J. Agric. Food. Tech., 1(4) 31-37, 2011

ISSN 2090 – 424X
Journal of Agriculture and Food Technology
www.textroad.com

Effects of jugo bean [*Vigna subterranea* (L.) Verdc.] plant population on nutrient element concentrations in storage roots and soils of intercropped sweetpotato [*Ipomoea batatas* (L.) Lam.] in Swaziland

[1]Baring S. Nkambule, [2]E.M. Ossom, [3]R.L. Rhykerd, and [4]C.L. Rhykerd

[1]Crop Production Department, Faculty of Agriculture, University of Swaziland Private Bag Luyengo, Luyengo M205, Swaziland
[2*]School of Agriculture & Food Technology, The University of the South Pacific, Private Mail Bag, Apia, Samoa
[3]Department of Agriculture, Illinois State University, Normal, IL 61790-5020, USA.
[4]Professor Emeritus of Agronomy, Purdue University, West Lafayette, IN 47907-2054, USA

ABSTRACT

Intercropping is a cropping system that involves planting two or more crops at the same time in the same field. Sweetpotato [*Ipomoea batatas* (L.) Lam.] is the most important storage root crop cultivated in Swaziland. This crop has been grown in association with groundnut (*Arachis hypogaea* L.), field beans (*Phaseolus vulgaris* L.) or other crop grain legumes that a small-scale farmer considers to be important to his/her family. Jugo bean [*Vigna subterranea* (L.) Verdc.] is a grain legume that is also commonly grown in Swaziland. There is no documented information on nutrient and soil mineral nutrient concentrations under intercropping of sweet potato and jugo bean. Therefore the objective of the experiment was to assess the influence of varying jugo bean plant population on mineral nutrient concentrations in storage roots and soil under intercropping with sweetpotato. Five plant population treatments were evaluated in a randomized complete block design, replicated four times. The treatments were: 1, sweetpotato only (30 cm x 100 cm) – 33,333 plants/ha; 2, Jugo bean only (15 cm x 100 cm) – 66,666 plants/ha; 3, Sweetpotato (30 cm x 100 cm) - 33,333 plants/ha and jugo bean (15 cm x100 cm) – 66,666 plants/ha; 4, Sweetpotato (30 cm x100 cm) - 33,333 plants/ha and jugo bean (7.5 cm x 100 cm) – 133,333 plants/ha; and 5, Sweetpotato (30 cm x100 cm) - 33,333 plants/ha and jugo bean (30 cm x 100 cm) – 33,333 plants/ha. Results showed significantly ($p < 0.05$) higher concentrations of nitrogen (0.56-0.63 g/kg) and nitrate nitrogen (0.001-0.002(g/kg)) were accumulated in jugo bean-associated sweetpotato storage roots than in sole sweetpotato (N, 0.5(g/kg); Nitrate N, 0.001(g/kg). Micronutrient and Al concentrations in storage roots did not significantly vary among the cropping systems. Soil pH was most improved (from original soil pH value of 4.8) when jugo bean at 66,666 plants/ha was associated with sweetpotato (soil pH, 5.78) though there were no significantly differences among the cropping systems. Available P in soil was significantly ($p < 0.05$) higher (62.50 mg/kg) when 66,666 plants/ha of jugo bean was interplanted with sweetpotato. Other soil parameters did not show any significant differences among treatments. It is concluded that intercropping jugo bean at 66,666 plants/ha with sweetpotato was beneficial to soil and tubers. It is recommended that small-scale farmers interplant jugo bean at 66,666 plants/ha with sweetpotato to improve their soils. Further investigations would be useful.

Key words: Jugo bean; mineral nutrients; nutrient elements; nutrients in sweetpotato storage roots; organic farming; soil nutrients; sweetpotato; storage root yield

INTRODUCTION

Intercropping is the cultivation of two or more crops at the same time in the same field [1]. Intercropping has been practiced for centuries in Africa and other regions of the world; intercropping is one way to increase the diversity of cropping systems. There are many advantages of intercropping, including a greater efficiency in the utilization of limited soil and water resources [2]. Jugo bean [*Vigna subterranea* (L.) Verdc.], also known as Bambara groundnut, is similar to peanut (*Arachis hypogaea* L.), as both types of plants

***Corresponding Author:** Prof. E.M. Ossom, School of Agriculture & Food Technology, The University of the South Pacific, Private Mail Bag, Apia, Samoa. Email: ossom_e@usp.ac.fj

have pods that develop and mature underground. Jugo bean has the advantage of being able to be reasonably productive even under extreme conditions such as drought and poor soil [3]. Sweetpotato [*Ipomoea batatas* (L.) Lam.] is the most important storage root crop cultivated in Swaziland. Sweetpotato is also grown in other countries; more than 95% of the global sweetpotato crop is grown in developing countries, where it is the fifth most important food crop [4]. Sweetpotato reliably provides food on marginal and degraded soils, with little labour and few or no inputs from outside the farm [5].

