INTERACTIVE EFFECT OF NITROGEN RATES ON GROWTH OF SPIDER PLANT (*CLEOME GYNANDRA* L.) ACCESSIONS IN RUIRU, KENYA

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Abstract

Spider plant (*Cleome gynandra* L.) is one of the important African leafy vegetables (ALVs). It has been used by local African communities as a source of nutrition in their diets for many years. In Kenya, Spider plant is among the ALVs whose consumption has grown steadily. However, limited access by farmers to high yielding spider plant varieties has been a major constraint to its production in Kenya. The plant has high demand for its nutritive and health promoting bioactive compounds that combat malnutrition and reduce human degenerative diseases. Despite its contribution to nutrition for many years, the yields of spider plant are below potential. Its supply and cultivation remain low, primarily due to unavailability of high yielding varieties. A study carried out at Ruiru and Juja Sub-counties, Kiambu County in Kenya sought to establish the influence of both nitrogen rates and genotypic variation on spider plant accessions growth as a basis for future breeding and conservation programs. A split plot experiment arranged in a randomized complete block design with three replications was used in this study. There were three nitrogen rates, i.e. 2.6 g and 5.2 g N per plant and 120 g per plant manure (2.3% N). Accessions evaluated included UGSF12, MLSF17, MLSF3, UGSF14, UGSF25, UGSF36, IP3 and UGSF9 and commercial variety P6. Data was collected on leaf size, plant height, number of leaves, leaf area, stem size and petiole size. Data obtained was analysed using Analysis of variance and significant means separated using LSD at $\alpha = 0.05$. The results indicated that accessions MLSF3, UGSF36, UGSF14 and MLSF17 produced the highest number of flowers, large petioles, big stem sizes and large leaf area, respectively. The study recommends adoption of accessions MLSF3, MLSF17, UGSF36 and UGSF14 by breeders in the breeding programs for commercialization.

Key words: *Accessions, African leafy vegetable, Cleome gynandra, growth parameters*

INTRODUCTION

Spider plant (*Cleome gynandra* L.) belongs to the family Capparaceae of the order Capparales (Porter, 1967; Cronquist, 1988). Capparaceae is made up mostly of two sub-families: Capparoideae, which are mainly woody and Cleomoidaea, which are herbaceous (Porter, 1967). *Cleome gynandra* is wide spread in the tropics as a weed and it is native to Africa, South America, Asia and Middle East (Chweya and Mnzava, 1997; Fletcher, 1999). It is an annual herb commonly used as a vegetable in the tropics (Fox and Young, 1982) and is related to the Brassicaceae (Hall et al., 2002), which includes the model plant, *Arabidopsis thaliana*. Spider plant is erect, mainly branched with a long tap root. The height of the plant varies between 0.5 m and 1.5 m, depending on the environment. Leaves are alternate, palmately compound with three to seven leaflets. Stems and leaves are covered with glandular hair. Pigmentation on the stems varies from green to pink and purple. The terminal inflorescences have very distinct small white flowers, but pink and lilac coloured flowers also occur. These plants flower mostly at night after a minimum number of palmately compound leaves have been formed (Iltis, 1967).

Spider plant *(Cleome gynandra* (L.) is among the most important traditional leafy vegetables widely used in Africa (Schippers, 2000). In English, *Cleome gynandra* is known as spider flower or plant, cats' whiskers, spider wisp, and African cabbage. This tropical plant has different names among the African dialects. Among the different *Cleome* species, *Cleome gynandra* is the most widely used as a leafy vegetable but *Cleome monophylla* and *Cleome hirta,* which are close relatives, are also used occasionally (Vorster and Jansen, 2005). Accordingly, spider plant is used as both food and medicine. It was noted by Oniang'o *et al*. (2008) that ALVs, which are rich in micronutrients and vitamins, could play an important role in alleviating hunger and malnutrition. The plant has been evaluated for nutrient content and showed to have high values especially for calcium, magnesium, iron, zinc, vitamin A, C and E (Oniang'o *et al*., 2008), making it suitable for combating malnutrition and life style diseases especially in Sub-Saharan Africa (WHO/FAO, 2012). The African leafy vegetables (ALVs) have several advantages over other exotic vegetables. They have high nutritive value (Letting, 2018), medicinal value and health benefits (Oniang'o *et al.,* 2008).

