American-Eurasian Journal of Agronomy 2 (1): 01-06, 2009
ISSN 1995-896X

Effects of Plant Population on Yield Components and Yield of Intercropped Sweetpotato [*Ipomoea batatas* (L.) Lam.] and Groundnut (*Arachis hypogaea* L.)

[1]E.M. Ossom, [1]L.M. Kuhlase and R.L. [2]Rhykerd

[1]Crop Production Department, Faculty of Agriculture,
University of Swaziland, Private Bag Luyengo, Luyengo M205, Swaziland
[2]Department of Agriculture, Illinois State University, Normal, IL 61790-5020, USA

Abstract: The commonest cropping system in the tropics is intercropping, in which various crops are associated in the same piece of land and in the same cropping season. Though small-scale farmers commonly use intercropping, it is not clear what effects crop association could have on yield components and yield. The objective of this experiment was to assess the effects of plant population on yield components and yields of sweetpotato [*Ipomoea batatas* (L.) Lam.] under intercropping with groundnut (*Arachis hypogaea* L.). Five population treatments were investigated in a randomized complete block design, replicated four times. The treatments were: [1, monocropped sweetpotato (100 cm x 30 cm = 33,333 plants/ha); 2, monocropped groundnut (100 cm x 10 cm = 200,000 plants/ha); 3, monocropped sweetpotato (100 cm x 60 cm = 16,667 plants/ha); 4, groundnut (200,000 plants/ha) intercropped with sweetpotato at 33,333 plants/ha; and 5, groundnut (200,000 plants/ha) intercropped with sweetpotato at 16,667 plants/ha]. Results showed declining leaf areas in sweetpotato at 20 weeks, probably because of leaf senescence. Correlation data at 16 weeks after planting showed that leaf area (r = 0.368), leaf area index (r = 0.368), 100-pod dry mass (r = 0.055), number of pods/plant (r = 0.392) and number of seeds/plant (r = 0.500) were all positively correlated to seed dry mass/plant. The marketable tuber yields (28.6 tonnes/ha) were highest when pure sweetpotato was planted at 16,667 plants/ha and lowest (25.2 t/ha) when sweetpotato (33,333 plants/ha) was intercropped with groundnut; there were no significant differences in tuber yields. Land equivalent ratio was 1.62 when sweetpotato was intercropped at a population of 33,333 plants/ha, but was higher (1.67) at a population of 16,667 plants/ha, indicating that intercropping was beneficial in both cases but more advantageous in the lower sweet potato population. Based on crop productivity/ha, sweetpotato at 16,667 plants/ha intercropped with 200,000 plants/ha of groundnut, is recommended to small-scale farmers in Swaziland. Further research on growth parameters involving different sweetpotato populations in association with groundnut, is recommended.

Key words: Groundnut · Yield components · Yields · Plant population · Sweetpotato

INTRODUCTION

Throughout the humid tropics, the commonest and most popular cropping system is intercropping, that has been variously described as the space-dependent form of multiple cropping [1], polyculture [2] and mixed cropping [3]. The definition of Ruthernberg [3] showed that intercropping differs from mixed cropping, where two or more crops are grown simultaneously and intermingled, with no row arrangement; there is intercrop competition during all or part of crop growth.

Gomez and Gomez [4] explained intercropping to imply the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage of all associated crops. They further classified intercropping into two: mixed cropping, an intercropping with no distinct row arrangement and row intercropping, which is intercropping where at least one crop is planted in rows. Gomez and Gomez [4] considered row intercropping as one sub-category under the general category of intercropping and explained row intercropping as the growing of two or more crops simultaneously, where one

Corresponding Author: Prof. E.M. Ossom, Crop Production Department, Faculty of Agriculture, University of Swaziland, Private Bag Luyengo, Luyengo M205, Swaziland

or more crops are planted in rows. Intercropping is a widespread form of agriculture and has been practised for many years by small-scale farmers.

