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Research Article

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# Potassium Nutrition: Towards sustainable and profitable production of Vegetable African Nightshades (*Solanum* L. Section *Solanum*) in Western Kenya

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**ABSTRACT**

*Vegetable African nightshades (Solanum L. Section Solanum) are important in food and financial security. Their yields are limited by low soil fertility. Effect of varied rates of potassium on performance and profitability of these vegetables was determined in a 2 x 4 x 4 factorial experiment (RCBD) conducted at Malava and Bukura areas in Western Kenya. The main factors were site (two agro ecological zones), genotype and potassium. Each of four species representing genotype; Solanum villosum subsp. Villosum, Solanum villosum Miller subsp. Miniatum, Solanum scabrum Miller and Solanum sarrachoides Sendtner received 0, 33, 66 and 99 kg K ha$^{-1}$ (KCl 60 % K) hence sixteen treatment combinations replicated three times per site. Low soil exchangeable K and organic carbon were found in Bukura (0.1 Cmol K kg$^{-1}$) and Malava (0.2 Cmol K kg$^{-1}$). Genotype interacted significantly ($P \le 0.001$) with potassium in affecting fresh leaf yields. Overall, mean yields of Solanum villosum subsp. Villosum (4.89 tons ha$^{-1}$), Solanum villosum Miller subsp. Miniatum, (4.58 tons ha$^{-1}$) and Solanum scabrum Miller (11.46 tons ha$^{-1}$) receiving 66 kg K ha$^{-1}$ were significantly higher ($P \le 0.05$) than control (3.88, 3.04 and 5.27 tons ha$^{-1}$ respectively). Solanum scabrum Miller had higher Benefit/Cost ratios (61.16, 53.55) at 33 kg K ha$^{-1}$ compared to Solanum villosum subsp. Villosum (7.18, 9.57) and Solanum villosum Miller subsp. Miniatum (10.93, 2.75) in Malava and Bukura respectively. Solanum sarrachoides Sendtner had low Benefit/Cost ratios (-5.46 to 1.54). Effect of manure and inorganic K sources on the yield of vegetable African nightshades should be investigated.*

**Key words:** Potassium nutrition, vegetable African nightshade species, leaf yield, profitability.

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## INTRODUCTION

Vegetable African nightshades are important in food security, nutrition and income generation. Farmers in Kenya realize very low yields from vegetable African nightshades, ranging between 1 to 3 tons ha$^{-1}$ which is far below the optimal levels of 20-40 tons ha$^{-1}$ [1]. This is caused by poor soil fertility; low levels of phosphorus, potassium, calcium and organic carbon in the soil among other factors [2].

Previous work has elucidated the role of nitrogen and phosphorus on the yield and quality of vegetable African nightshades [3, 4, 2]. However, supply of nitrogen and phosphorus to crops should be balanced with potassium for optimum yields [5]. Potassium deficiency has been reported to limit crop yields in some parts of western Kenya, like Vihiga, Mumias and Kakamega [6]. Fifty three percent of farmers in these areas use organic manures to improve production of vegetable African nightshades [7]. Organic manures have significant levels of potassium [2] and when combined with inorganic sources of nitrogen and phosphorus, the yield of vegetable African nightshades is improved compared to the use of inorganic fertilizers alone [3]. However there is no information on the effect of potassium on growth and yield of vegetable African nightshades.

Species of vegetable African nightshade vary in their growth, leaf yield and nutritive quality [8, 9]. The common species grown in Kenya are: *Solanum villosum* subsp. *Villosum* (finely lobed dentate leaf margins and mature berries are orange dull in colour), *Solanum villosum* Miller subsp. *Miniatum* (entire, sinuate, sinuate-dented or dentate leaf margins and mature berries are orange dull in colour) *Solanum scabrum* Miller (entire to sinuate leaf margins and mature berries are dark purplish black in colour) and *Solanum sarrachoides* Sendtner (Mature berries are light green in colour with clearly lobed dentate leaf margins which are densely pubescent) [10]. Response of these species of vegetable African nightshade to potassium has not been established. The aim of this study was therefore to determine the effect of varied rates of potassium on the growth, leaf yield and profitability of species of vegetable African nightshade (*Solanum* L. Section *Solanum*).

## EXPERIMENTAL SECTION

On farm experiments were setup in two sites located in Kakamega district, western province of Kenya during the long rain season of April to June 2007. Malava (North Kabras location), LM 2 agro-ecological zone [11] with Ferrallo-orthic Acrisols (FAO/ UNESCO) soils. Bukura, LM 1 agro-ecological zone [11] with soils classified as Rhodic to orthic Ferralsols (FAO/ UNESCO).

