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FORTIFIED COMPOST MANURE IMPROVES YIELD AND GROWTH OF AFRICAN NIGHTSHADES

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ABSTRACT
Response of three African nightshade species subjected to different levels of fortified compost manure was evaluated in a field experiment conducted for two seasons in 2006/2007. The three African nightshades were: - *Solanum villosum* Miller, *Solanum americanum* Miller and *Solanum scabrum* Miller. The species were subjected to four levels of fortified compost manure applications (2t/ha, 4t/ha, 6t/ha, 8t/ha) and no manure application as the control. The experimental design was a Randomized Complete Block Design with 15 treatment combinations. Data collection started three weeks after transplanting and continued for nine weeks. The colleted data were subjected to analysis of variance (ANOVA) using a Mixed Models procedure of SAS. Biomass accumulation and average edible yield were affected by compost manure application. Of the three species, *S. americanum* subjected to 8 t/ha compost manure level gave the highest yield of 5.2 t/ha. The height and internode lengths of the same species were increased by an average of 34% and the stem thickness by 30% compared to the control over the two seasons. Longer internodes, thicker stems and higher number of branches as exhibited by *S. americanum* are good characteristic as these parameters improve on the amount of harvestable biomass that often include tender stems

KEYWORDS: African nightshade, fortified compost manure, *Solanum villosum, Solanum americanum* and *Solanum scabrum*.

INTRODUCTION

African nightshades are among the many traditional leafy vegetables that continue to be cultivated by Kenyan communities. Like many traditional vegetables, African nightshades act as food security and are source of better nutrition as they are rich in, calcium, iron, and vitamins A and C (Schippers *et al.*, 2001). Nightshades are also a source of income for the rural poor. There exist market opportunities for these traditional vegetables especially in less favorable environments where they have a comparative advantage over major staples or commercial crops. Not withstanding all its cultural and socio economic importance, African nightshades are still underutilized by the contemporary community. The vegetable is mainly grown by traditional farmers for subsistence. One way of improving its utilization is by promoting its production by use of compost manures.

According to Peter *et al.*, (1997), compost manure has multiple benefits on both the improvement of the soil and vegetable performance. As a soil fertility amendment, it can be used as a source of soil nutrients as well as a mulch to raise soil temperatures. Compost manure provides alternative weed control and/or can be used in an integrated weed management program. Compost manures are generally environment friendly. In cases where compost manures could be nutrient deficient due to the type of raw materials used, artificial fortification can be done by adding the deficient nutrient hence ensuring its appropriateness. Although few farmers have tried to produce African nightshades using compost manure, no detailed study has been done and documented for use by the wider farming community in Kenya. Moreover, the type of compost these farmers have used is either from within domestic premises which could be nutrient variable or deficient depending on the raw materials and methods used during composting; hence the need for fortification to make them more appropriate. In a study to determine the effect of nitrogen application on leaf yield and nutritive quality of African nightshade *Solanum nigrum* L, (Opiyo, 2004) reported that nitrogen application increased leaf yield. The study also reports no interaction between nitrogen level and application method on the performance of *S. nigrum*.

Production of African nightshade using compost manures is limited. According to Chweya (1985), and Chweya and Eyzaguirre (1999). Rates of 2-3 kg/m^2 of well decomposed cattle manure is recommended; but can vary up to 6 kg/m^2 depending on soil type and manure quality. For chicken manures, half to a quarter the rate of cattle manure can be used. Murage (1990) reported that out of the 0, 5, 10, and 15 gN/plant rates used in a study to determine the effect of nitrogen fertilizer application on plant growth, leaf yield and nutritive quality of *Solanum nigrum,* 5 gN/plant was optimal. Opiyo (2004) on the other hand reported that yields were significantly higher at rates of 52, 78, and 104 kgN/ha than at 26 kgN/ha and the control in an experiment designed to study the effects of nitrogen application on leaf yield and nutritive quality of black nightshade. Since there were no significant difference between 52, 78 and 104 kgN/ha, it seems the optimum rate for this study was anywhere between 26-52 kgN/ha. This is in the range of 2-4 50 kg CAN bags of 26%N per hectare.

MATERIALS AND METHODS

The research was carried out at Kisii Agricultural Training Center (ATC-Kisii) in the years 2006/2007 and was repeated once. The research site falls under upper midland agro-ecological zone with an altitude of between 1570 and

2015 m a.s.l. The soils are mainly loam soils classified as phaeozems (FAO/UNESCO, 1974). The average annual rainfall ranges between 1200 – 2000 mm. The average daily temperature range is 18-22°C

Seeds of the three species tested were obtained from National Gene Bank Muguga in the year 2006. Seedlings were raised in the nursery and transplanting was done five weeks after sowing when the seedlings had at least 6 true leaves. At this stage, they were about 10 cm – 15 cm tall.