Legumes are also known to have a beneficial effect on succeeding crops [6]. The beneficial effect on succeeding crops is usually attributed to the increased soil fertility because of nitrogen fixation by the previous leguminous crop [7]. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Despite both jugo bean and sweetpotato being grown in Swaziland for hundreds of years, there is no research information on nutrient and soil mineral nutrient concentrations under intercropping of sweetpotato and jugo bean in Swaziland. Therefore, the objective of the experiment was to assess the influence of varying jugo bean plant population on mineral nutrient concentrations in storage roots and soil under intercropping with sweetpotato.

MATERIALS AND METHODS

Location and experimental design

This was a field experiment conducted at Malkerns Research Station, which is in the Middleveld agro-ecological zone of Swaziland and geographically at 26.34°S, 31.10°E and 750 m above sea level; mean annual rainfall range, 800 mm and mean annual temperature of 18°C [8]. The experiment was conducted during the 2009/2010 cropping season, from 7 November 2009 to 24 April 2010.

The experimental design was a randomized complete block design, with five plant population treatments. Each treatment was replicated four times. The treatments were: 1, sweetpotato only (30 cm x 100 cm) – 33,333 plants/ha; 2, Jugo bean only (15 cm x 100 cm) – 66,666 plants/ha; 3, Sweetpotato (30 cm x 100 cm) - 33,333 plants/ha and jugo bean (15 cm x100 cm) – 66,666 plants/ha; 4, Sweetpotato (30 cm x100 cm) - 33,333 plants/ha and jugo bean (7.5 cm x 100 cm) – 133,333 plants/ha; and 5, Sweetpotato (30 cm x100 cm) - 33,333 plants/ha and jugo bean (30 cm x 100 cm) – 33,333 plants/ha.

Land preparation and planting

The experiment site was prepared using a tractor-mounted moldboard plow; this was followed by disc harrowing, after which 1.0-m ridges were prepared using a tractor-mounted disc ridger. Before marking out the plots, a composite soil sample of the experiment site was taken (0-15-cm depth) using a soil probe. There were seven ridges per plot, each plot measuring 5.4 m x 6.0 m. Each plot and each replicate were separated from others by a 1.0-m perimeter space.

Before planting, dolomitic lime ($CaMgCO_3$) was broadcast and mixed on the ridges using spades and garden forks. This was done because the soil pH was less than 5.0. Thereafter, re-constructing of the ridges with spades and hoes was done to maintain the required shape when planting sweetpotato. Anonymous [9] recommended that in Swaziland, if soil pH is below 5.3, liming should be done. Soil acidity is the major problem in most agricultural soils especially the Middleveld and Highveld of Swaziland. The recommended rate farmers use in the Highveld and Middleved ecological zones of Swaziland is 1-2 tonnes/ha of dolomitic lime every 3-4 years. Agricultural lime is important because it can improve the soil pH, making nutrient elements more available to plants [10]. The sweetpotato variety planted was 'Kenya`; the jugo bean variety was UNISWA Red. Both sweetpotato and jugo bean were obtained from Malkerns Research Station. Both crops were planted on the same day (7 November 2009), and on top of ridges. Replacing of sweetpotato vines and jugo bean seeds that did not emerge was carried out during the first two weeks after planting (WAP). This was done to have a good establishment of the crops.

Fertilizer application

At planting, 350 kg/ha of mixed fertilizer, N:P:K, 2-3-2 (38) that also contained 0.5% Zinc, was applied to all plots; 50 kg/ha of single superphosphate was also applied to all plots, except where jugo bean only was grown. At six WAP, side dressing with 10 parts of urea (45% N) and 50 parts of muriate of potash (KCl, 60% K) was applied at a rate of 120 kg/ha [11], except where jugo bean only was grown. In all cases, the method of fertilizer application was banding and incorporation method [5].