### Soil sampling and analysis

Ten soil samples were taken randomly from the top 0-20 cm depth and bulked in each experimental site for analysis in laboratories at Moi University, Department of Soil Science and Mumias Sugar Company, Department of Agronomy (exchangeable K). They were air-dried and crushed to pass through a 2 mm sieve and sub-samples were crushed further and passed through a 60 mesh screen for total N and organic carbon analyses. Soil pH was determined using a pH meter with a glass electrode where 2.5:1 water to soil suspension was used [12]. Exchangeable K determination involved extraction of the soil samples with excess 1 M $NH_4OAc$ solution and flame photometry. Available P was determined by extracting soils using 0.5 M Sodium carbonate [13]. Orthophosphate ion in the extract was analysed by ascorbic acid based colorimetry [12]. Total organic carbon was determined by wet combustion oxidation using $H_2SO_4$ and $K_2CrO_7$ oxidation. Total nitrogen was determined by Kjeldahl oxidation method, which involves complete breakdown of soil organic matter by digesting the soil to 360$^o$C in order to convert organic N to ammonium nitrogen ($NH_4$-N) before its determination in the digest.

### Sources of experimental materials

Seeds of vegetable African nightshade (*Solanum* L. Section *Solanum)* species; *Solanum villosum* subsp. *villosum*, *Solanum villosum* Miller subsp. *miniatum*, *Solanum scabrum* Miller used in this study were obtained from Kenya Seed Company. While seeds of *Solanum sarrachoides* Sendtner were collected from Moi University, Department of Seed, Crop and Horticultural Sciences farm.

### Experimental design and layout

A 2 x 4 x 4 factorial experiment was setup in a RCBD with three main factors site (two agro-ecological zones), genotype and potassium rates. Plots measured 3 m by 2 m separated by 0.5 m alleys and 1 m paths between the blocks. Genotype consisted of four species of vegetable African nightshade (*Solanum* L. Section *Solanum)*: *Solanum villosum* subsp. *villosum*, *Solanum villosum* Miller subsp. *miniatum*, *Solanum scabrum* Miller and *Solanum sarrachoides* sendtner. Four rates of potassium (KCl, 60 % $K_2O$) were applied as follows; K0-Control, K1-33 kg K ha$^{-1}$, K2- 66 kg K ha$^{-1}$ and K3- 99 kg K ha$^{-1}$. There were sixteen treatment combinations as shown in table 1 which were randomized in each site. Soils were ploughed and cultivated to a fine tilth. The Various doses of potassium were broadcast evenly on respective plots. A Blanket application of 46 kg P ha$^{-1}$ and 18 kg N ha$^{-1}$ was done before sowing seeds. Seeds of various species of vegetable African nightshades were drilled in respective plots at 30 cm inter row spacing and thinned to a spacing of 30 cm by 30 cm two weeks after emergence resulting in a final plant population of 70 plants per plot. All plots received 154 kg N ha$^{-1}$ six weeks after seed emergence hence a total of 172 kg N ha$^{-1}$ was applied.

**Parameter measures and data analysis**

Plant growth rate was determined as plant height, number of branches plant$^{-1}$, number of leaves plant$^{-1}$ and leaf width recorded at one week interval as from three weeks after emergence. Plant height was measured from the crown to the apex of the youngest leaf using a meter rule. One leaf in each plant at the third node from the ground of the primary stem was tagged from which readings of the largest leaf width were taken. Leaves were harvested once only, nine weeks after about 100 % seed emergence from the two sites (at flowering stage). Plant leaf yield was determined as fresh weight in kg which was recorded from 40 plants per plot. This was converted to leaf fresh weight in tons ha$^{-1}$. The statistical analysis system [14] was used for analysis of variance (ANOVA) in a general linear model to determine whether the various treatments had significant effects ($P \leq 0.05$) on the plant growth rate and leaf yields. Means were separated by LSD tests at $P \leq 0.05$. A simple linear correlation analysis was done to determine whether there was a linear relationship between the various plant growth parameters and leaf fresh yield.