The experiment was a factorial arrangement of treatments in a randomized complete block design (RCBD) in which two factors (African nightshade species and fortified compost manure) were studied. The three African nightshades tested in this study were namely: *Solanum scabrum* Miller, *Solanum villosum* Miller and *Solanum americanum* Miller.

In this study, considering the source of nitrogen which was fortified compost manure (2.13%N) and a soil composition of 0.31%N, a rate of 3kg compost/m^2 was taken to be the maximum rate (Schippers *et al.,* 2001). This translated to 1.35 gN/plant given a compost composition of 0.5%N (Robinson and Neil, 1977). On that basis, the following rates were adopted: C_0- 0 t/ha, C_{1-} 2 t/ha, C_2- 4 t/ha, C_3- 6 t/ha and C_4- 8 t/ha. These rates translated into 0 kgN/ha, 42.6 kgN/ha, 85.2 kgN/ha, 127.8 kgN/ha and 170.4 kgN/ha respectively. Fortified compost manure from James Finlay Company, Kericho was used. This manure is made from tea by-product. At the start, the by-product has a moisture content of about 70% and is brown in color. The product is dried by covering it with black polythene in the open and turned at least twice a week. Temperatures at the start of composting is 48 °C, and rises to 70 °C in the 5^{th}–6^{th} week before coming down to less than 48 °C at the 8^{th} week when the compost is ready. At this time, the moisture content is approximately 40% (although it can vary depending on weather); and the color would have also changed to black. The compost is then fortified by adding rock phosphate at a rate of 100 kg ton^{-1}, murate of potash at a rate of 10kg ton^{-1} and magnesium oxide (MgO) at a rate of 1 kg ton^{-1}. Nutrient content of the final product was determined according to Hinga *et al.*, (1980) and was found to be N=2.13%, K=5%, P=3.38% and Mg=0.57%.

Experiment layout was done and compost manure applied one week to transplanting. An experimental unit measured 2 m by 2 m with a footpath of 0.5 m all round. The spacing of African nightshade plants was 30 cm by 30 cm giving a total of 36 plants per 2 m^2.

Because there were no significant differences in the two seasons, each set of data of a measured parameter were pooled together and then subjected to analysis of variance (ANOVA) using a Mixed Models procedure of SAS V8 statistical package (SAS Institute 1999). The UNIVARIATE procedure of SAS was used to check that the data were normally distributed before analysis. Cultivation was done to attain a favorable tilth before transplanting. Soil and fortified manure analysis was done before planting as described by Hinga, *et al.*, (1980). To measure the growth and yield parameters, nine plants per experimental unit were randomly selected and tagged for data collection and the following parameters were measured:

Plant height: The height of each of the tagged plants was determined by measuring from ground level to tip of the longest stem of the plant on a weekly interval for four weeks.

Fresh weight: Each of the nine sample plants was harvested on continuous basis for four weeks after transplanting, and the mean used to compute fresh weight.

Dry weight: The nine sample plants that were harvested for fresh weight determination were placed under shade for 6 hrs to remove excess moisture. The plants were then dried at 70 °C to constant weight. The weight of each plant was recorded and average for each treatment taken as dry weight per plant for that treatment.

Internodes length: The fourth internodes of tagged plants in an experimental unit were marked and their lengths determined between the adjacent nodes. The measurements continued at weekly interval starting from 6^{th} week after transplanting to the termination of the experiment

Stem diameter: Fourth internodes of each of the nine sample plants were marked and their diameters determined using micrometer screw gauge. The measurement continued to be taken at weekly intervals starting from 6^{th} week after transplanting to the termination of the experiment.

Edible yield: The term yield in this research was used to include all parts of the plant that is usually harvested and used as vegetable. It included two leaves and a bud. Harvesting was done from a set of nine plants per treatment on a weekly interval starting from six weeks after transplanting. Total weight of the harvested plants was determined using Salter Elite Electronic scale model 3001 with an accuracy of ±1g.

Light interception: Light interception was determined using Sunfleck PAR Ceptometers Model SF – 80 with which measurements were taken within the photosynthetically active radiation (PAR) waveband. This was done at the 4^{th} week after transplanting. The formula F = 1 - t (Sunfleck PAR Ceptometers; operators manual) was used to get light interception where: F - Fractional PAR canopy absorption t – Fraction of incident PAR radiation transmitted by canopy.