Data collection and analysis

General management included weeding and monitoring for insect pests and diseases. At harvest, soil samples (0-15 cm depth) were collected from each plot and air-dried in the laboratory for four days. Also, 300 g of storage roots from the plots were washed in water, sliced into thin pieces to facilitate drying (80°C in a hot-air oven for four days). After drying, plant samples were ground in a mill and packaged in plastic bags. Thereafter, soil and plant samples were sent to a reputable commercial laboratory in the United States for chemical analysis using standard analytical methods [12]. Meteorological data were collected from Malkerns Research Station [13]. The data were analyzed using MSTAT-C version 2.0 [14] and mean comparisons were made using the F-protected least significant difference for separation [15], at 5% level of significance.

RESULTS

Meteorological information

Rainfall distribution and air temperatures are shown in Table 1. The distribution of rainfall varied over the months. A total of 1043 mm rainfall was received during the investigation. February 2010 recorded the least (89.5 mm) amount of rainfall whereas January 2010 recorded the highest (280.8 mm) amount of rainfall. Also, highest (28.2°C) temperatures were experienced in February 2010, whereas minimum (14.8°C) temperatures were recorded in November 2009.

Table 1: Mean temperature (°C) and total rainfall (mm) from October 2009 to April 2010.

Month and year	Mean monthly temperature (°C)			Total rainfall (mm)
	Maximum	Minimum	Mean	
November 2009	23.8	14.8	19.3	269.0
December 2009	27.3	17.0	22.2	140.3
January 2010	26.4	16.8	21.6	280.8
February 2010	28.2	18.6	23.4	89.5
March 2010	26.4	17.7	22.1	94.4
April 2010	24.8	15.2	20.0	169.0
Totals	156.9	100.1	128.5	1043
Means	26.2	16.7	21.4	173.8

Source: [13]

Nutrient concentrations in sweetpotato storage roots

Table 2 shows the concentrations of nutrients in storage roots of sweetpotato. Results showed significantly ($p < 0.05$) higher concentration of nitrogen (0.63 g/kg) and nitrate nitrogen (0.001-0.002 g/kg) were accumulated in jugo-bean-associated sweetpotato storage roots than in sole sweetpotato (N, 0.5 g/kg; nitrate N, 0.001-0.002 g/kg). Sweetpotato intercropped with 133,333 plants/ha of jugo bean had the lowest nitrogen concentration (0.45 g/kg), though this was not significantly different from the sole sweetpotato (0.5 g/kg). A significantly ($p < 0.05$) higher concentration of N (0.63 g/kg) was accumulated by sweetpotato storage roots when sweetpotato was intercropped with 33,333 plants/ha of jugo bean. Micronutrient and Al concentrations in storage roots did not significantly vary among the cropping systems.

Soil nutrient concentrations

Table 3 shows the concentrations of soil nutrients at harvest. Soil pH was most improved (from original soil pH value of 4.8) when jugo bean at 66,666 plants/ha was associated with sweetpotato (soil pH, 5.78); but there were no significant differences among the cropping systems (pH, 5.40-5.78). Available P in soil was significantly ($p < 0.05$) higher (62.50 mg/kg) when 66,666 plants/ha of jugo bean was interplanted through sweetpotato. The available P range was 17.25-62.50 mg/kg. The cropping system where 66,666 plants/ha of jugo bean was associated with sweetpotato seemed to have better soil improvement status, though the differences were not significantly different from the other crop combinations.

Table 2: Nutrient concentrations in sweetpotato storage roots under intercropping with jugo beans

Cropping system	Nutrient content in sweetpotato storage roots													
	(g/kg)								(mg/kg)					
	N	NO_3-N	S	P	K	Mg	Ca	Na	B	Zn	Mn	Fe	Cu	Al
Sole sweetpotato at 33,333 plants/ha	0.50a	0.001a	0.07b	0.14a	1.16a	0.08a	0.08a	0.06a	4.00a	11.25a	8.00a	52.00a	5.50a	50.75a
Sweetpotato + jugo bean - 66,666 plants/ha	0.56a	0.002b	0.06a	0.15a	0.93a	0.08a	0.09a	0.10a	2.53a	10.03a	5.53a	43.20a	5.33a	51.39a
Sweetpotato + jugo beans - 133,333 plants/ha	0.45a	0.001a	0.06a	0.14a	0.87a	0.09a	0.11b	0.11a	3.25a	10.00a	7.50a	47.25a	4.25a	52.50a
Sweetpotato + jugo beans - 33,333 plants/ha	0.63b	0.001a	0.07b	0.17a	0.94a	0.09a	0.09a	0.13b	4.00a	10.50a	6.75a	80.00a	5.25a	79.25a
Mean	0.52	0.001	0.06	0.15	0.97	0.08	0.09	0.10	3.44	10.44	6.94	55.61	5.08	58.47
Significance at 5% level	*	*	*	Ns	Ns	Ns	*	*	Ns	Ns	Ns	Ns	Ns	Ns

*, Significant at 5% level; Ns, Not significant
Numbers in the same column followed by the same letters are not significantly different according to the least significant difference test.

