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Response of the African nightshade to phosphate fertilizer application in Western Kenya

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ABSTRACT

Although the African nightshade is increasingly becoming an important vegetable in Kenya, the consumer demand has not been met due to its low yields occasioned by lack of fertilizer use. The general belief is that traditional vegetables are adapted to low fertility. This is despite the fact that phosphorus limits crop production in many parts of western Kenya. The objective of this study was therefore to investigate the effect of phosphorus fertilizer application rate on growth and leaf yields of three types of the African nightshade; Solanum Scabrum (SS), solanum villosum subsp villosum (SVV) and solanum villosum subsp miniatum (SVM). The treatments consisted of four rates of phosphorus (0, 20, 40 and 60 Kg P ha^{-1}) in a factorial combination with three types of the African Nightshade, SS, SVV and SVM. To assess the effect of treatments on plant growth, eight randomly selected plants in each plot were tagged and their heights, number of leaves per plant, leaf area and leaf yields determined. The available soil P levels were also determined. There was a general increase in available soil P with increasing P rate. Similarly the plant heights, leaf numbers, leaf area and leaf yields increased with increasing P rate. The leaf yields ranged from 2.38 t ha^{-1} (SVM with 0 P) to 13.35 t ha^{-1} (SS with 60 kg P ha^{-1}) in the first season and from 2.01 t ha^{-1} (SVV with 0 P) to 8.67 t ha^{-1} (SVM with 60 kg p ha^{-1}) in the second season. Among the genotypes, SS had the highest leaf yields, at same P levels, followed by SVV and SVM respectively, except at the P rate of 40 kg ha^{-1} where the difference between SVV and SVM was not significant in the first season. However, SVM had the highest mean leaf yields in the second season followed by SS and SVV respectively. We conclude that although P fertilization was beneficial to all the genotypes, there is need to target it carefully because the response appeared to be season specific. When there is adequate rainfall, SS appears to be a good choice but under low rainfall conditions, SVM could be more attractive.

INTRODUCTION

The marketing and consumption of indigenous vegetables in Kenya have steadily changed over the years. In the earlier year times, they were eaten by lower socio-economic groups and hence were grown mainly for subsistence [1] although limited amounts were also sold at the farm level and local markets. However, after it was demonstrated that these vegetables have nutritional and medicinal value [2], they gained acceptance among the relatively wealthy Kenyans and are, therefore, now are found in the formal markets such as supermarkets and the municipal markets where medium and higher socio-economic classes shop. This shifting consumer taste for indigenous vegetables therefore offers unique opportunities to diversify farming systems, ensure food security and alleviate poverty, while increasing income and improving human health in Kenya.

Among these indigenous vegetables, the African nightshade is increasingly becoming important and was the second most preferred vegetable among the main communities inhabiting western Kenya according to a survey by [3]. However, the area under its cultivation is still low because it is traditionally produced at subsistence level where it is grown in home gardens around homestead or collected from the wild [4]. This coupled with the low leaf yields, ranging between 1-3 tons ha^{-1}, have conspired to ensure that the consumer demand for the African nightshade is not satisfied. The low productivity has been attributed to several factors that include environmental and agronomic ones. In western Kenya, soil fertility depletion, particularly of N and P, was identified as a fundamental root cause of declining crop productivity [5]. The need to replenish these nutrients in food production has thus been recognized for a long time. However, the general belief that traditional vegetables are adapted to low fertility has led to low or no usage of fertilizers on these crops. Furthermore, there is paucity of information on fertilizer recommendations for these vegetables as they have attracted little research attention. It is only recently that some workers in Kenya have taken keen interest in this research area. Focus has mainly been on nitrogen with several workers (e.g. [6], [7] and [8]) demonstrating response to N application in Kenya. However, in many parts of Kenya, P is also a major limiting nutrient and response to N and other nutrients is usually inhibited unless P limitations are overcome. The relative leaf growth rate is one of the most sensitive parameters to phosphorus deficiency and it affects the photosynthetic rate per unit area [9] and hence the yield of vegetables. The objective of this study was therefore to contribute to our understanding of the effect of fertilizers on indigenous leafy vegetables by determining the effect of phosphorus fertilizer application rate on growth and leaf yields of three African nightshade types; *Solanum Scabrum*, *solanum villosum* subsp *villosum and solanum villosum* subsp *miniatum*.