The-ALVs are also important in conserving a rich diversity of accessions of importance for future generations and breeding (Chadha *et al*., 2007). Despite the above benefits, Commercial spider plant varieties are limited in terms of growth and yield. Additionally, production areas are concentrated only in some agro-ecological zones (AEZ) and it is not known which accessions gives high yields under different nitrogen treatments. According to Kenya Genetic Resources Research Institute, there are only two spider plant accessions that have been collected in Kiambu County as landraces, compared to Nyamira and Busia with 39 and 24 respectively. To address these bottlenecks, there is dire need to introduce suitable new varieties with superior agronomic characteristics. Evaluation and selection of these new varieties should be scientific and be done under local environmental conditions in Kiambu. This approach corroborates the Kenya Government Big Four Agenda that is part of Vision 2030 Blueprint, to enhance food and nutritional security in the country (PSC, 2018).

MATERIALS AND METHODS

Experimental Sites

Ruiru

Field experiments were conducted in Ruiru ward situated in Kiambu County, Kenya, between October – December 2011 and April – July 2012; its geographical coordinates are latitude 1° 9' 0" S, and longitude 36° 58' 0" E. The area is classified under sub-tropical highland climate, by Köppen climate classification system, receives average annual rainfall of 1,025 mm. Temperature range is 10 – 26 °C with altitude of 1,795 m above sea level. The soils are typically red on an undulating topography. Main human activities include coffee farming, dairy, and horticulture (Mwaura, 2013).

Juja

Another field trial was conducted at the department of Horticulture & Food Security, Jomo Kenyatta University of Agriculture and Technology (JKUAT) main campus farm between June and September, 2012. Greenhouse trials were set up at JKUAT between March-June, and June-September 2012. The JKUAT geographical coordinates are latitude 1° 10' 48" S and longitude 37° 07' 12" E. The soils are acrisols with increase of clay content in sub-soil (Gachene and Kimura, 2003; FAO, 2006).

Experiments

Field Experiments

The field experiments were laid out as a split-plot in a completely randomized block design (CRBD), with three replications and three nitrogen rates. There were nine spider plant accessions in Ruiru (IP3, MLSF17, MLSF3, UGSF9, UGSF12, UGSF25, UGSF36, UGSF14 and P6 while in Juja, five accessions; MLSF17, control (P6), UGSF14, UGSF36 and UGSF9 were evaluated.

Nitrogen treatments in both field sites (Ruiru and Juja) were; 120 g/plant of well-decomposed cattle manure, 2.6 and 5.2 g N/plant. The manure was composed of 2.3% N. The nitrogen rates were the sub-plots while the accessions formed the main plots. Three soil samples were randomly collected from the project site and taken for laboratory analysis at JKUAT for residual nitrogen and pH. Mean nitrogen level of 0.04% in the soil was found to be insufficient, thus the need to add more. Prior to seeding, the low pH was corrected to 6.2 by raking in and incorporating calcitic agricultural lime in the soil at a rate of 20 g/m^2 after the soil analysis.

The land was ploughed and well prepared by removing all plant debris, stones and clods. Plots measuring 1.2 m by 10 m were raised and polyethene paper was placed 45 cm vertically in the soil between the plots to minimize nitrogen movement between treatments. Direct sowing was done on finely tilled and raised beds where seeds were placed in shallow furrows 5 − 10 mm deep made at a spacing of 30 cm between furrows. The furrows were covered lightly using loose soil, mulched by hay grass and irrigated. The beds were regularly watered to keep them moist. The seeds began to germinate four days after planting. Termites were controlled by drenching beds with Gladiator® (active ingredient: *chlorpyrifos*) at dilution rate of 20 ml per litre of water. Irrigation and weeding were undertaken constantly after germination. Three weeks after planting, thinning was done to remove weak plants leaving intra-row plant spacing of 10 cm. Plant population per sub-plot was determined through physical counting. The fertilizer CAN treatments were applied in two splits, with the first half being applied after thinning and the second half at two weeks later. The fertilizer was weighed according to the plant population and its respective fertilizer rate. It was applied along drills on the plots and carefully incorporated into the soil. Each row of plants was in between two fertilizer drills on either side to avoid plant damage by scorching.