Chlorophyll concentration: Fresh tissue (1 g) was sampled from the youngest fully expanded leaf, extracted with 90% acetone and read using a UV/Visible Spectrophotometer (Bausch & Lomb, Belgium) at 663, 645 and 750 nm wavelengths. Absorbance at 750 nm was subtracted from absorbance at the other two wavelengths to correct for any turbidity in solution before chlorophyll concentrations were calculated using the formulae given by Strain and Svec (1966). Chl.*a* (mg.ml –1) = 11.64x(A663) – 2.16x(A645) and Chl.*b* (mg.ml –1) = 20.97x(A645) – 3.94x(A663), where (A663) and (A645) represents absorbance values read at 663 and 645 nm wavelengths respectively.

RESULTS

Plant height: There was a general increase in plant height with an increase in the compost manure level. However, only *S. americanum* subjected to 8 t/ha of compost manure had a significant height difference when compared to the control. At 8 t/ha, the height of this species was increased by 48% compared to the control (Table 1). *S. scabrum* and *S. villosum* remained consistently shorter and taller respectively under all levels of the compost manure tested (Table 1).

TABLE 1. Effect of compost manure levels on the height of African nightshade species

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8	Mean
	Height (cm)					
S. scabrum	10.9d*	15.7d	15.9d	15.7d	15.6d	14.4c
S. villosum	30.1ab	35.4a	37.5a	35.6a	37.9a	34.9a
S. americanum	16.2d	18.3bcd	27.7abc	24.7abc	31.3ab	22.9b
Mean	20.6	23.1	27.0	22.5	26.9	

*Means with the same letter(s) within a column or row are not significantly different. at P≤0.05 by DMRT.

TABLE 2. Internode length of African nightshade species as affected by compost manure levels

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8	Mean
	Internode length (cm)					
S. scabrum	1.48cd*	1.61cd	1.46cd	1.55cd	1.33cd	1.48b
S. villosum	2.08abc	1.78bcd	2.07abc	2.41ab	2.43ab	2.17a
S. americanum	1.75bcd	2.01abcd	1.47cd	2.12abc	2.68a	2.01a
Mean	1.77ba	1.83ba	1.67b	2.03ab	2.15a	

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT.

Internode length: The average internode length of African nightshade species tested increased with increase in compost manure levels by an average of 13% over the control (Table 2). At the highest compost manure level of 8 t/ha, the internode length of *S. villosum* and *S. americanum* species were longer (14% and 35% respectively) compared to those produced with no compost manure (Table 2).

Stem diameter: Average stem thickness of African nightshades increased with an increase in the amount of compost manure applied. An increase in stem diameter of 17% was observed in the African nightshades subjected to 8 t/ha of compost manure compared to those grown with no compost manure. Among the three species compost manure rate of 8tons/ha increased stem diameter of *S. villous* by 30% compared to the control (Table 3). The stem thickness of the other two species was not affected by the compost manure application.

Number of branches: Compost manure application above 2 t/ha significantly increased the number of branches in *S. scabrum* and *S. villosum* compared to the control (Table 4). The least number of branches was observed in all the three species in the plots with no compost manure application. However, the height of the African nightshades were the same when averaged across the compost manure levels (Table 4)

TABLE 3. Effect of compost manure levels on the stem diameter of African nightshade species

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8	Mean
	Stem diameter (mm)					
S. scabrum	5.5bc*	6.6abc	7.1ab	7.1ab	6.9ab	6.64a
S. villosum	4.9c	6.0bc	6.7abc	5.9bc	6.2abc	5.93b
S. americanum	5.5bc	5.9bc	6.3abc	5.8bc	7.9a	6.25ab
Mean	5.29b	6.19a	6.70a	6.23a	6.97a	

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT.

TABLE 4. Number of branches of African nightshade species as affected by compost manure levels for experiment two

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8	Mean
	Number of branches					
S. scabrum	11.7cd*	15.3a	15.1a	14.8ab	13.6abc	14.1
S. villosum	12.1bcd	14.2abc	14.1abc	14.0abc	14.6abc	13.8
S. americanum	12.9bcd	12.5bcd	14.9ab	14.4abc	14.6abc	13.0
Mean	12.2c	14.0ab	14.7a	13.0cb	14.2ab	

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT.

