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Phaseolus vulgaris L. Population Density Affects Intercropped *Ipomoea batatas* (L.) Lam.

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ABSTRACT

Intercropping is a popular farming system in the tropics. Small-scale farmers combine different crops as they wish, but do not know the best plant population densities to use. It would be expedient to elucidate the plant population density of a grain legume that could be planted with a constant density of sweetpotato to obtain the best benefits. A field investigation was conducted in Swaziland to determine the most beneficial plant population size of field bean (*Phaseolus vulgaris* L.) that could be associated with a constant density of sweetpotato [*Ipomoea batatas* (L.) Lam.]. Five cropping systems [monocropped sweetpotato at 33,333 plants ha^{-1}; monocropped field bean at 100,000 plants ha^{-1}; sweetpotato (33,333 plants ha^{-1}) + field bean at 100,000 plants ha^{-1}; sweetpotato (33,333 plants ha^{-1}) + field bean at 66,667 plants ha^{-1}; and sweetpotato (33,333 plants ha^{-1}) + field bean at 33,333 plants ha^{-1}] were compared in a randomized complete block design, replicated four times.

In this study, monocropped sweetpotato (33,333 plants ha^{-1}) gave the highest tuber yield (34.1 t ha^{-1}) but was not significantly different from the lowest yield (28.9 t ha^{-1}) from sweetpotato intercropped with 100,000 plants ha^{-1} of field beans. When the combined yield of field beans and sweetpotatoes was considered as indicated by Land Equivalent Ratios (LERs), there was a yield advantage of 56 to 79% greater than monoculture. This study, concerning the effect of intercropping sweetpotato with various field bean population densities, clearly shows the advantages of intercropping on the Oxisol soils of Swaziland.

Mineral concentration of tubers was not significantly (0.05%) affected by monoculture or intercropping with various field bean densities. Most soil chemical properties tested were also found not to be affected by the cropping systems evaluated by this experiment.

Keywords: Sweetpotato, field bean, Land Equivalent Ratio, intercropping, mineral concentration, soil chemical properties

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INTRODUCTION

The most dominant cropping system used by small-scale farmers in the humid tropics is mixed cropping (Ruthernberg, 1980; Gomez and Gomez, 1983; Vandermeer, 1992; Sullivan, 2000). Sullivan (2003) reported that in Central America, farmers traditionally mix-cropped corn, beans and squash. Intercropping is differentiated from mixedcropping in that in the former, the component crops in the mixture have a definite spacing and are arranged in definite rows whereas in the latter, no specific row arrangement is involved but farmers plant the crops at any convenient spacing (Ruthernberg, 1980). Intercropping is more commonly used in agricultural research stations and other institutions that might be interested in investigating crop associations. Typical crop associations can involve grain legumes and sweetpotato (Ossom et al., 2005), but cassava (*Manihot esculenta* Cranz), yams (*Dioscorea* spp.), cereals and legumes, sugarcane, maize and grain legumes (Zwane, 2003) have also been intercropped.

Sweetpotato is the most important storage root or root tuber crop in Swaziland. This crop, and recently cassava, are the two main storage root crops that are grown in Swaziland. But the importance of sweetpotato as a food security crop has only recently been realized as a result of changes in the physical and socio-economic environments brought about by persistent drought and increases in input prices largely caused by diminishing strength of the Swaziland currency (Lilangeni) since the 1990's (MoAC, 2003). Field bean, commonly known as sugar bean in Swaziland, is the second most important pulse after peanut (Thwala and Ossom, 2004).