Economic analysis was carried out to determine the Benefit/Cost ratio and gross margin resulting from the application of different rates of potassium fertilizer to each species of vegetable African nightshades. Benefit/Cost ratio was determined based on a partial budget [15] where the change in leaf yield of each species over the control was assumed to be solely due to application of potassium. The costs of acquiring potassium fertiliser and labour involved in application were used in Benefit/Cost analysis. Costs of seed, labour, and the other fertilisers except potassium were not included in the partial budget. Change in net benefit was estimated by subtracting the total costs of applying potassium fertiliser from the income realised due to the use of each rate of potassium. This was then used to calculate the Benefit/Cost ratio obtained by dividing the net benefit due to increased leaf yield by cost of potassium application as compared to the control. Total costs were subtracted from the total returns from each plot to determine gross margin. A market price of Kshs. 30 per kg (Kakamega Municipal Market rates) of each of the species of vegetable African nightshade was multiplied by the fresh yields from each plot to determine total returns. Costs used to determine gross margin were estimated from the expenditures involved in purchase of fertilisers, seeds and labour costs. The prices of fertilisers were obtained from MEA Ltd. Kenya which is the main distributor at Kakamega. Prices of seeds from Kenya Seed Company were used in determining the cost of different seeds. Cost of labour was based on the rates prevailing then at the two sites, which was Kshs.100 per man-day

**Table 1. Treatment combinations of various species of vegetable African nightshade and potassium rates used at each site. The species were: S0- *Solanum villosum* subsp. *villosum*, S1- *Solanum villosum* Miller subsp. *miniatum*, S2- *Solanum scabrum* Miller and S3- *Solanum sarrachoides* Sendtner. Potassium rates were: K0-Control, K1-33 kg K ha$^{-1}$, K2-66 kg K ha$^{-1}$ and K3-99 kg K ha$^{-1}$**

| Treatment | Treatment combination |
|---|---|
| T1 | S0XK0 |
| T2 | S0XK1 |
| T3 | S0XK2 |
| T4 | S0XK3 |
| T5 | S1XK0 |
| T6 | S1XK1 |
| T7 | S1XK2 |
| T8 | S1XK3 |
| T9 | S2XK0 |
| T10 | S2XK1 |
| T11 | S2XK2 |
| T12 | S2XK3 |
| T13 | S3XK0 |
| T14 | S3XK1 |
| T15 | S3XK2 |
| T16 | S3XK3 |

## RESULTS AND DISCUSSION

**Initial soil chemical and physical properties**

Soils from both Malava and Bukura had low levels of exchangeable potassium which were 0.2 and 0.1 Cmol K kg$^{-1}$ respectively. Similar values were obtained by Gikonyo *et al*, [6], as critical range; 0.12 to 0.2 Cmol kg$^{-1}$ soil for maize, sorghum, beans, potatoes and cabbage. The soils also had low levels of organic carbon and they were acidic (Table. 2).

**Table 2. Initial chemical and physical characteristics of soils from different sites**

| Site | pH | Total N (%) | Available P (ppm) | K Cmol $kg^{-1}$ | O C (%) | CEC Cmol $kg^{-1}$ | Textural class |
|---|---|---|---|---|---|---|---|
| Malava | 5.2 | 0.34 | 10.5 | 0.2 | 2.63 | 9.5 | Sandy clay loam |
| Bukura | 5.4 | 0.41 | 17 | 0.1 | 2.12 | 21.9 | Sandy clay |

**Leaf yield**

There was a highly significant interaction ($P \leq 0.001$) between genotype and potassium rate in their effects on the fresh leaf yield. Application of potassium at the rate of 66 kg $ha^{-1}$ significantly ($P \leq 0.05$) increased the mean fresh leaf yields from Bukura and Malava, in *Solanum villosum* subsp. *Villosum* (4.89 tons $ha^{-1}$), *Solanum villosum* Miller subsp. *Miniatum*, (4.58 tons $ha^{-1}$) and *Solanum scabrum* Miller (11.46 tons $ha^{-1}$) compared to the control where 3.88, 3.04 and 5.27 tons $ha^{-1}$ were obtained respectively (Fig 1). This confirms that adequate supply of N and P increases crop yields hence it causes increased demand for K [5]. Crops respond to potassium application when the soil exchangeable K is 0.1 to 0.2 Cmol $kg^{-1}$ [16]. The fresh leaf yield of *Solanum sarrachoides* Sendtner declined significantly ($P \leq 0.05$) from 3.42 tons $ha^{-1}$ in the control to 2.78 tons $ha^{-1}$ at 66 kg K $ha^{-1}$. It is possible that this decline could have been caused by the early bearing characteristics of this species which reduces uptake of potassium. Reduced uptake of K is associated with a strong sink competition for carbohydrates between fruits and roots during the period of high demand for potassium [17].