Table 3: Concentrations of soil mineral nutrients in jugo bean-associated cropping systems

Cropping sysem	Organic matter (g/kg)	(mg/kg)				Soil pH	CEC	Base saturation (%)			
		Available P	K	Mg	Ca			K	Mg	Ca	H
Sole sweetpotato at 33,333 plants/ha	4.30a	21.75a	55.50a	185.0a	487.50 a	5.73a	5.60a	2.75a	27.95a	41.13a	28.88a
Pure jugo bean at 66,666 plants/ha	4.30a	17.25a	74.75a	145.0a	337.50 a	5.40a	5.20a	3.83a	25.98a	33.20a	38.53a
Sweetpotato + jugo bean - 66,666 plants/ha	4.15a	62.50b	58.25a	188.8a	425.00 a	5.78a	5.35a	3.08a	29.10a	39.25a	28.55a
Sweetpotato + jugo beans -133,333 plants/ha	4.40a	21.75a	58.50a	165.0a	350.00 a	5.55a	4.78a	3.30a	27.28a	36.15a	31.95a
Sweetpotato + jugo beans -33,333 plants/ha	4.30a	30.8a	51.00a	157.5a	412.50 a	5.53a	5.30a	2.70a	25.13a	37.85a	34.30a
Mean	4.29	30.80	59.60	168.3	402.50	5.60	5.25	3.13	26.95	37.52	32.44
Significance	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Values in original soil	4.1	12.0	85.0	80.0	200.0	4.80	4.3	5.1	15.6	23.3	56.0

*, Significant at 5% level; Ns, Not significant
Numbers followed by the same letters in the same row are not significantly different according to the least significant difference test.

Table 4: Micronutrient and nitrogen concentration in soil planted to different populations of jugo bean

Cropping system	(mg/kg)						Total N (g/kg)
	S	Zn	Mn	Cu	B	Nitrate nitrogen	
Sole sweetpotato at 33,333 plants/ha	16.75a	3.75a	15.50a	1.20a	0.23a	4.50a	0.15a
Pure jugo bean at 66,666 plants/ha	21.00b	4.40a	10.25a	1.11a	0.20a	5.25a	0.15a
Sweetpotato + jugo bean - 66,666 plants/ha	11.50a	6.03a	13.50a	1.18a	0.23a	5.25a	0.15a
Sweetpotato + jugo beans -133,333 plants/ha	17.00a	3.60a	14.25a	1.13a	0.23a	5.50a	0.14a
Sweetpotato + jugo beans -33,333 plants/ha	14.75a	4.45a	9.50a	1.13a	0.20a	5.50a	0.14a
Mean	16.20	4.45	12.60	1.15	0.23	5.20	0.14
Significance at 5% level	*	Ns	Ns	Ns	Ns	Ns	Ns
Values in original soil	25.0	2.5	5.0	1.0	0.2	4.0	0.15

*, Significant at 5% level; Ns, Not significant
Numbers followed by the same letters in the same row are not significantly different according to the least significant difference test.

Table 5: Relationships between soil parameters and yield of sweetpotato.

Parameters	Organic matter	Phosphorus (P)	Potassium (K)	Soil pH	CEC[1]	Total nitrogen	Total storage root yield
Phosphorus	0.114						
Potassium	0.386	0.242					
Soil pH	- 0.242	- 0.204	- 0.725				
Cation exchange capacity	- 0.265	- 0.350	0.586	0.685**			
Total nitrogen	- 0.202	-0.241	0.064	0.171	0.129		
Storage root yield	- 0.051	0.127	0.179	0.008	0.079	0.141	
Marketable tubers	0.162	0.193	0.014	0.316	0.609 *	0.058	0.256

**, Significant at $p < 0.01$; *, Significant at $p < 0.05$
[1]Cation exchange capacity

Table 6: Total storage root yields (tonnes/ha) of sweetpotato under jugo bean intercropping

Cropping system	Yield (tonnes/ha)
Sole sweetpotato at 33,333 plants/ha	42.89b
Sweetpotato intercropped with jugo bean at 66,666 plants/ha	36.36 a
Sweetpotato intercropped with jugo bean at 133,333 plants/ha	31.78a
Sweetpotato intercropped with jugo bean at 33,333 plants/ha	33.48a
Mean	36.12
Significance	*

*, Significant at 5% level
Numbers followed by the same letters in the same row are not significantly different according to the least significant difference test.