Intercropping has advantages that need to be further investigated in the interest of the small-scale farmer of developing countries on whose shoulders rests the onerous task of producing sufficient food to feed the ever-increasing population. Such advantages include a more stable yield over space and time, than monocultures in terms of income level, stability and risk [5]. There is the possibility that competition between crops could offer some solutions to weed control. van Schoonhoven and Voysest [6] noted that intercropping with beans was more important than sole cropping, especially in the tropics and subtropics because of the predominance of small-scale farmers who cultivate beans in these areas; the report suggested that intercropping could be a contributing factor to low bean yields.

Grain legumes are often used in different cropping systems because of their known beneficial effects through nitrogen fixation. Lindemann and Glover [7] reported that groundnut (*Arachis hypogaea* L.), soya beans (*Glycine max*) and cowpea (*Vigna unguiculata*) are good nitrogen fixers, being able to fix up to 280 kg of nitrogen/hectare.

Growth parameters have been reported to influence crop growth. Tsubo *et al.* [8], using population densities of 4.2, 8.3 and 12.5 plants/m^2 for pure field bean and 2.1, 4.2 and 6.3 plants/m^2 for bean-maize intercrop, showed that plant density affected crop productivity and resource use in intercropping. They concluded that good crop growth resulted in high crop yield. Zwane and Ossom [9], investigating the influence of different plant populations of field bean (*Phaseolus vulgaris* L.) on growth parameters in intercropping, reported that plant population parameters influenced the growth and yield of the grain legume.

It would be beneficial to know how different plant populations of sweetpotato might influence different growth parameters under intercropping with groundnut in Swaziland. From such knowledge, management decisions could be made on how to better grow and manage sweetpotato in small-scale farming. Therefore, this study was undertaken to determine the effects of different sweetpotato plant populations, in association with a fixed population of groundnut, on some growth parameters and tuber yield of sweetpotato.

MATERIALS AND METHODS

Experiment Site and Land Preparation: The experiment was sited at the Crop Production Department Experimental Farm in the University of Swaziland, in Luyengo (26.68°S, 31.20°E; 732.5 m above sea level; mean annual rainfall range, 850-1000 mm). The location was in the Middleveld agro-ecological zone of Swaziland. The soil type was an Oxisol of the Malkerns soil series [10]. The land was prepared with tractor-mounted implements, ending up with the making of 1.0-m ridges for sweetpotato that was the main crop in the investigation. Using a soil probe, soil samples were obtained at 0-15 cm depth and used to determine the initial soil fertility level.

Design of Experiment and Treatments: The design of the experiment was a randomized complete block design. There were five treatments and four replicates. The treatments (T) were T_1, pure sweetpotato (33,333 plants/ha); T_2, pure groundnut (200,000 plants/ha); T_3, pure sweetpotato (16,667 plants/ha); T_4, groundnut (200,000 plants/ha) intercropped with sweetpotato at 33,333 plants/ha; and T_5, groundnut (200,000 plants/ha) intercropped with sweetpotato at 16,667 plants/ha. Plot sizes were 7.2 m x 8.0 m, with nine ridges per plot; there were five discard rows and four experimental rows per plot. A 1.0-m space separated contiguous plots; a 1.0-m perimeter space on all sides also surrounded the experiment.

Fertilization and Crop Establishment: Dolomitic lime was applied at the rate of 1.0 tonne/ha, before planting. The lime was spread on the ridges and manually worked into the ridges using a rake. Fertilizer applications were: compound fertilizer, N: P: K [2:3:2 (38)], which also contained 0.5% zinc, applied before planting, at the rate of 350 kg/ha. Single superphosphate (10.5% P) was also applied at the rate of 50 kg/ha [11]. At 6 WAP, a side dressing fertilizer was applied using a mixture of 10 parts urea (45% N) and 50 parts muriate of potash, KCl (50% K) at the rate of 120 kg/ha. In all cases, the method of application was banding and incorporation, 10 cm away from the crop rows.