The mean fresh leaf yield from all sites, species and regardless of whether potassium was applied or not ranged between 2.33 to 11.65 tons $ha^{-1}$ which is lower than that obtained by other workers. Fresh leaf yields of 15 to 20 tons $ha^{-1}$ [18] in West Java, Netherlands and 20 to 51 tons $ha^{-1}$ [4] at the University of Nairobi, Kenya were obtained using a spacing of 30 x 30 cm and harvesting done once. This suggests the possible influence of factors other than potassium and genotype on the performance of vegetable African nightshades given sufficient supply of nitrogen and phosphorus. Schippers [19] and Wanjekeche *et al*., [2] reported that the level of soil organic matter affects the yield of vegetable African nightshades. This could also be the reason as to why Malava with more soil organic matter had a significantly higher ($P \leq 0.05$) mean fresh leaf yield of 5.1 tons $ha^{-1}$ compared to Bukura (4.7 tons $ha^{-1}$). Correlation coefficients between plant growth parameters and fresh leaf yield were not significant ($P \leq 0.05$) in all species except *Solanum sarrachoides* Sendtner, thus these were not good predictors of fresh leaf yield in vegetable African nightshades.

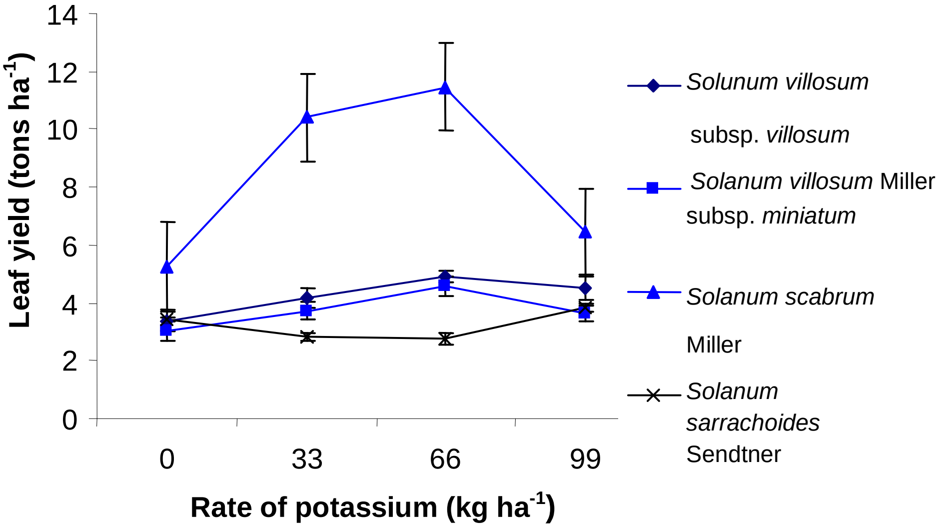


**Fig. 1. Fresh leaf yield of different species of vegetable African nightshade subjected to varying rates of potassium at nine weeks after seedling emergence from Bukura and Malava (LSD P≤0.05).**

**Profitability of using potassium in production of vegetable African nightshades**

The highest gross margins were obtained when using 66 kg K $ha^{-1}$ and growing *Solanum scabrum* Miller (Ksh. 218,047 $ha^{-1}$). The Benefit/Cost ratio realized from *Solanum scabrum* Miller was higher when 33 kg K $ha^{-1}$ was applied compared to 66 kg K $ha^{-1}$. This species was therefore more cost effective to produce than *Solanum villosum* subsp. *Villosum* and *Solanum villosum* Miller subsp. *Miniatum* which had higher benefit cost ratios at 66 kg K $ha^{-1}$ than 33 kg K $ha^{-1}$. *Solanum scabrum* Miller had higher Benefit/Cost ratios (61.16, 53.55) at 33 kg K $ha^{-1}$ compared to *Solanum villosum* subsp. *Villosum* (7.18, 9.57) and *Solanum villosum* Miller subsp. *Miniatum* (10.93, 2.75) in Malava and Bukura respectively. *Solanum sarrachoides* Sendtner had values of Benefit /Cost ratio ranging from -5.46 to 1.54 considering all K treatments and sites hence the use of potassium in this species was uneconomical.

## CONCLUSION

The soils of Malava, Bukura and Ikolomani were found to be acidic besides having low levels of exchangeable potassium and organic carbon. Therefore, they were incapable of sustaining the satisfactory production of vegetable African nightshades. It emanated from this study that potassium application can increase leaf yields of vegetable African nightshades. Profits from vegetable African nightshades can be maximized when *Solanum scabrum* Miller is produced using 66 kg K $ha^{-1}$. The effect of organic and inorganic sources of potassium on the yield of vegetable African nightshades should be established so that farmers particularly in small scale can use manure and inorganic fertilisers optimally to maximize the production of this important vegetable. Potassium use efficiency needs to be assessed in different species of vegetable African nightshade and various sites.

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