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Effects of phosphorus deficiency on secondary metabolites and African nightshade distribution in Kisii, Siaya and Kakamega counties, Kenya

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Abstract

African indigenous vegetables form an integral part of the Kenyan diets, among the most commonly consumed being the African nightshade. These vegetables contain important phenolics that have medicinal values and good health attributes. The abundance of these phenolic substances has strongly been associated with phosphorus use efficiency. In order to investigate the effect of phosphorus deficiency on African nightshade distribution, a purposive research was done on 30 random farmers growing the crop using semi-structured questionnaires in Kisii and Siaya counties of Kenya on February 2014. *Solanum scabrum* had 79% distribution whereas *Solanum villosum* had 21%. The two species were planted under greenhouse production in Kenyatta University with varying Phosphorus pot treatments (0, 6, 12 and 18 gms). Plant variables were recorded during their growth period and later the effects resulting from these treatments were established. Analysis on Total Phenolic Content is under way. The results obtained will be used to educate farmers and extension personnel about ways of improving productivity of African nightshade.

Key words: Phenolics, *Solanum scabrum, Solanum villosum*

Résumé

Légumes indigènes africains font partie intégrante des régimes alimentaire du Kenya, parmi les plus couramment consommée étant les solanacées africains. Ces légumes contiennent des composés phénoliques importants qui ont des valeurs médicinales et les attributs de bonne santé. L'abondance de ces substances phénoliques a fortement été associée à l'utilisation du phosphore efficacité. Afin d'étudier l'effet de la carence en phosphore sur la distribution de solanacées africains, une recherche calculée a été faite sur 30 agriculteurs aléatoires qui plantent cette culture en utilisant des questionnaires semi-structurés dans les comtés de Kisii et Siaya du Kenya en février 2014. Le *Solanum scabrum* a obtenu 79% de distribution, tandis que le *Solanum villosum* a obtenu 21%. Les deux espèces ont été plantés dans la production en serre à l'Université Kenyatta avec différents traitements de pot de phosphore (0, 6, 12 et 18 gms). Des variables de plantes ont été enregistrées au cours de leur période de croissance et plus tard, les effets résultant de ces traitements ont été établis. L'analyse sur le contenu phénolique total est en cours. Les résultats obtenus seront utilisés pour informer les agriculteurs et les agents de vulgarisation sur les moyens d'améliorer la productivité de solanacées africains.

Mots clés: Composés phénoliques, *Solanum scabrum, Solanum villosum*

Introduction

Herbal medicine has been practiced worldwide (Ameyaw *et al*., 2005) and a vast store of knowledge concerning the therapeutic properties of different plants has been accumulated (Felix *et al*., 2009). Medical evidence increasingly suggests that consumption of a diet rich in phytochemicals has a protective effect against cardiovascular disease and certain forms of cancer (Surch, 2003). Although the nutritional benefits derived from eating phytochemical rich plant foods are well known, foods and beverages containing the highest phytochemical levels are often lacking or absent in many diets, particularly in Kenya and other developing countries (Beecher, 2003). Therefore, there has been growing interest in developing simple methodologies for instance through controlled fertilizer use, irrigation and acquisition of new improved varieties to increase antioxidants concentrations in more commonly consumed plant foods (Schreiner *et al*., 2006). This is interesting for the case of the neglected African indigenous vegetables. Availability of key macronutrients during plant growth has significant potential to affect phytochemical accumulation (Parr *et al*., 2000). This research explores the enhancement of secondary metabolites in light of phosphorus status of the soils and thereby finds a trade-off between biomass yield and secondary metabolites, particularly phenolics and related antioxidants. Although phosphorus has been shown to directly correlate with the growth, yield, and essential oil content of African nightshade (Petersen *et al*., 2003), the effect of phosphorus availability on the phytochemical composition and antioxidant properties of African nightshade is underway.