MATERIALS AND METHODS

Site description

The study was conducted in Moiben location, Uasin Gishu County of Kenya. The site lies at an altitude of 2163 m above sea level and is within latitude 0^0 49`0 N and longitude $35^0$ 49`60 E. The average rainfall is 900 - 1200 mm per annum distributed mainly between the months of March and December with two distinct peaks in May and October. The temperatures range between 8.4^0C and 26.1^0C. The soils at the site are rhodic ferralsols which are acidic, moderately deep and well drained [10].

Experimental layout and management

The experiments were conducted over two cropping seasons; the long rains of May to August 2010 and short rains season of August to December 2010. A randomized complete block design with three replications was used with each experimental plot measuring 2 m x 3 m. The treatments consisted of four rates of phosphorus (0, 20, 40 and 60 Kg P ha^{-1}) in a factorial combination with three types of the African Nightshade: *Solanum scabrum*,(SS) *Solanum villosum* subsp *villosum* (SVV) and *Solanum villosum* subsp *miniatum* (SVM). The soils were worked out to a fine tilth as recommended for small seeds. Appropriate rates of phosphate fertilizer were broadcasted evenly on the respective plots at the time of planting. Calcium ammonium nitrate (26% N) at 60 Kg N ha^{-1} and Muriate of potash (60% K_2O) at 30 Kg K ha^{-1} were uniformly broadcasted and incorporated into the soil in each of the two seasons. The intention was to supply sufficient amounts of N and K to ensure that the two nutrients were not limiting factors on plant growth when studying the P effects. Four seeds of the respective African nightshade types were directly sown at a spacing of 30 cm x 30 cm on the 19^{th} of May 2010 in the first season and 13^{th} of August 2010 in the second season. The fields were kept weed free by manually weeding using a hoe. Insect pests and diseases were controlled using appropriate pesticides. Thinning was done at four weeks after sowing (WAS) while top dressing with the N fertilizer was done two week later. In each of the two seasons, soil samples were collected (0–0.15 m depth) at 6 WAS from each plot and analyzed for available P using the Olsen method as described by [11].

To assess the effect of treatments on plant growth, eight randomly selected plants in each plot were tagged and their heights, determined starting from six WAS and then weekly thereafter until harvesting. The number of leaves on the main stem and leaf area were determined at 7 WAS. The leaf area was calculated using the formula, leaf area= L x W x K, where L is leaf length, W is leaf width and K is a multiplying factor obtained from the ratio of leaf area as traced on a graph paper to the calculated leaf area (length × width) [12]. Plant height was measured from the ground level up to the apex of the youngest leaf. Harvesting was done at 9 WAS by picking all the leaves and tender shoots and their fresh weight taken and recorded immediately. All data were subjected to Analysis of variance (ANOVA) using the Genstat statistical package [13] and the means separated using standard errors of differences of means (SED) at $p \leq 0.05$.

RESULTS AND DISCUSSION

Initial soil properties and available phosphorus.

Selected soil properties at the experimental site are shown in Table 1. The soil was acidic (pH < 5.5) and low in total soil N (< 0.2%), organic carbon (< 2%) and available phosphorus (< 10 mg kg^{-1}) all which were below the critical levels (shown in brackets) prescribed by [10] thus signifying the general infertility of this soil. The mean available P levels were 6.4 and 9.6 mg P kg^{-1} for the treatments with no P application in the first and second seasons respectively (Table 1). Such low P Levels are to be expected in this type of soil (Ferralsol) which is inherently low in P and also high in P-fixation [5]. There was no significant interaction between type of black nightshade and P rate on available soil P but the effect of P rate was highly significant (p < 0.001). The increase in available phosphorus with increasing phosphorus rates in both seasons can be attributed to the fact that phosphorus sorption by soil decreases as more P is applied to soil [14] thus maintaining a high P availability.