Table 4 shows the micronutrient and nitrogen concentrations in soil planted to different populations of jugo bean, with or without sweetpotato. Other than sulfur concentrations (11.50-21.00 mg/kg), there were no significant differences in micronutrient concentrations among the cropping systems. Table 5 shows the relationships between soil parameters and yield of sweetpotato. Soil pH was positively and significantly ($p < 0.001$) correlated to cation exchange capacity (r = 0.685; R^2 = 46.92%). Total nitrogen was positively but not significantly correlated to storage root yield (r = 0.141; R^2 =1.98%), indicating that about 2% increase in storage root yield could be associated with increased total soil nitrogen.

Total storage roots yields

As seen in Table 6, the sole sweetpotato had a significantly ($p < 0.05$) higher (42.9 tonnes/ha) yield, followed by the sweetpotato associated with jugo bean at 66,666 plants/ha (36.4 tonnes/ha). The lowest yield (31.78 tonnes/ha) was attained by the intercrop of sweetpotato and jugo bean at 133,333 plants/ha.

Discussion

Meteorological information

Rainfall is the major limiting factor in the growth and production of crops worldwide [16]. Adequate moisture is critical for plants, especially during germination and fruit development. Many nations have constructed irrigation systems to pump water from rivers, lakes, and aquifers. Sangakkara [17] from his experiment in Sri Lanka, reported that planting sweetpotato with the onset of rains in October produced the highest yields.

Nutrient concentrations in sweetpotato storage roots

Ossom and Rhykerd [18] recorded no significant differences of mineral concentrations in the storage roots of sweetpotato among the cropping systems. Nevertheless, among the macronutrients, Mg, Ca, and S were positively correlated to tuber yield, whereas the other mineral nutrients negatively correlated to the tuber yield. Norman [19] stressed that crop yields could be adversely affected by high concentrations of aluminum. Soil acidity is the major problem in most agricultural soils, especially in the Middleveld and Highveld agro-ecological zones of Swaziland (Dr. G.N. Shongwe, University of Swaziland, personal communication, August 2009).

Soil nutrient concentrations

LSU [20] advised that liming could reduce 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 jugo bean. Low pH (5.0-5.5) is desirable to reducing tuber rot in the soil [21].

Total storage root yields

Our results of monocropped sweetpotato yielding higher than the intercropped plant were in agreement with previous research findings [22, 23, 24] that monocrops usually yield higher than intercrops under similar levels of management practices. Higher yields of sole sweetpotato than in mixtures might have been caused by less plant competition for soil nutrients, water, and sunlight, as tuber formation was taking place. Nitrogen fixation in the root nodules of grain legumes is usually the reason given for increased soil fertility when grain legumes are part of a cropping system. Thus, it is thought that jugo bean contributed to improve soil fertility in this investigation.

Conclusion and recommendation

This investigation established that there were benefits of improved mineral nutrient levels in tubers and soil, depending on the plant population of jugo bean that was associated with sweetpotato. It is recommended that for best nutrient benefits from storage roots and soil, small-scale farmers should intercrop sweetpotato and jugo bean at 66,666 plants/ha. More investigations in this area are also recommended.

References

1. van Wolfswinkel, 2009.van Wolfswinkel, M., 2010. Intercropping of annual food crops. http:www.agromisa.org/agrobriefs/AB-4%20Intercropping.pdf. 24/01/10.
2. Anonymous, 2009. Fundamentals of Sustainable Agriculture. http://attar.ncat.org/apub/ipm.html. 05/08/09.
3. van Wyk, B. E. and Gericke, N., 2000. “Peoples plants” A guide to useful plants of Southern Africa. Briza Publications, Pretoria, South Africa.
4. Fugile, K. O., 2007. Priorities for sweetpotato research in developing countries: Results of a survey. American society for horticulture. Washington D.C., U.S.A.
5. Ossom, E. M. and Rhykerd, R. L., 2008. Effects of lime on soil and tuber chemical properties and yield of

sweetpotato [*Ipomoea batatas* (L.) Lam.] in Swaziland. *American-Eurasian Journal of Agronomy* 1 (1): 01-05.