Greenhouse Trials

Two greenhouse trials were undertaken at JKUAT, Juja, for five accessions after conducting field experiments. The best performing five accessions from the field experiment were then evaluated in the greenhouse. The accessions were MLSF17, control (P6), UGSF14, UGSF36 and UGSF9. Both experiments were laid out as a complete randomized design (CRD) with three replications. The total number of pots in the greenhouse was 225, with capacity of four litres each. There were five accessions, each under three nitrogen treatments replicated thrice. This set up of 45 pots was then replicated five times to cater for plants that were required for five rounds of destructive sampling, thus total 225 plants. The soil used in this study was a mixture of red soil and black cotton soil (weight ratio 1:1), with composite nitrogen level of 0.04% N and pH corrected to 6.2. Average diurnal indoor temperatures ranged from 15-37 ^{o}C for the first season and 11-31 ^{o}C for the second season. Temperature was measured using thermometer (model: *Sinokit DT-3*) that was kept in the greenhouse throughout the two trials. The plastic pots were each filled with four kilogram of air-dried soil each. Ten seeds of each accession were then sown in each of the pots, watered and mulched using dry grass. Watering was done by hose pipe daily to keep the soil moist. Thinning of weak seedlings was done before treatment, leaving one plant/pot.

The nitrogen treatments of 0 (control), 2.6 and 5.2 g N/plant were applied in four splits, with first quarter of the nitrogen level at three weeks after planting, and the rest four days apart after planting using CAN (26% N) fertilizer. Aphids were controlled by spraying with pirimor® (2-Dimethylamino-5,6-dimethylpyrimidin-4-yl dimethyl-carbamate), at 2.5 mg per litre of water. During flowering, the flowers were removed daily to encourage vegetative growth.

Destructive and non-destructive sampling was done at ten days interval starting from the day the first nitrogen split was applied. Plant height only for the sampled plants was measured weekly by use of a meter rule and the number of leaves counted. Total chlorophyll concentration in leaves was measured weekly using the portable chlorophyll meter (*SPAD-502,* Minolta, Japan) for different nitrogen treatment. Chlorophyll content influences growth rates of plants (Fageria and Baligar, 2005). The device instantly provided a measure of leaf chlorophyll content each time measuring the tenth youngest leaf on the main stem, without damaging the leaf. A total of five harvests were made throughout the growing season. At each harvest, one plant was selected randomly and cut at the stem base for each nitrogen rate and accession. The shoots were then divided into the stem, leaf blades and petioles. The area of the leaf blades was measured by using leaf area meter *(model 3100 LICOR* Lincoln Nebraska. USA,). The plant parts were then oven-dried at 72 ^{o}C for 72 hours, then weighed to obtain the dry weights.

Data Analysis

Analyses of variance (ANOVA) were done using SAS computer software (SAS 9.1.3) for dry weight, leaf area, height, number of leaves and chlorophyll using SPAD meter. The level of significance was at $\alpha = 0.05$ and significant means were separation was done using Least Significance Difference (LSD).

RESULTS

There was a significant ($p < 0.05$) for the interaction between nitrogen rates and spider plant accessions during short rain seasons at sixth and seventh week of harvesting in the field experiment (Table 1). However, the interaction was not significant at fifth, eighth and ninth week of harvesting. Accession P6, MLSF3, MLSF17 and UGSF9 produced significantly taller plants than other accessions when manure was used at both harvesting periods (Table 1).