Table 1. Selected initial soil properties at the experimental site

Parameter	pH	% N	Olsen P (mg kg^{-1})	% Organic	% Sand	% Clay	% Silt
Value	5.47	0.11	6.00	1.82	66%	12	22

Table 2. Effect of phosphorus rate and type of *Solanum* on Olsen P in mg P kg^{-1} at six weeks after planting

P rate (kg ha-^{1})	Season one				Season two			
	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	5.3	5.1	6.9	5.7	7.7	8.9	9.5	8.7
20	7.1	5.3	8.8	7.1	11.3	11.0	10.1	10.8
40	10.5	6.9	9.3	8.9	17.4	14.6	19.0	17.0
60	14.2	13.9	15.2	14.4	18.0	22. 0	18.1	18.5
Means	9.3	7.8	10.0	9.0	13.6	14.1	14.8	14.0
SED								
P rate	2.0				2.2			
Cultivar	NS				NS			
SED P rate X Cultivar	NS				NS			

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum
SVM= Solanum villosum subsp miniatum
SED = Standard error of difference of means

Effect of phosphorus rate and type of black nightshade on growth parameters

Plant height

The data for plant heights for the first and second seasons are presented in Tables 4 and 5 respectively. There was no significant interaction between cultivar and the phosphorus rate on plant height in both seasons indicating that the genotypes responded similarly to P application in terms of plant height. The effect of P rate and type of black nightshade were however significant with the plant heights generally increasing with an increase in P rates within each type of black nightshade at all sampling times in both seasons. This response is to be expected in a P-deficient soil such as the one in the present study. Among the genotypes, at the same P rate, the plant heights in the first season generally followed the order; SS > SVV > SS in the first 52 days but in subsequent sampling times, the order changed to SVV > SS > SSM. In the second season, the trend was SVV > SS > SSM at all sampling times. SS had taller plants in the absence of P but SVV responded more strongly to P than SS. Given that the genotypes responded similarly to P application, the differences in their heights at similar P rates can be attributed to their inherent morphological characteristics.

Table 3 Effect of phosphorus rate and type of solanum on plant height in the first season (cm)

P rate (kg ha^{-1})	Time of sampling: 45 DAS				52 DAS				59 DAS				66 DAS				73 DAS			
	Type of black nightshade: SS	SVV	SVM	Means	SS	SVM	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	3.9	4.3	2.8	3.7	6.7	8.0	5.0	6.6	12.6	14.8	8.6	12.0	20.8	23.3	12.6	18.9	32.1	36.8	25.3	31.4
20	5.5	4.4	3.4	4.4	13.7	8.3	10.3	10.3	20.3	16.9	14.9	17.4	30.2	25.2	22.9	26.1	40.8	38.5	37.0	38.8
40	6.3	6.2	5.0	5.8	12.7	9.9	11.8	11.8	22.6	24.5	16.8	21.3	35.3	39.5	23.5	32.8	48.0	57.5	40.0	48.5
60	7.2	6.5	5.0	6.2	11.8	13.7	11.3	12.3	17.8	25.9	20.4	21.4	30.1	37.9	29.6	32.5	43.4	48.9	47.8	46.7
Means	5.7	5.4	4.0	5.0	11.2	10.8	8.6	10.2	18.3	20.5	15.2	18.0	29.1	31.5	22.2	27.6	41.1	45.4	37.5	41.3
SED P rate	0.41				1.18				1.58				2.11				3.11			
SED Cultivar	0.35				1.02				1.37				1.83				2.70			
SED P rate X Cultivar	NS				NS				NS				NS				NS			

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum, SVM= Solanum villosum subsp miniatum. SED = Standard error of difference of means, NS = Not significant, DAS = Days after sowing.