While farmers use mixedcropping as an insurance against the risk of crop failure, and as a pest-control measure (Karel, 1993), the proponents of monocropping typically emphasize reduced crop yields under mixed cropping as the greatest disadvantages of crop associations, and hardly mention the benefits of mixed cropping and intercropping. Walker and Jodha (1986) explained that risk reduction in intercropping originates from the ability of at least one crop in the system to compensate for the failure or low yield of another crop. Compensation would not be possible in pure stands, because all plants would be affected in the same way. But planting crops in combination has stood the test of time, as this cropping system has been practiced in many tropical regions for many centuries (Ruthernberg, 1980; Vandermeer, 1992; Wolfe, 2000). Recent investigations in the tropics (Ossom et al., 2005) employing the concept of land equivalent ratio (LER) have demonstrated the advantage of intercropping on yield. Farmers do plant major crops (such as sweetpotato) with companion crops (such as grain legumes) in various combinations and spatial arrangements, not knowing which specific plant population densities to sow in order to obtain the best advantages. This investigation was undertaken to determine the influence of different field bean population densities on intercropped sweetpotato yields when the latter is planted at a constant density, LER, mineral concentration in sweetpotato tubers and chemical properties of the soil.

METHODS

Experimental site and design

This field investigation was conducted in the University of Swaziland, Crop Production Department Farm in Luyengo (26°34'S, 31°12'E; 750 m above sea level; mean annual temperature, 18ºC; annual rainfall, 800 mm) on an Oxisol (Murdoch, 1968). Soil test values at the beginning of the experiment, measured using procedures described by the University of Missouri Extension (1998), were: pH, 5.32; N, 0.13%; P, 4.54 ppm; K, 4.10 meq 100 g^{-1}; exchangeable acidity, 0.29 meq 100 g^{-1}; and organic matter, 2.40%.

The investigation was done from October 2005 to April 2006. A randomized complete block design with five population treatments was replicated four times. The treatments and their respective plant populations were: T_1, monocropped sweetpotato at 33,333 plants ha^{-1} – 30 cm within rows x 100 cm between rows; T_2, monocropped field bean at 100,000 plants ha^{-1} - 10 cm within rows x 100 cm between rows; T_3, sweetpotato (33,333 plants ha^{-1}) + field bean at 100,000 plants ha^{-1} – 10 cm within rows x 100 cm between rows; T_4, sweetpotato (33,333 plants ha^{-1}) + field bean at 66,667 plants ha^{-1} – 15 cm within rows x 100 cm between rows; and T_5, sweetpotato (33,333 plants ha^{-1}) + field bean at 33,333 plants ha^{-1} – 30 cm within rows x 100 cm between rows. Plot sizes were 5.1 m x 6.0 m; plots were spaced 100 cm apart. There were 7 ridges/plot.

Soil amendments and planting

On the day of planting, dolomitic lime was broadcast on the ridges and worked into the soil at the rate of 2 t/ha (Anon., 1991). Thereafter, compound fertilizer [N:P:K, 2:3:2 (22)] that also contained 0.5% Zn, was applied at the rate of 350 kg ha^{-1} (Anon., 1991). Single superphosphate was also applied at the rate of 50 kg ha^{-1} to only plots of monocropped sweetpotato or sweetpotato with field beans, but was not applied to monocropped field bean. The method of application was banding and incorporation, 10 cm away from the planting rows. All crops were planted on 1.0-m ridges as recommended for the main crop, sweetpotato (Anon., 1991). Vines that were 30 cm in length were used as planting materials for sweetpotato. At six weeks after planting (WAP), a side dressing of 10 parts urea and 50 parts KCl was applied at the rate of 120 kg/ha only to plots of pure sweetpotato or sweetpotato with field beans, but none was applied to pure field bean as recommended by Anon. (1991). The variety of sweetpotato planted was 'Kenya' and that of field bean was 'PAN 159'; both were obtained from Malkerns Research Station.

Management, harvesting and sampling

The crop was routinely managed as recommended by Anon. (1991). No pesticides were applied as there was no pest infestation that warranted any control measures. At 12 WAP, field beans were harvested by hand picking. At 24 WAP, sweetpotato was harvested using garden forks to dig up the tubers from the ridges. After harvest, five soil samples (15-cm depth) were collected from each experimental row; all samples from each plot were mixed together to obtain a composite sample for that plot. Whole tuber samples were obtained and washed to remove any adhering soil. Samples (300-400 g) were sliced to facilitate drying. The samples were dried in a hot air oven (Tafaj et al., 2006). All samples were analyzed for chemical properties including macro- and micronutrients at A & L Great Lakes Laboratories, Inc., Fort Wayne, IN, using methods outlined in Recommended Chemical Soil Test Procedures for the North Central Region (University of Missouri Extension, 1998).