Both crops were hand-planted on 22 and 23 October 2007. The planting materials for sweetpotato were terminal vine cuttings (each 30 cm long) per station; two groundnut seeds were planted per station. Using a sprinkler irrigation system, the plots were watered to field capacity, immediately after planting and thereafter, twice a week, during the first 4 WAP, when rain was not regular.

Data Collection and Analysis: Data were collected at harvest on yields, relationships among yield components, and land equivalent ratio (LER). Monocropped sweetpotato and intercropped sweetpotato were harvested at 20 WAP; however, pure groundnut was harvested at 16 WAP because of the incidence of a fungal disease that threatened the groundnut. The harvest of the intercropped groundnut was delayed till 20 WAP, in order to harvest both sweetpotato and groundnut at the same time. It was reasoned that harvesting intercropped groundnut at 16 WAP could adversely affect the root system of sweetpotato. Garden forks were used to dig up each crop at harvest. The tubers were sorted into marketable and non-marketable tubers. Marketable tubers were whole tubers that had no harvest wounds and weighed between 100 g and 1.4 kg [12]; non-marketable tubers were tubers that had harvest wounds or were outside the mass range for marketable tubers.

Data collected from groundnut at harvest included dry pod yield and the number of groundnut pegs/plant that did not reach the soil. The LER compared the yield in intercropping with that of a pure stand [13] and was calculated as:

$$LER = \frac{\text{Yield of crop A mixture}}{\text{Yield of pure crop A}} + \frac{\text{Yield of crop B mixture}}{\text{Yield of pure crop B}}$$

Data were analysed using MSTAT-C, version 1.3 [14]. The least significant difference test [15] was used for mean separation at $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

The Soil and Environment: The soil pH was 5.3; this was below 5.5 that is the lower pH level for sweetpotato in Swaziland [11]. Other soil properties were exchangeable acidity, 0.15 cmol/kg; P, 122.0 mg/kg; Mg, 255.0 mg/kg; and Ca, 2.49 mg/kg. The total rainfall (Table 1) received during the period of the experiment was 654.8 mm; therefore, irrigation was necessary in the first four weeks after planting when rainfall was not regular.

Marketable Tuber Yields and Land Equivalent Ratio (LER): As shown in Table 2, sole sweetpotato at 16,667 plants/ha had the highest yield (28.6 tonnes/ha). Intercropped sweetpotato (16,667 plants/ha associated with groundnut) had a lower yield (28.1 t/ha). Sole sweetpotato at 33,333 plants/ha yielded 26.9 t/ha and sweetpotato at 33,333 plants/ha associated with groundnut had the lowest tuber yield (25.2 t/ha).

That sole sweetpotato yielded higher than the intercrops was consistent with previous findings [13, 17, 18], which established that there were usually higher crop yields in pure crop stands than in associated crops.

Based on the LER (Table 2), intercropping was beneficial in this investigation, with the higher LER at lower sweetpotato populations compared to higher populations, with an LER 1.67 and 1.62, respectively. Producing two crops from one garden is among the benefits of intercropping [3, 5, 19] that has endeared small-scale farmers to this cropping system.

Table 1: Rainfall and temperature during the experiment (October 2007 to March 2008)

	Temperature (°C)		
Month/Year	Minimum	Maximum	Rainfall (mm)
October 2007	14.4	24.1	54.0
November 2007	15.9	24.9	139.2
December 2007	16.9	27.1	111.7
January 2008	18.2	27.2	81.9
February 2008	17.3	28.7	73.0
March 2008	16.5	26.4	195.6
Total	99.2	158.4	654.8
Mean	16.5	26.4	109.1

Source: Malkerns Research Station [16]

Table 2: Effects of sweetpotato plant population on marketable tuber yield under intercropping with a fixed population of groundnut

Cropping system	Marketable sweetpotato yield (tonnes/ha)	Groundnut pod yield (kg/ha)	Land equivalent ratio
Pure sweetpotato (33,333 plants/ha)	26.9	-	-
Pure groundnut (200,000 plants/ha)	-	2001.0	-
Pure sweetpotato (16,667 plants/ha)	28.6	-	-
Sweetpotato (33,333 plants/ha) groundnut (200,000 plants/ha) +	25.2	1,382.0	1.62
Sweetpotato (16,667 plants/ha) + groundnut (200,000 plants/ha)	28.1	1,366.9	1.67
Means	27.2	1,583.3	-
LSD $_{(P<0.05)}$	13.9	786.26	-
Significance	Ns	Ns	-