Table 4: Effect of phosphorus rate and type of solanum on plant height, season two height (cm)

	Time of measurement: 45 DAS				52 DAS				59 DAS				66 DAS				73 DAS			
P rate (kg ha^{-1})	Type of black nightshade: SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	2.3	2.1	1.2	1.8	3.7	3.1	2.0	2.9	7.6	5.6	3.6	5.6	9.8	9.0	5.3	8.1	17.5	16.2	8.1	14.0
20	2.4	2.7	2.4	2.5	4.1	4.4	4.1	4.2	8.0	6.8	10.4	8.4	11.8	12.7	10.2	11.5	19.4	20.4	17.8	19.2
40	3.5	4.5	3.6	3.9	6.0	7.5	6.6	6.7	9.7	15.1	12.3	12.4	16.6	22.9	17.0	18.9	26.3	32.5	39.8	32.8
60	3.9	4.2	3.7	3.9	7.6	7.2	6.1	7.0	11.7	13.5	11.6	12.3	18.1	21.8	17.8	19.2	28.6	29.8	25.2	27.8
Means	3.0	3.4	2.7	3.0	5.3	5.5	4.7	5.2	9.2	10.2	9.5	9.7	14.1	16.6	12.6	14.4	23.0	24.7	22.7	23.5
SED P rate	0.38				0.64				1.57				1.66				4.66			
SED Cultivar	NS				NS				NS				1.43				NS			
SED P rate X Cultivar	NS				NS				NS				NS				NS			

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum, SVM= Solanum villosum subsp miniatum. SED = Standard error of difference of means, NS = Not significant, DAS = Days after sowing.

Effect of phosphorus rate and type of solanum on total number of leaves and leaf area

The effect of the rate of phosphorus application on leaf number varied with the type of black nightshade, sampling time and season (Tables 5 and 6). In season one, there was an increase in the number of leaves at all rates of P application for all the genotypes although statistical significance was observed at the P rates of 40 and 60 kg ha^{-1} but not 20 kg ha^{-1} at all the three sampling times. The highest response in season one was obtained at the P rate of 60 kg ha^{-1} for all the genotypes at all sampling times although the differences between 40 and 60 kg ha^{-1} were not always statistically significant. The number of leaves for SS was fewer in the second season than the first. However, for SVV and SVM the number of leaves was fewer in the second than first season only when P was not applied but due to the strong response to P application, the treatments with P rates of 20, 40 and 60 kg ha^{-1} P had more leaves than similar leaf numbers as in the first season. This was more pronounced for SVM. Among the genotypes, SS had the least number of leaves while SVM and SVV leaf numbers were not significantly different. The SS plants tended to have fewer but larger leaves than the SVV and SVM attributed mainly to genotypic differences.

Table 5: Effect of phosphorus rate and type of solanum on total number of leaves in a plant, season one

P rate (kg ha^{-1})	59 DAS				66 DAS				73 DAS			
	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	13	32	44	29	28	69	75	57	72	110	119	103
20	23	44	65	45	35	78	86	66	74	130	127	119
40	25	53	61	46	39	91	81	70	94	147	129	129
60	27	69	74	57	43	139	123	102	84	198	154	154
Means	22	49	61	44	36	94	91	74	81	146	126	126
SED												
P rate		6				11				14		
Genotype		6				9				12		
SED P rate X Genotype		NS				NS				NS		

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum; SVM= Solanum villosum subsp miniatum
SED = Standard error of difference of means, NS = Not significant, DAS = Days after sowing.

Table 6: Effect of phosphorus rate and genotype of solanum on total number of leaves in a plant, season two

P rate (kg ha^{-1})	59 DAS				66 DAS				73 DAS			
	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	18	23	15	19	32	34	32	33	54	59	67	60
20	20	40	41	34	27	75	87	63	55	121	163	113
40	20	52	87	53	40	119	154	104	74	231	249	185
60	24	49	77	50	42	118	122	94	69	177	245	164
Means	21	41	55	39	35	87	99	74	63	147	181	130
SED												
P rate	7				14				19			
SED Genotype	6				12				16			
SED P rate X Genotype	12				NS				32			

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum; SVM= Solanum villosum subsp miniatum
SED = Standard error of difference of means, NS = Not significant, DAS = Days after sowing

Table 7: Effect of Phosphorus rate and variety of solanum on leaf area in cm^2 leaf area