Literature review

Among 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 (Abukutsa-Onyango, 2007). 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 (Fontem *et al*., 2004). 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 constraints and due to these production constraints, plants have evolved adaptive mechanisms to Phosphorus stress and phenolic production is one such mechanism. There has been reported increase in phenolic concentration under Phosphorus stress (Ren *et al*., 2007). These products are important components in health fitness and many consumers give emphasis on these; forcing marketers to label the produce (Cohen and Kennedy, 2010). Several hypotheses and models have attempted to explain variation in concentrations of phenolics, two such theories are; The Carbon: Nutrient Balance Hypothesis (CNBH) which predicts that the amount plants invest in secondary compounds depends on the relative supply of carbon and nutrients to the sites of metabolism and Protein Competition Model (PCM) which is based on a more mechanistic understanding of biochemical pathways. A key issue considered in the PCM but not in the CNBH is whether different nutrients have different influences on the production of phenolic compounds and they further extended the PCM prediction to suggest that deficiency of nitrogen not phosphorus will lead to increased phenolic concentrations, comparing the effects of these nutrients quantitatively.

Materials and methods

A survey was conducted between on February 2014 to determine the distribution of African nightshade in terms of Phosphorus, agronomic management practices, preference, distribution and abundance of African nightshade in major African nightshade growing regions in the Siaya and Kisii counties, Kenya. According to the survey, *Solanum scabrum* had 79% distribution and it was followed by *Solanum villosum* with 21% were the highly distributed hence chosen for greenhouse production. Experiment was conducted in Kenyatta University greenhouse; *Solanum scabrum* and *Solanum villosum* seeds were pre-germinated and transplanted in 5 kilograms pots filled with 4 kilograms of sterilized sand. Treatments included the factorial combination of four P levels and two accessions of African nightshade. There were four P application rates namely as 0, 6, 12 and 18 gms. All pots were administered with recommended plant nutrients through Hoagland solution. Hoagland solution was administered two times every month at the rate of 15ml of stock solution in 1litre of water per pot. Phosphorus was administered in form of Triple superphosphate when transplanting. The pots were arranged in completely randomised block design (CRBD) in a factorial combination with two types of the African Nightshade, *Solanum scabrum* and *Solanum villosum* as main plot and there were four replicates. Data on plant height, fresh weight, and number of secondary buds, leaf area and root area were recorded on weekly basis 20 days after transplanting.

Results and discussion

Number of secondary buds. Preliminary results show that the number of secondary buds were significantly ($P<0.05$) affected by the different levels of phosphorus (Fig. 1). This effect can be clearly understood from the control pots but the number of secondary buds increase with increase in P; there was a significant decrease of the number of buds treated with 18 gms of P. Increase of P is associated with increased rapid growth and development, thus pots that received optimum P produced more secondary buds as compared to control pots. Arain *et al.* (1989) reported that number of secondary buds increased with increase in P application.

Leaf area. Leaf area preliminary data revealed that different levels of phosphorus had a significant ($P<0.05$) effect on leaf area (Fig. 2). The increase of leaf area with P increase is attributed to good root growth as a result of P supply which directly affects the overall plant performance. The results are in accordance with those of Sharma and Sharma (1989) who reported that P fertilizer applications significantly affected the size of leaves in beans. Given that the genotypes responded similarly to P application, the differences in their leaf area at