Ns, not significant

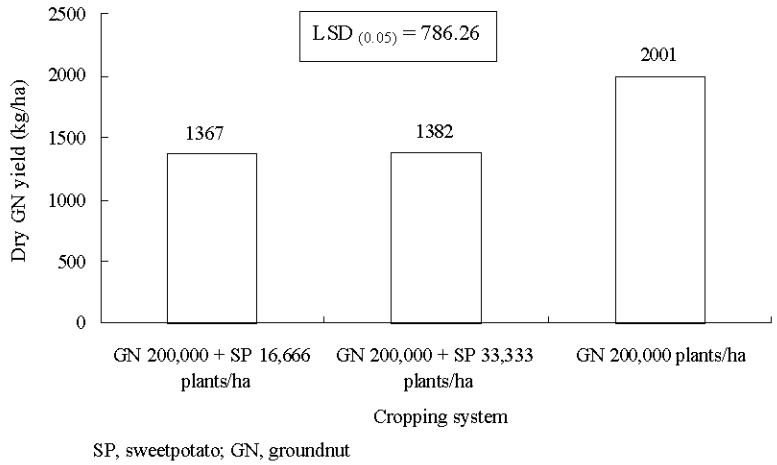

Fig. 1: Effects of cropping systems on groundnut pod yield (kg/ha) at harvest

Table 3: Effects of cropping systems on dry mass (g) of 100 seeds of groundnut

Cropping system	Dry mass (g) of 100 seeds
Groundnut (200,000 plants/ha)	36.4
Groundnut (200,000 plants/ha) + sweetpotato (33,333 plants/ha)	33.6
Groundnut (200,000 plants/ha) + sweetpotato (16,667 plants/ha)	31.3
Means	33.8
Least significant difference$_{(0.05)}$	5.97
Not significant at 5% level	NS

Table 4: Effects of sweetpotato population on groundnut shelling percentage

Cropping system	Shelling percentage (%)
Groundnut (200,000 plants/ha)	63.4
Groundnut (200,000 plants/ha) + sweetpotato (33,333 plants/ha)	64.4
Groundnut (200,000 plants/ha) + sweetpotato (16,667 plants/ha)	59.3
Means 62.4	
Least significant difference$_{(0.05)}$	5.53
Not significant at p > 0.05	NS

Table 5: Number of groundnut pegs/plant that did not reach the soil at harvest

Cropping system	Number of pegs
Pure groundnut (200,000 plants/ha)	10.9
Groundnut (200,000 plants/ha) + sweetpotato (33,333 plants/ha)	8.8
Groundnut (200,000 plants/ha) + sweetpotato (16,667 plants/ha)	13.4
Means	11.0
Least significant difference$_{(0.05)}$	5.66
Not significant at p > 0.05	NS

Dry Groundnut Pod Yield (kg/ha) at Harvest: Figure 1 shows groundnut pod yield (kg/ha) at harvest. Pure groundnut stand had the highest yield (2,001.0 kg/ha). Groundnut at 200,000 plants/ha associated with sweetpotato at 33,333 plants/ha was second with 1,382.0 kg/ha and groundnut at 200,000 plants/ha, in association with sweetpotato at 16,667 plants/ha, yielded 1,366.9 kg/ha. There was no significant difference in pod yield at harvest among the cropping systems. Taylor [20] reported that if water first became limiting in soybean after flowering, high plant population densities could exacerbate a reduction in canopy photosynthesis and may result in less yield than moderate plant densities.