Calculation of Land Equivalent Ratio

Land equivalent ratio is a useful concept for comparison of the yield of intercropping to that of a pure stand (Sullivan, 2000; Ossom et al., 2005). LER was calculated as follows:

$$\text{LER} = \frac{\text{yield of crop A in intercrop mixture}}{\text{yield of pure crop A}} + \frac{\text{yield of crop B in intercrop mixture}}{\text{yield of pure crop B}}$$

DATA ANALYSIS

Data were analyzed using MSTAT-C statistical software, version 1.3 (Nissen, 1983). The least significant difference (LSD) test was used for mean separation at $P \leq 0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Tuber and pod yields

Table 1 shows the effect of field bean population density on tuber yield of sweetpotato and pod yield of field bean. Interestingly, there was no significant difference in sweetpotato tuber yield at the 5% level when comparing a pure culture of sweetpotato with intercropped sweetpotato at a constant population density with the three population densities of field bean. However, highest tuber yield was obtained with pure culture (34.1 t ha^{-1}) and lowest tuber yield (28.9 t ha^{-1}) at the highest plant density of field bean.

As also shown in Table 1, field bean pod yields were significantly affected (0.05) by field bean plant density and intercropping with sweetpotato. Pure field bean yielded 3,192.5 kg ha^{-1} while intercropped field bean at 33,333 plant ha^{-1} with sweetpotato yielded only 2000 kg ha^{-1}. Field bean pod yields were not significantly reduced by intercropping with sweetpotato at a field bean population density of 66,667 or 100,000 plants ha^{-1}. Apparently, 33,333 plants ha^{-1} of field bean plant density was insufficient when intercropped with sweetpotato to produce a yield comparable to a field bean monoculture. Expressing field bean yield as pod yields (Thwala and Ossom, 2004; Ossom and Nxumalo, 2003) appears to be important to livestock farmers for the reason that the family can eat the grain whereas the pods are fed to livestock.

Field bean pods per plant, seeds per pod, and weight of 100 seeds

Data in Table 1 also indicate that field bean density and intercropping with sweetpotato significantly affected the number of pods per field bean plant as well as the number of seeds per pod. Intercropping sweetpotato (33,333 plants ha^{-1}) with field bean at field bean population densities of 33,333 and 66,667 plants ha^{-1} significantly reduced the number of pods per plant. The number of field bean seeds per pod was significantly reduced at the 33,333 plants ha^{-1} when intercropped with sweetpotato.

The weight of field bean seeds was unaffected by cropping system.

Land Equivalent Ratio (LER)

It is readily apparent from the data presented in Table 1 that intercropping results in considerably greater yield per ha. LER for intercropped sweetpotato and field bean ranged from a low of 1.56 for sweetpotato (33,333 plants ha^{-1}) intercropped with a field bean plant density 33,333 plants ha^{-1} to a high of 1.79 for intercropped sweetpotato and field bean plant density at 66,667 plants ha^{-1}. This means that a combined yield increase of 79% was obtained by intercropping sweetpotato planted at 33,333 plants ha^{-1} and field bean at a plant density of 66,667 plants ha^{-1}. Our results were in agreement with a previous investigation (Ossom and Nxumalo, 2003) in which an LER of 1.79 was obtained in sweetpotato-peanut intercropping, and 1.48 in sweetpotato-field bean association, both results confirming the advantages of sweetpotato intercropping. Other researchers (Spio, 1996; Fininsa, 1997) concluded that based on LERs, intercropping was superior to sole cropping if the same level of crop management in terms of labor utilization, land and other inputs concerned were applied to both.

Tuber mineral concentrations

As seen in Tables 2 and 3, there were no significant differences in mineral concentrations among the cropping systems.