6. Edwards, J. H., Thurlow, D. L. and Eason, J. T., 1988. Influence of tillage and crop rotation on yields of corn, soybean and wheat. *Agronomy Journal* 80: 76-80.
7. Hoshikawa, K., 1991. Significance of legume crops in improving productivity and stability of cropping systems. pp. 173-181. *In*: Phosphorus nutrition of grain legumes in the semi-arid tropics. Johanson, C., Lee, K. K.,and Sahrwat, K. L. (eds.). International Crop Research Institute for Semi-Arid tropics (ICRISAT), India.
8. Ossom, E. M., Nxumalo, H. M. and Rhykerd, R. L., 2006. Contributions of grain legume companion crops to sweetpotato [*Ipomoea batatas* (L.) Lam.] ecological properties and yield in Swaziland. *UNISW Research J. Agric., Sci., & Tech.* 9 (2): 149-158.
9. Anonymous, 1991. Field crops production. pp. 12-14. *In*: Pitts, C. W. (Ed.). Farmer's handbook. Ministry of Agriculture and Co-operatives, Mbabane, Swaziland.
10. Thomas, B., Flurry, F., Maxwell, D., Rollins, J. and Ladd, J. C., 2004. Important facts to know about agricultural lime. http://ltsed.tx.nacdnct.org/fact%20sheet%20lime.htm. 12/09/09.
11. Edje, O. T. and Ossom, E. M., 2009. Crop Science Handbook. Blue Moon Printers, Manzini, Swaziland.
12. Association of Official Analytical Chemists, AOAC., 1990. Official methods of analysis, 15th edn., Arlington, Virginia, U.S.A.
13. Malkerns Research Station, 2010. Unpublished meteorological data, Malkerns Research Station, Malkerns, Swaziland.
14. Nissen, O., 1983. MSTAT-C – A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University. East Lansing, Michigan, U.S.A.
15. Steel, R. G. D., Torrie, J. H., and Dickey, D. A., 1997. Principles and procedures of statistics: A biometric approach, 3rd edn. McGraw-Hill, New York, U.S.A.
16. Pimentel, D., 1993. Climate changes and food supply. *Forum for Applied Research and Public Policy* 8 (4): 54-60.
17. Sangakkara, U. R., 2008. Response of sweetpotato (*Ipomoea batatas* L.) to different planting times. *Journal of Agronomy and Crop Science*. 172: 113 – 118.
18. Ossom, E. M. and Rhykerd, R. L., 2008. Implications of associating sweetpotato [*Ipomoea batatas* (L.) Lam.] with different groundnut (*Arachis hypogaea* L.) populations on tuber yield and soil and tuber chemical properties. *American-Eurasian Journal of Agriculture and Environmental Sciences* 3(1): 63-69.
19. Norman, J. C., 1992. Tropical Vegetable Crops. Arthur H. Stockwell Ltd., London, UK.
20. LSU AgCenter Communications, 2000. Sweet potato production best management practices. http://www.lsuagcenter.com/NR/rdonlyres/535E3804-6E27-4F40-8299-305176E1A37C/3125/pub2832SweetPotatoBMP4.pdf . 08/16/2006.
21. Dainello, F. J., 2003. Sweetpotato. http://aggiehorticulture.tamu.edu/extension/vegetable/cropguides/sweetpotato.html. 01/04/10.
22. Ossom, E. M., Kuhlase L. M., and Rhykerd R. L., 2009. Effects of plant population on yield components and yield of intercropped sweetpotato [*Ipomoea batatas* (L.) Lam.] and groundnut (*Arachis hypogaea* L.) *American-Eurasian Journal of Agronomy* 2 (1): 01-06.
23. Sullivan, P., 2003. Intercropping principles and production practices. http://www. attra-pub/PDF/intercrop.pdf. 11/10/09.
24. Kuhlase, L. M., Ossom, E. M., and Rhykerd, R. L., 2008. Effects of plant population on morphological and physiological parameters of intercropped sweetpotato [*Ipomoea batatas* (L.) Lam.] and groundnut (*Arachis hypogaea* L.). *Academic Journal of Plant Sciences* 2 (1): 16-24.