Interaction effect between nitrogen rates and spider plant accessions on plant height in greenhouse during long and short rain seasons

There was a significant ($p < 0.05$) interaction between nitrogen rates and spider plant accessions on the plant height in the greenhouse experiment during both long and short rain seasons at sixth, seventh, eighth and ninth week of harvesting (Table 2). However, the interaction was not significant at fifth week of harvesting in the long rains and fifth, sixth, eighth and ninth week of harvesting in the short rain season. Accessions UGSF9, P6 and MLSF17 produced the tallest plants under 2.6g N/plant and manure during both harvesting periods (Table 2).

Doubling nitrogen rates did not have significant effect on height. Farmers would therefore, better use lower rate of 2.6g N/plant as opposed to 5.2g N/plant for economic and phytotoxicity reasons. Currently, there are conversations at both local, regional and global level to reduce external inputs, thus reduce cost of production as well as environmental concerns.

Table 1: Interactive effect between nitrogen rates and spider plant accessions on height in open field during short rain season.

Accession	Treatments	Harvesting period (in weeks after sowing)	
		6	7
P6	Manure	41.33a	72.33a
	2.6 g N/plant	27.33bc	45.33bc
	5.2 g N/plant	25.33bc	45.00bc
MLSF17	Manure	31.33ab	67.33ab
	2.6 g N/plant	32.00ab	52.67ab
	5.2 g N/plant	33.33ab	52.33ab
MLSF3	Manure	39.67ab	67.67ab
	2.6 g N/plant	26.33bc	39.67bc
	5.2 g N/plant	25.33bc	40.00bc
UGSF9	Manure	37.67a	73.33ab
	2.6 g N/plant	24.33bc	39.67bc
	5.2 g N/plant	24.33bc	40.67bc
UGSF12	Manure	36.67ab	61.67ab
	2.6 g N/plant	22.67c	39.00bc
	5.2 g N/plant	25.33bc	47.00ab
UGSF25	Manure	35.67ab	56.33ab
	2.6 g N/plant	25.33bc	41.33bc
	5.2 g N/plant	25.67bc	40.00bc
UGSF36	Manure	28.67bc	47.67b
	2.6 g N/plant	20.33c	42.33bc
	5.2 g N/plant	21.00c	51.33ab
IP3	Manure	26.33bc	44.33bc
	2.6 g N/plant	20.67c	33.67bc
	5.2 g N/plant	24.00bc	37.67bc
UGSF14	Manure	33.33ab	49.33ab
	2.6 g N/plant	27.00bc	46.00bc
	5.2 g N/plant	27.33bc	38.00bc
LSD		5.41	13.23
AxN		*	**

Means in a same column followed by different letter (s) are significantly different at $\alpha = 0.05$.
* Significant at α=0.05** Significant at α=0.01

Interaction effect between nitrogen rates and spider plant accessions on the number of leaves in Ruiru during long and short rain season

There was a significant ($p < 0.05$) interaction between nitrogen rates and spider plant accessions on the number of leaves in the field experiment during both long and short rain seasons at sixth, seventh and eighth week of harvesting (Table 3). However, the interaction was not significant at fifth, sixth and ninth week of harvesting in the long rains and fifth, seventh, eighth and ninth week of harvesting in the short rain season. Accession UGSF36, UGSF14, MLSF17, MLSF3 and IP3 produced the highest number of leaves under 2.6g N/plant and manure application (Table 3).

The number of leaves is generally a genotypic trait whereby UGSF36 has the highest number. However, it can also be influenced phenotypically by rate and form of nitrogen. For instance, nitrate-N encourages more leaf nodes as opposed to ammoniacal-N.

