ha^{-1})	11.8	4.7	28.5	1.4	0.3	8.4	28.1	47.1	16.5
Means	12.3	4.6	28.1	1.4	0.3	7.7	24.4	46.2	17.7
[1]LSD $_{(0.05)}$	4.29	1.45	3.17	0.28	0.11	2.16	4.23	6.98	3.79
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Least significant difference
*, significant at P < 0.05
NS, non-significant at P > 0.05

Table III. Yields of marketable and non-marketable sweet potato tubers under intercropping in Swaziland

Cropping system	Marketable tubers (tonnes ha^{-1})	Non-marketable tubers (kg ha^{-1})
Sole sweetpotato (33,333 plants ha^{-1})	26.9	703.1
Sole sweetpotato (16,667 plants ha^{-1})	28.6	717.0
Sweetpotato (33,333 plants ha^{-1}) + groundnut (200,000 plants ha^{-1})	25.2	588.5
Sweetpotato (16,667 plants ha^{-1}) + groundnut (200,000 plants ha^{-1})	28.1	630.2
Means	27.2	0.66
Least significant difference $_{(0.05)}$	13.93	0.33
Non-significant at 5% level	Ns	Ns

An LER of 1.67 indicated a yield advantage of 67% of the sweet potato-groundnut intercrop at a lower sweet potato plant population (wider spacing), over the sole sweet potato or groundnut crop. An LER of 1.62 implied a yield advantage of 62% of the sweet potato-groundnut intercrop at a higher groundnut population (narrower spacing), over the sole sweet potato or groundnut crop. Andrews and Kassam (1976) and Yancey (1994) had earlier indicated that based on LERs, intercropping was beneficial in small-scale farming. In an earlier investigation Ossom *et al.* (2005), who worked on mixtures of grain legumes and sweet potato, reported LERs that ranged from 1.48 to 1.79, indicating that there was a total increase (48-79%) yield advantage from the intercropping systems. The greatest advantage was attained in groundnut associated with sweet potato (LER, 1.79), whereas the lowest advantage was from the bean-sweet potato association (LER, 1.48).

Table IV. Groundnut pod yield (kg ha^{-1}) under intercropping with different sweet potato populations

Cropping system	Groundnut pod yield (kg ha^{-1})
Pure groundnut (200,000 plants ha^{-1})	2,001.0
Groundnut (200,000 plants ha^{-1}) + sweetpotato (33,333 plants ha^{-1})	1,382.0
Groundnut (200,000 plants ha^{-1}) + sweetpotato (16,667 plants ha^{-1})	1,366.9
Mean	1,583.4
Least significant difference $_{(0.05)}$	786.26
Non-significant at 5% level	Ns

CONCLUSION

Sweet potato population affected tuber yield as well as groundnut pod yield. Based on LER, it was more beneficial to intercrop sweet potato at 16,667 plants ha^{-1} than at 33,333 plants ha^{-1}. It is recommended that small-scale farmers intercrop sweet potato at 16,667 plants ha^{-1}, with groundnut at 0.2 million plants ha^{-1}.

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