Soil chemical properties

Table 4 shows the influence of field bean population on the concentration of soil mineral nutrients in sweetpotato plots. There were no significant differences among these soil chemical properties, except Ca concentration that was significantly ($P < 0.05$) higher in monocropped field bean soils than when sweetpotato was intercropped with 33,333 plants ha^{-1} of field bean. Table 5 shows the effects of different field bean populations on the base saturation and micronutrient concentrations in intercropped sweetpotato. Only Mg, Ca, and H base saturations showed significant differences among the treatments.

The optimum soil pH for field bean ranges from 5.5 to 7.0 (Norman, 1992). If the pH of the soil is less than 5.5, liming is recommended because field beans are sensitive to high concentrations of aluminum and manganese (Norman, 1992). LSU (2003) recommended that for sweetpotato, if the soil pH was below 5.2, liming would be required, and advised that liming sweetpotato could reduce soil acidity, improve fertilizer use efficiency and improve decomposition of crop residues. It is most probable that the advantages observed in the crop combination could be associated with the beneficial influence of nitrogen-fixing bacteria in field bean.

CONCLUSIONS AND RECOMMENDATIONS

This study, concerning the effect of intercropping sweetpotato with various field bean population densities, clearly shows the advantage of intercropping on the Oxisol soils of Swaziland. Although a monoculture of sweetpotato produced highest yields, the intercropping of sweetpotato with field bean populations of 33,333, 66,667, and 100,000 plants ha^{-1} resulted in a yield increase of 56 to 79% as determined by LERs. The 79% increase was obtained by intercropping sweetpotato with a field bean population density of 66,667 plants ha^{-1}. Therefore, Swaziland producers are encouraged to intercrop field beans and sweetpotatoes at plant population densities of 66,667 field bean plants ha^{-1} and 33,333 sweetpotato plants ha^{-1}.

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Table 1. Yield and Land Equivalent Ration (LER) response to varying field bean densities intercropped with sweetpotato.

Cropping system	LER	Tuber	Field Bean			
		Yield ($t\ ha^{-1}$)	Pod yield ($kg\ ha^{-1}$)	Number of pods per plant	Number of seeds per pod	100–seed mass (g)
Pure field bean at 100,000 plants ha^{-1}	NA	NA	3,192.5	13.7	6.1	32.2
Pure sweetpotato at 33,333 plants ha^{-1}	NA	34.1	NA	NA	NA	NA
Sweetpotato + field bean at 100,000 plants ha^{-1}	1.69	28.9	2,682.5	10.2	5.3	27.6
Sweetpotato + field bean at 67,667 plants ha^{-1}	1.79	31.3	2,762.5	8.5	5.3	27.3
Sweetpotato + field bean at 33,333 plants ha^{-1}	1.56	31.7	2,000.0	7.2	4.0	28.9
Mean		31.5	2,659.4	9.9	5.2	29.0
LSD[1] $_{(0.05)}$		9.88	847.06	3.74	1.61	5.54
Significance		Ns	*	*	*	Ns

[1]Least significant difference; NA, not applicable; NS, not significant at $P > 0.05$.

Table 2. Concentrations of macronutrients (%) in sweetpotato tubers intercropped under different field bean population densities.

Cropping system	N	P	K	Mg	Ca	S	Na
Pure sweetpotato at 33,333 plants/ha	0.455	0.147	1.087	0.062	0.055	0.053	0.090
Sweetpotato + field bean at 100,000 plants/ha	0.372	0.152	1.105	0.070	0.065	0.053	0.060
Sweetpotato + field bean at 66,667 plants/ha	0.422	0.145	0.902	0.070	0.060	0.050	0.108
Sweetpotato + field bean at 33,333 plants/ha	0.395	0.135	1.015	0.070	0.063	0.053	0.080
Mean	0.412	0.145	1.028	0.068	0.061	0.052	0.084
LSD[1] $_{(0.05)}$	0.122	0.040	0.297	0.029	0.038	0.009	0.055
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Correlation coefficient with tuber yield	-0.388	- 0.392	- 0.443	0.060	0.504	0.126	- 0.106

[1]Least significant difference; NA, Not applicable; Ns, not significant at $P > 0.05$.