Fresh weight: The average fresh weight of the species was highest at the maximum manure application of 8 ton/ha compared to the control (Table 5). When the response of the three species was checked against individual compost manure levels, fresh weight of *S. americanum* species subjected to the highest application rate of 8 ton/ha was increased by 50% compared to those with no compost manure application (Table 5).

Dry weight: The average dry weight of African nightshade increased with increase in the organic manure.

The dry weight of *S. scabrum* was increased by between 21% and 45% under 8 t/ha of compost manure while the dry weights of other species was not affected by the different levels of compost manure (Tables 6).

TABLE 5. Fresh weight of African nightshade species as affected by compost manure levels

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8	
	Fresh weight (g/plant)					Mean
S. scabrum	292.0c*	556.3bc	724.7abc	649.7bc	621.3bc	568.8a
S. villosum	487.3bc	649.3bc	604.3bc	801.7ab	721.3abc	652.8a
S. americanum	567.0bc	604.7bc	659.7bc	607.3bc	1125.7a	712.9a
Mean	448.8b	603.4ab	728.7a	620.4ab	822.8a	

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT. .

TABLE 6. Dry weight of African nightshade species as affected by compost manure levels

Species	Compost manure levels (tonha^{-1}) 0	2	4	6	8
	Dry weight (g/plant)				
S. scabrum	44.0b*	47.0b	46.0b	49.7b	80.7a
S. villosum	50.7b	45.3b	48.3	46.3b	48.3b
S. americanum	42.3b	50.0b	51.0b	60.3b	56.3b

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT. .

FIGURE 1. Effects of compost levels on percentage light interception across African nightshades.

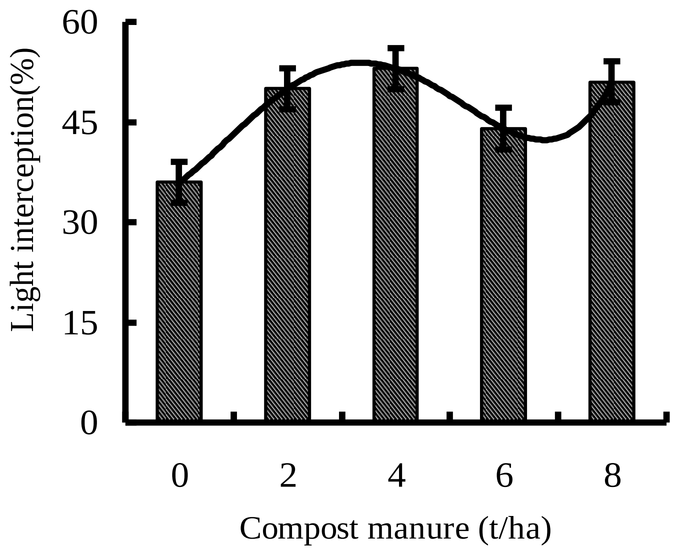

TABLE 7. Variations in the chlorophyll (mg/kg fresh weight) content of three selected black nightshade species as affected by fortified manure application

African nightshades	Manure Level	Season One		Season Two	
	0	*Chlo a*	*Chlo b*	*Chlo a*	*Chlo b*
S. scabrum	2	1082a*	1177abcd	1298a	883a
	4	1109ab	942bcd	1037a	836a
	6	1002b	1543ab	1205a	625a
	8	1048ab	1488abc	1025a	952a
S. villosum	0	1128a	1176abcd	1006a	584a
	2	1044ab	1580a	905a	701a
	4	1137a	1130qbcd	1053a	631a
	6	1043ab	1200abcd	1280a	638a
	8	1045ab	1325abcd	1223a	852a
S. americanum	0	1076ab	1206abcd	891a	475a
	2	1143a	846d	1045a	498a
	4	1094ab	885cd	856a	644a
	6	1112ab	859d	1064a	508a
	8	1072ab	914cd	1044a	852a

*Means with the same letter(s) within a column are not significantly different at P≤0.05.

Light interception

There was a general but insignificant increase on the percent light interception when averaged across the three African nightshades tested. The highest interception of 70% was at the highest manure application (8 tons/ha), this was 53% more than percent light interception by the plants grown with no compost manure (Fig. 1).

Chlorophyll content of African nightshade leaves

When the effects of compost manure levels were checked against the individual African nightshade species, significant but inconsistent differences were observed in the amount of *chlo a* in the tissues in season one, but not in season two. The lowest amount of *chlo b* was observed in the tissues of *S. americanum.* However, the results could not be tied to a specific level of compost manure applied (Table7).