P rate (kg ha^{-1})	Season one								Season two							
	52 DAS				59 DAS				52 DAS				59 DAS			
	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	15.7	8.4	6.4	10.2	31.5	11.6	8.8	17.3	7.5	3.4	0.7	3.9	22.9	6.6	5.1	11.5
20	27.7	8.7	11.0	15.8	46.9	11.3	12.8	23.7	9.2	4.2	3.9	6.9	26.0	10.6	9.5	15.4
40	31.9	13.0	11.8	19.3	65.3	16.2	13.5	31.6	12.7	6.6	6.1	7.5	28.7	17.2	17.8	21.3
60	33.2	14.1	13.4	19.8	52.9	17.5	15.6	28.7	26.3	7.4	6.8	13.2	46.3	15.4	15.7	25.8
Means	27.1	11.1	10.7	16.3	49.2	14.1	12.7	25.3	13.9	5.4	4.4	7.9	40.0	12.5	12.0	18.5
SED																
P rate		1.65				4.01				1.46				2.76		
Genotype		1.43				3.47				1.27				2.39		
P rate X Genotype		NS				NS				NS				NS		

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum; SVM= Solanum villosum subsp miniatum;
SED = Standard error of difference of means, NS = Not significant, DAS = Days after sowing

The mean leaf areas in season one were greater than those of season two (Table 7). There was no significant phosphorus rate by cultivar interaction on the leaf area in both seasons. However, the P rate and cultivar effects on leaf area were highly ($p < 0.01$) significant. Averaged across all P rates, SS had the highest leaf area followed by SVV and SVM in both seasons. As would be expected, the leaf area in each of the seasons increased from 59 days after sowing to 62 days due expansion of leaves as a result of growth. The response to P application within each genotype was very similar to that of number of leaves with increasing P rate resulting in higher leaf area.

Effect of phosphorus rate and cultivar on fresh leaf yields

There was a significant interaction between cultivar and the phosphorus rate on fresh leaf yields in both seasons. The effect of phosphorus rate and cultivar were also highly significant. The fresh leaf yield increased with increasing phosphorus rate in both seasons (Table 8) thus confirming that P was limiting in this soil as reflected in the soil test P values (Tables 1 and 2). Among the genotypes, SS had the highest leaf yields, at same P levels, followed by SVV and SVM respectively, except at the P rate of 40 kg ha^{-1} where the difference between SVV and SVM was not significant in the first season. However, SVM had the highest mean yields in the second season followed by SS and SVV respectively. The higher mean yields in season one than season two observed for all the genotypes is attributed to mainly the better rainfall in the first season (400 mm) compared to the second (259 mm). The lower rains in the second season are likely to have reduced the ability of these genotypes to fully utilize the applied P. This is confirmed by the lower response to P application in the second compared to the first for the two genotypes. For example, the highest response relative to the control with no P application for SS in the first and second seasons was 335% and 84% respectively while that of SVV was 345% and 285% respectively. [15] have similarly demonstrated that SS seedlings are very sensitive to drought since the stressed seedlings exhibited about 97% reduction in leaf area, 84% reduction in shoot height, 88% reduction in shoot dry weight relative to control plants. However, the converse was true for SVM whose mean yields were comparable to those of season one, suggesting that it is more drought tolerant than the other two types of black nightshades used in this study and was thus able to strongly respond to P especially at the higher rates even under low rainfall where the increase in yield over the control was 312% in the second. Despite the lower yields in the second season, P fertilization was still beneficial to all the genotypes. This reinforces other studies that have reported that P nutrition under water deficits increase drought resistance and improve growth and yield of plants [16]. Presumably, increased root growth due to P application would lead to a greater volume of soil explored and hence a greater potential reservoir of soil water. It is also possible that P enables the plant to better withstand drought conditions due to its role in energy storage and protein formation [17].

Table 8. Effect of Phosphorus rate and variety of the black African nightshade on fresh leaf yield (t ha^{-1})

P rate kg (ha^{-1})	Season one				Season two			
	SS	SVV	SVM	Means	SS	SVV	SVM	Means
0	3.07	2.48	2.38	2.64	3.69	2.01	2.10	2.60
20	7.93	6.42	5.50	6.62	4.91	4.52	5.86	5.10
40	11.22	7.38	7.49	8.70	5.17	4.91	7.15	5.74
60	13.35	11.03	9.16	11.18	6.79	7.70	8.67	7.72
Means	8.89	6.83	6.13	7.28	5.14	4.79	5.95	5.29
SED								
P rate	0.45				0.54			
Cultivar	0.39				0.47			
P rate x cultivar	0.77				0.93			

SS= Solanum scabrum, SVV= Solanum villosum subsp villosum, SVM= Solanum villosum subsp miniatum., SED = Standard error of difference of means.