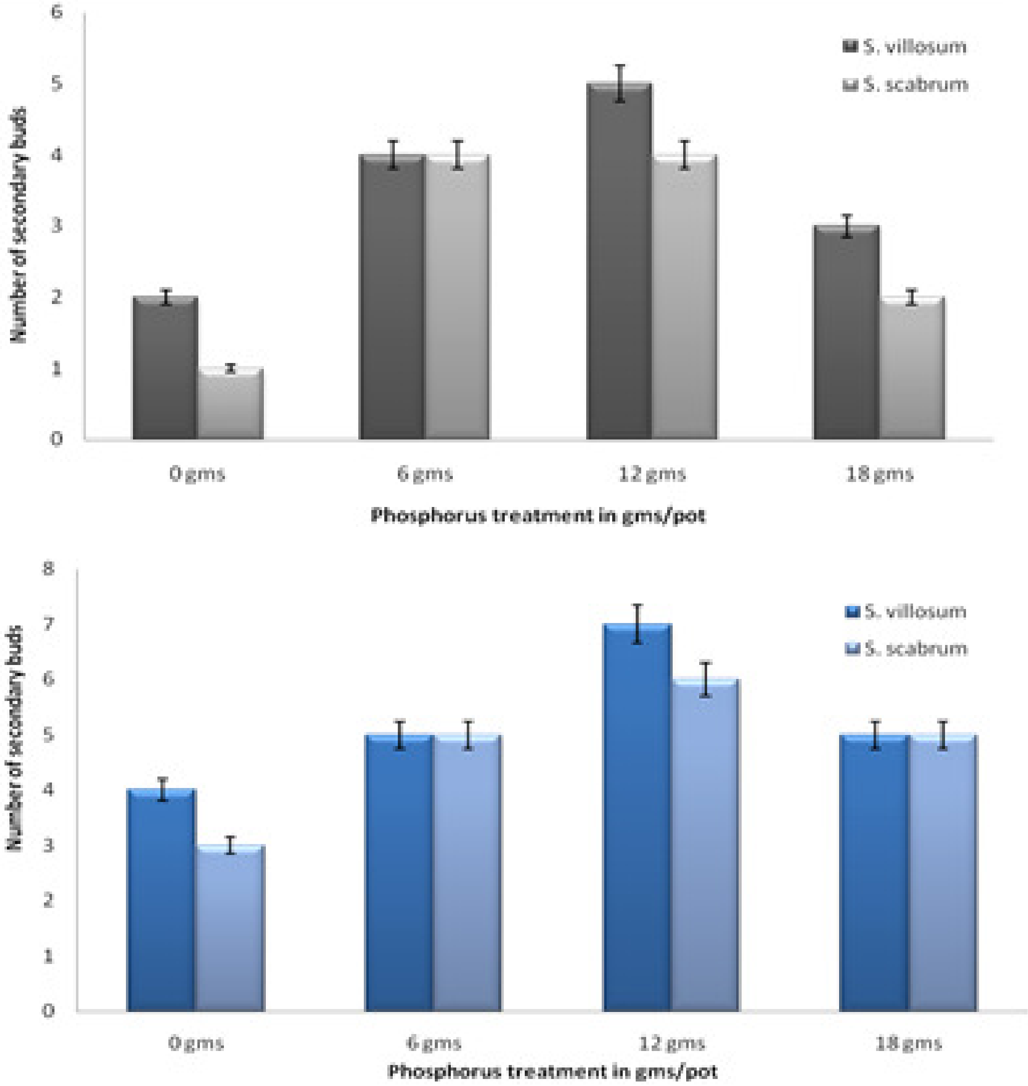

Figure 1. Mean numbers of secondary buds in 20 and 27 days after transplanting.

similar P rates are attributed to their inherent morphological characteristics; *S. scabrum* has genetically bigger leaves as compared to *S. villosum.*

Fresh weight. The effect of different levels of P on fresh weight was significant ($P<0.05$) (Fig. 3). Preliminary results indicate there was increase in weight with increase of P; P being responsible for good root growth directly affected the fresh weight. Hussain *et al.* (2006) observed an increase in fresh weight with increase in NP application. Given that the genotypes responded similarly to P application, the differences in their leaf area at similar P rates can be attributed to their inherent morphological characteristics.