Dry Mass of 100 Seeds of Groundnut: Table 3 shows the dry mass of 100 seeds of groundnut. Pure groundnut had the highest mean value (36.4 g). Groundnut associated with sweetpotato at 33,333 plants/ha had a lower mean mass (33.6 g) and groundnut associated with sweetpotato at 16,667 plants/ha had the lowest mass (31.3 g). There was no significant difference observed in dry mass of 100 seeds of groundnut from the three cropping systems

Effects of Cropping System on Shelling Percentage: The shelling percentage of groundnut in different sweetpotato populations is shown in Table 4. The groundnut in association with sweetpotato at 33,333 plants/ha had the highest mean value of 64.4%. Pure groundnut had a lower shelling percentage (63.4%) and groundnut intercropped with sweetpotato at 16,667

Table 6: Correlation coefficients among groundnut parameters at harvest

Parameters	Leaf area	Leaf area index	Dry pod yield	100-pod dry mass	100-seed dry mass	Shelling%	Dry pod yield	Dry matter pods/plant	Number of pods/plant	Number of seeds/plant
Leaf area index	1.000***									
Dry pod yield	-0.032	-0.032								
100-pod dry mass	-0.339	-0.339	0.593*							
100-seed dry mass	-0.336	-0.336	0.816**	0.694*						
Shelling %	-0.069	-0.069	0.693*	0.708**	0.524					
Dry pod yield	-0.031	-0.031	1.000***	0.593*	0.816**	0.693*				
Dry matter pods/plant	0.497	0.497	0.118	-0.180	-0.208	-0.005	0.119			
Number of pods/plant	0.492	0.492	0.243	-0.032	-0.115	0.210	0.244	0.975***		
Number of seeds/plant	0.378	0.378	0.268	-0.183	-0.072	-0.165	0.269	0.788**	0.730**	
Seed dry mass/plant	0.368	0.368	-0.057	0.055	-0.121	-0.129	-0.056	0.431	0.392	0.500

*, significant at $p < 0.05$; **, significant at $p < 0.01$; ***, significant at $p < 0.1$.

plants/ha had the lowest shelling percentage (59.3%). There were no significant differences in the shelling percentage of groundnut at harvest in these cropping systems.

Number of Groundnut Pegs/plant That Did Not Contact the Soil: Table 5 shows the number of groundnut pegs that did not make any contact with the soil by harvest time. Groundnut associated with sweetpotato at 16,667 plants/ha had the highest number (13.4) of pegs/plant that did not reach the soil. Pure groundnut had a mean value of 10.9 and groundnut in association with sweetpotato at 33,333 plants/ha had the lowest mean value of 8.8.

There were no significant differences in number of groundnut pegs/plant that did not contact the soil by harvest time. It was reported [21] that in groundnut, all the pegs formed do not grow long enough to reach the soil and develop into pods; also all the pegs that enter the soil do not form mature pods. Significant cultivar differences have been observed [21] in the proportion of pegs developing into pods.

Relationships among Yield Components: At groundnut harvest (16 WAP), correlation data (Table 6) showed that leaf area ($r = 0.368$), leaf area index ($r = 0.368$), 100-pod dry mass ($r = 0.055$), number of pods/plant ($r = 0.392$) and number of seeds/plant ($r = 0.500$) were all positively correlated to seed dry mass/plant. The number of seeds/plant was positively and highly significantly ($p < 0.01$) related to the dry matter of pods/plant ($r = 0.788$) and to the number of pods/plant ($r = 0.730$).

CONCLUSION AND RECOMMENDATION

This investigation showed that plant population influenced yield and yield components of both sweetpotato and groundnut. Land equivalent ratio data showed the superiority of intercropping over monocropping. Based on crop productivity/ha, sweetpotato at 16,667 plants/ha intercropped with 200,000 plants/ha of groundnut, is recommended to small-scale farmers in Swaziland.

ACKNOWLEDGEMENTS

The following institutions assisted the authors during the investigation: Malkerns Research Station, Malkerns; the Ministry of Agriculture and Cooperatives, Mbabane, Swaziland; Crop Production Department, University of Swaziland; and the Department of Agriculture, Illinois State University, Normal, U.S.A. The authors are thankful to these institutions.

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