CONCLUSION

There was a general increase in available soil P with increasing P rate. Similarly the plant heights, leaf numbers, leaf area and leaf yields increased with increasing P rate although the differences between 40 and 60 kg P ha^{-1} were not always significant. We conclude that although P fertilization was beneficial to all the genotypes, there is need to target it carefully because the response appeared to be season specific. When there is adequate rainfall, SS appears to be a good choice but under low rainfall conditions, SVM could be more attractive. Ultimately the choice of the rate of fertilizer P and type of nightshade to be planted should be based on economic considerations.

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REFERENCES

[1] C. M. Onyango, J.K. Imungi, L.O. Mose, J. Habinson and O. Kooten. *Africa Crop Science Conference Proceedings*, **2009**, 9: 767 – 772. African Crop Science Society.
[2] R.R. Schippers, Chatham, UK. Natural Resources Institute /ACP-EU Technical Centre for Agricultural and rural Cooperation. **2002.**
[3] M.O. Abukutsa-Onyango. *African Journal of Food Agriculture Nutrition and Development.* 7:1-15. **2007.**
[4] D.A. Fontem and R.R. Schippers, *Solanum scabrum* Mill. In: G.J.H. Grubben and O.A. Denton, (Editors). PROTA 2: Vegetables/Legumes. PROTA. Wageningen, Netherlands. **2004.**
[5] P.A. Sanchez, K.D. Shepherd, M..J. Soule; F.M. Place, R.J. Buresh, A.M. Izac, A.U. Mokwunye, F.R. Kwesiga, C.G. Nderitu, and P.L. Woomer. In: Buresh R.J., P.A. Sanchez, and F. Calhoun (eds.). Replenishing soil fertility in Africa. SSSA special publication no. 51. (Madison. Wisconsin. **1997**). 1-46.
[6] M.O. Abukutsa-Onyango & K. Karimi: *African Crop Science Conference Proceedings*, **2005**. 7:1237-1240.
[7] P.W. Masinde, J.M. Wesonga, C.O. Ojiewo, S.G. Agong and M. Masuda. *Dynamic soil, Dynamic Plant.* **2009,** 3:36-47.
[8] N.K. Rop, T.M. Mutui and E. Kiprop. *Afr. J. Hort. Sci*. **2012,** 6:111-117.
[9] I M. Rao. The role of phosphorus in photosynthesis. *In*: Pessarakli M. Handbook of Photosynthesis. New York: Marcel Dekker, **1996**: 173-194.
[10] R. Jaetzold and H. Schmidt. Farm management handbook of Kenya Vol. 2. Natural conditions and Farm management information. Part A: Western Kenya, Ministry of Agriculture. Nairobi, Kenya, **1982.**
[11] J.R. Okalebo, K.W Gathua and P.L Woomer. Laboratory methods in soil and plant analysis: A working manual. Second edition. TSBF-CIAT and SACRED Africa, Nairobi, Kenya. **2002.**
[12] J. Repkova , M. Brestic and K. Olsovoka. *Plant and soil environment*, **2009**, 55:551-557.
[13] Genstat. Genstat Release 8.1 for windows Lawes Agricultural Trust, Rothamstead Experimental Station, UK. **2005.**
[14] N.J. Barrow, M.D.A. Bolland and D.G. Allen.. *Aust J Soil Res.* **1998**, 36:359–372.
[15] J. Muthomi and D.M. Musyimi. *ARPN Journal of Agricultural and Biological Science*. **2009,** 4:24-31.
[16] V.G. Uarrota. *Journal of Agronomy*, **2010**, 9: 87-91.
[17] C.A. Jones, J.S. Jacobsen and J.M. Wraith. In: proceedings of Western Nutrient Management Conference. Salt Lake City, UT. **2003,** pp 88-93.