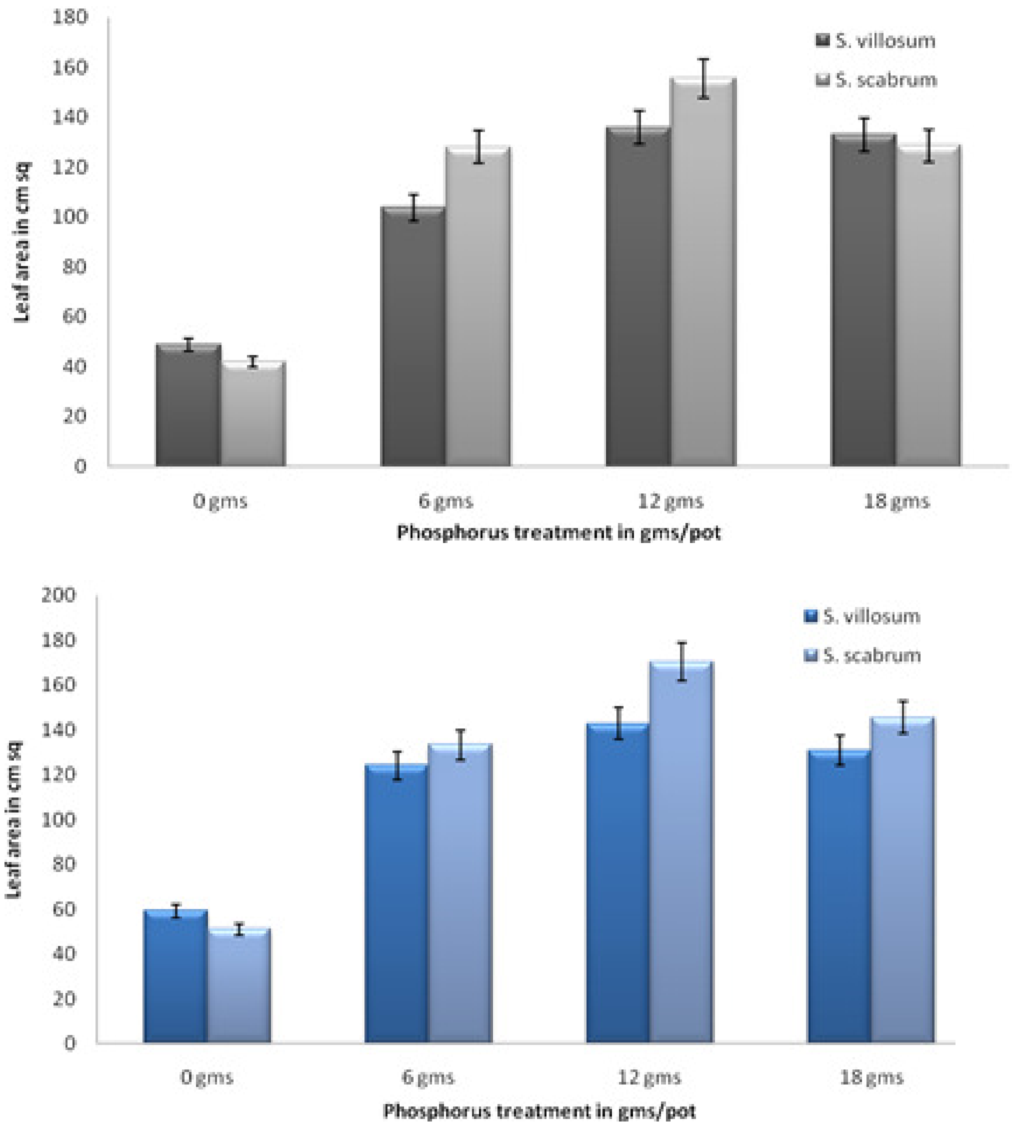

Figure 2. Mean leaf areas in 20 and 27 days after transplanting.

Root area. Root area was significantly (P<0.05) affected by different levels of Phosphorous (Fig. 4). Optimum supply of P is associated with increased root growth. However lack of P leads to increased root area as a result of plant effort to acquire P. This attributes to high root area in pots treated with 0 gms of P leading to negatively affecting other physiological functions of the African nightshade plants. Arain *et al.* (1989) reported that root area in tomatoes increased with increase in P application.