There was a general increase (Yield = 1.9624 + 0.5016x, R^2 = 0.9663) of the average edible yield of African nightshade species with increase in the compost manure levels. There highest increase of was 45% in the edible yield of all the three species was observed at the highest application rate (8 ton/ha) of compost manure compared to the control (Table 8).

TABLE 8. Yield of African nightshade species as affected by compost manure levels

	Compost manure levels (tonha^{-1})				
Species	0	2	4	6	8
	Edible component yield (ton/ha)				
S. scabrum	1.92d*	2.47cd	2.80cd	3.24bcd	3.78abc
S. villosum	2.81cd	3.11de	3.39bcd	3.32bcd	4.93ab
S. americanum	2.78cd	3.65abcd	4.05abc	4.92ab	5.19a

*Means with the same letter(s) within a column or row are not significantly different at P≤0.05 by DMRT.

DISCUSSIONS

Response of the various growth parameters measured depended on the variety of the African nightshade and the level of compost manure applied. Plant growth parameters such as plant height, number of leaves and leaf area easily respond to nitrogen application (Gungula *et al.,* 2005). Our results are similar to those reported in other studies that involved the use of both organic and inorganic sources of nitrogen nutrients. For example, Overcash *et al.,* (2005), reported an enhanced growth of many crops through replenishment of the used up nitrogen by addition of organic and inorganic sources of nitrogen into the soil. The organic sources retained the soil moisture for a longer period of time resulting into improved growth and yield of the tested crops.

Nitrogen is reportedly more responsible for plant growth than any other element. It stimulates vegetative growth resulting in large stems and leaves. Our observations support those reported by Edmonds and Chweya, (1997), Chweya, 1997, Schippers, 2000; and Mwai and Schippers, (2004). where this stage of growth was reached in four to five weeks after transplanting. The results also support the findings of Onyango *et al.,* (1999) who reported enhanced growth of plants grown under different organic and inorganic nitrogen sources.

African nightshade plants subjected to low levels or no fortified manure application exhibited poor growth rate associated with nitrogen deficiency. Plants suffering from nitrogen deficiency mature earlier and their vegetative growth stage is shortened (Wolf, 1999). On the other hand excess nitrogen results in lush plants with soft tissue and subsequent lateness in maturity (Wolf, 1999). These reports confirm the observation in this research where the internode diameter and internode length increased with increase in fortified compost manure levels. The results also confirm those reported by Indira (2005) who attributed the response of plants to nitrogen application to enhanced nitrogen mining capacity of plants due to increased translocation of photoassimilates brought about by faster root growth.

In this research, the highest yield of 5.19 ton/ha was obtained from *S. americanum* species under sequential harvesting in season two. Cumulative leaf yields of up to 12-20 t/ha^{-1} per growing season was reported by Edmonds and Chweya, (1997), with a total leaf yield of 5 t/ha-[1] obtained from six sequential harvests of *S. americunum* species. The improved yield of the African nightshades subjected to compost manure might be explained by the fact that weekly cumulative harvests allows for the regeneration of edible vegetative growth. It is possible that the spacing of 30 x 30 cm allowed for the formation of more branches at compost manure levels of above 6ton/ha leading to higher yields of edible parts. On the hand, the yield increases observed in the *S. americunum* species could be due to enhanced growth characteristics such as the stem diameter which was 7.9 mm at the highest compost manure level of 8 t/ha, this was 30% over those planted without compost manure. This increase in stem thickness together with the increase in the number of branches might have contributed to this species giving the best yield of 5.19 t/ha at the highest manure level of 8tons/ha, which was 55% more than those recorded from the same species grown without any external source of nutrients. Organic materials are reported to increase soil fertility and leaf yield of traditional vegetables. For example, Merinyo (1996) in his study, reported that the application of nitrogen (150 kg N/ha) in combination with FYM at the rate of 10 t/ha greatly influenced yield of *S. nigrum*.

This study provides useful information on the production of three different African nightshade species using fortified compost manure. It documents the variations in growth and yield components of the three species subjected to different levels of fortified compost manure. Among the important information that can be gathered from this research is that fortified compost manure is useful in the production of African nightshades. The growth and edible yield of all the three species were influenced by the compost manure levels. Although the degree of response varied, the best compost manure level was 8t/ha when used in the production of *S. americanum.* Produced under similar conditions, this species will give the highest edible yield parts. It also exhibited the best growth characteristics such as high number of branches and larger stems.

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