Table 3. Concentrations of micronutrients (ppm) in sweetpotato tubers intercropped under different field bean population densities.

Cropping system	B	Zn	Mn	Fe	Cu	Al
Pure sweetpotato at 33,333 plants/ha	3.500	6.750	5.000	30.500	3.250	15.000
Sweetpotato + field bean at 100,000 plants/ha	4.500	7.750	6.750	32.500	3.000	23.000
Sweetpotato + field bean at 66,667 plants/ha	3.750	9.000	6.000	42.000	3.000	27.500
Sweetpotato + field bean at 33,333 plants/ha	4.000	9.700	5.000	36.000	2.750	28.000
Mean	3.938	8.313	5.688	35.250	3.000	23.375
LSD[1] $_{(0.05)}$	0.933	4.859	2.533	22.020	0.998	22.195
Significance	Ns	Ns	Ns	Ns	Ns	Ns
Correlation coefficient with tuber yield	- 0.425	0.028	0.103	0.103	0.032	- 0.026

[1]Least significant difference; NA, Not applicable; Ns, not significant at $P > 0.05$.

Table 4. Influence of field bean population densities on concentration of soil mineral nutrients in sweetpotato plots.

Cropping system	%		Parts per million							pH	CEC[1] (meq/100 g)
	Organic matter	Total N	Nitrate N	P	K	Mg	Ca	Sulfur	Exchangeable Al		
Pure sweetpotato at 33,333 plants/ha	3.20	0.112	3.25	11.75	70.00	161.25	650.00	15.25	7.00	5.73	6.88
Pure field bean at 100,000 plants/ha	3.43	0.131	2.50	13.50	108.25	178.75	762.50	15.00	6.50	5.85	7.40
Sweet-potato + field bean at 100,000 plants/ha	3.38	0.117	3.50	13.00	87.00	172.50	637.50	14.75	4.25	5.80	6.65
Sweetpotato + field bean at 66,667 plants/ha	3.53	0.113	4.00	15.25	72.50	167.50	625.00	14.75	4.75	5.75	6.20
Sweetpotato + field bean at 33,333 plants/ha	3.13	0.120	3.50	14.00	66.75	158.75	437.50	15.25	6.00	5.73	4.85
Mean	3.33	0.118	3.35	13.50	80.90	167.75	622.50	15.00	5.70	5.77	6.40
LSD[1] $_{(0.05)}$	0.432	0.019	1.59	5.88	41.61	27.43	183.78	1.92	3.05	0.110	1.66
Significance	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	*

[1]Least significant difference; * significant at $P < 0.05$; Ns, not significant at $P > 0.05$.

Table 5. Base saturation and micronutrient concentrations in soil grown to sweetpotato and different field bean population densities.

	Base saturation (%)				Parts per million			
	K	Mg	Ca	H	Zn	Mn	Cu	B
Pure sweetpotato at 33,333 plants/ha	2.73	20.93	47.43	28.95	2.83	29.75	1.28	0.40
Pure field bean at 100,000 plants/ha	3.70	20.75	51.70	23.83	2.85	30.75	1.23	0.40
Sweet-potato + field bean at 100,000 plants/ha	3.50	22.43	47.60	26.48	2.75	29.75	1.20	0.43
Sweetpotato + field bean at 66,667 plants/ha	3.13	23.28	50.00	23.60	2.93	30.00	1.25	0.40
Sweetpotato + field bean at 33,333 plants/ha	3.45	27.15	44.65	24.78	3.00	30.00	1.23	0.40
Mean	3.30	22.91	48.28	25.53	2.87	30.05	1.24	0.41
LSD[1] $_{(0.05)}$	1.32	5.57	4.02	4.28	0.56	3.09	0.14	0.07
Significance	Ns	*	*	*	Ns	Ns	Ns	Ns

[1]Least significant difference; * significant at $P < 0.05$; Ns, not significant at $P > 0.05$.