Phosphorus toxicity is rear and usually buffered by pH limitation. Excess P can interfere with the availability of copper and zinc, that would lead to reduced leaf and root development hence this explains the reduction of grow parameters experienced by plants treated with 18

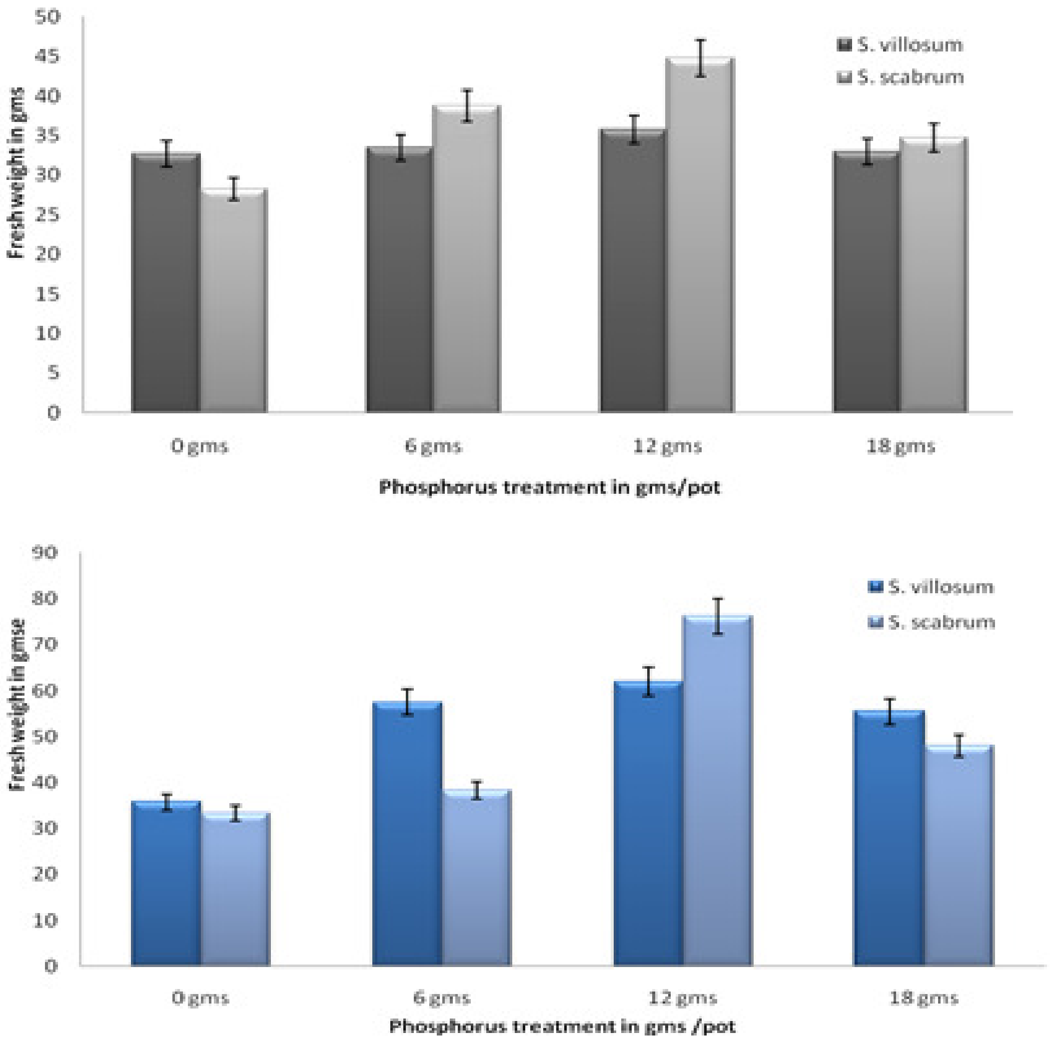

Figure 3. Mean fresh weights in 20 and 27 days after transplanting.

gms of P as compared to those treated with optimum P (12 gms) in accordance with Loneragan *et al*. (1979).

Conclusion

Phosphorus rate of 12 gms is highly recommended for optimum yield of African nightshade particularly in the mid agro-ecological zone and that any addition will result in plant luxury consumption that consequently leads to wastage of resources.

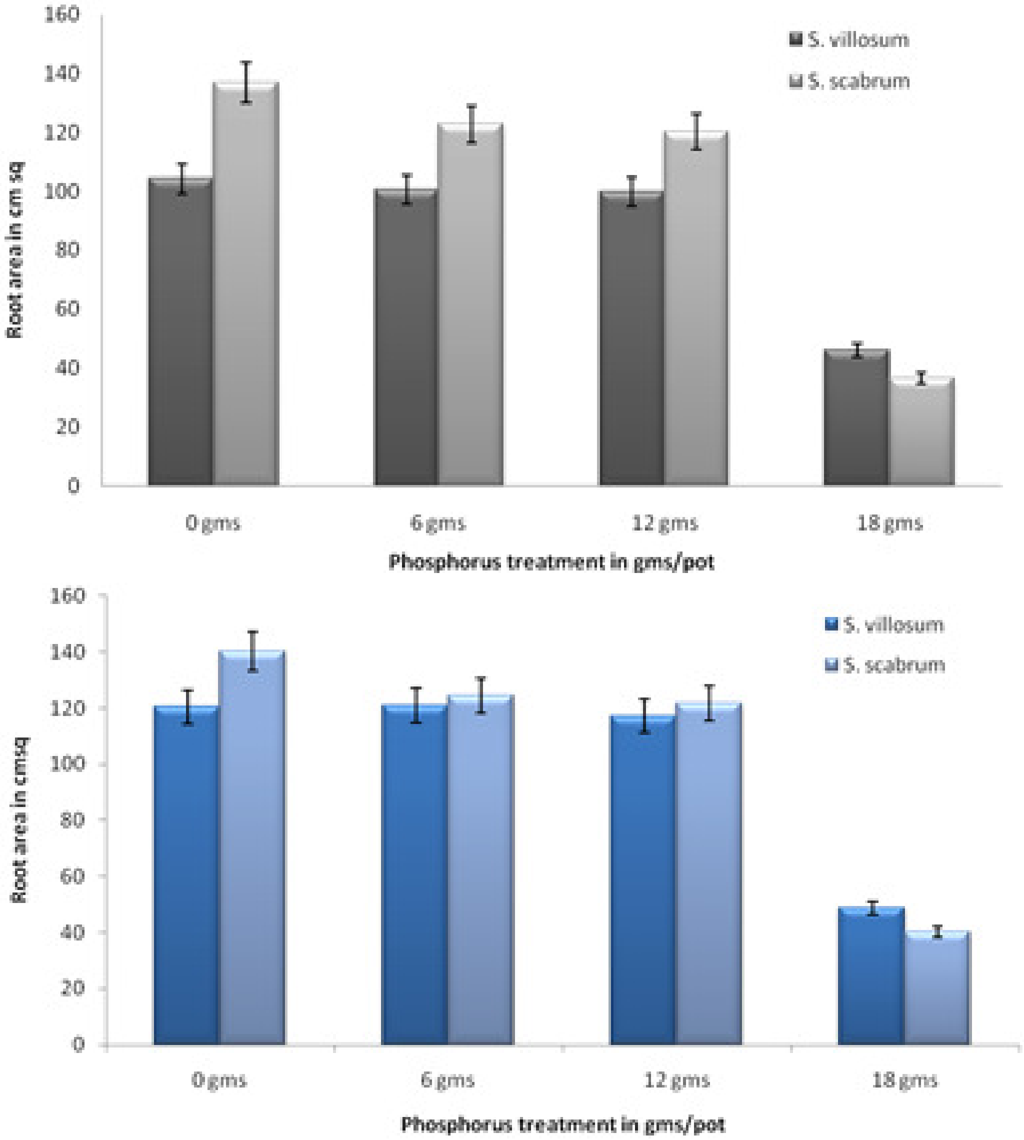

Figure 4. Mean root areas in 20 and 27 days after transplanting.

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