Table 2: Interaction effect between nitrogen rates and spider plant accessions on plant height in greenhouse season 1 and 2

Accessions	Treatments	Season 1				Season 2
		6	7	8	9	7
MLSF17	Manure	26.00ab	45.00ab	55.33ab	62.00ab	41.67ab
	2.6 g N/plant	23.67ab	30.67ab	39.00ab	48.33b	52.00ab
	5.2 g N/plant	24.00ab	34.00ab	46.00ab	59.00ab	53.33ab
UGSF14	Manure	24.67ab	33.33ab	43.00ab	53.00ab	67.00ab
	2.6 g N/plant	21.33ab	32.00ab	39.33ab	51.33ab	55.33ab
	5.2 g N/plant	25.33ab	38.67ab	46.33ab	53.67ab	50.33ab
UGSF36	Manure	26.67ab	33.67ab	43.00ab	51.33ab	47.33ab
	2.6 g N/plant	23.33ab	32.67ab	45.67ab	53.33ab	54.67ab
	5.2 g N/plant	24.67ab	36.00ab	47.00ab	57.00ab	58.00ab
UGSF9	Manure	23.33ab	34.33ab	43.00ab	54.33ab	59.67ab
	2.6 g N/plant	26.00ab	51.00ab	60.00ab	70.00ab	45.67ab
	5.2 g N/plant	24.67ab	35.33ab	48.00ab	59.33ab	58.67ab
P6	Manure	22.67ab	30.67b	42.33ab	50.67ab	61.67ab
	2.6 g N/plant	26.00ab	36.67ab	48.00ab	61.67ab	57.00ab
	5.2 g N/plant	23.67ab	39.33ab	48.67ab	55.67ab	66.67ab
LSD		3.48	9.20	10.42	12.51	12.82
AxN			*		**	

Means in a same column followed by different letter (s) are significantly different at α = 0.05.
* Significant at α = 0.05** Significant at α = 0.01

Discussion

Results indicate that the interactive effect of accessions and nitrogen rates produced tall plants under manure application in all accessions than mineral nitrogen application (Table 1 and 2). This was demonstrated both in open field and greenhouse experiments. Mineral nitrogen which produced tall spider plants was at the rates of 2.6g of N/plant as opposed to 5.2g of N per plant (Table 2). Nitrogen is an important nutrient that is constituent of amino acids, proteins and DNA that is responsible for cell division, plant metabolism and growth (Mutua, 2015). It is the major component of chlorophyll that is a growth factor which is the backbone of photosynthesis. Mineral fertilizer releases nitrogen faster than manure, which is a slow release, thus takes longer time to mineralize in the soil. In principle, manure-nitrogen will be available to the plants for a longer period due to lower prevalence to leaching and/or volatilization. Besides nitrogen, manure also has other important plant nutrients that are essential for plant growth. Manure is an important source of essential plant nutrients and organic matter for crop production (Kipkosgei, 2004; Ogendo *et al.,* 2008; Letting *et al*., 2018). It leads to improved soil physical properties, water-holding capacity, cation exchange capacity (Murage, 2000; Yafan *et al*., 2004; Rosin *et al*., 2009). Letting 2018). Nutrients in manure are released over a long period of time, which can be up to three years (Ng'etich, 2004). Manure also reduces soil carbon to nitrogen ratio, thus facilitating speedy nitrification (Fageria and Balkar, 2005). Manure thus, is advantageous as composite source of other primary, secondary and trace elements besides N (Sawyer, 2009). Manure makes soil healthy and living by promoting beneficial microbes' activity (Schoenau, 2006) such as nitrifying bacteria.

Previous research has shown that application of nitrogen increased fresh and dry above-ground biomass in leafy vegetables between rates of 100-250 kg N/ha (van Averbeke *et al*., 2007). These results corroborate the study by Kipkosgei (2004) that most indigenous vegetables perform better when fertilizers are used compared to when they are grown without fertilizers. These results also substantiate the study by Flexas (2008), which found that nitrogen supply has large effect on leaf growth because it increases the leaf area of plants thus, influences on photosynthesis. Accordingly, photosynthetic proteins represent a large proportion of total leaf nitrogen.

Table 3: Interactions between nitrogen rates and spider plant accessions on the number of leaves in the 6th, 7th and 8th harvesting week in Ruiru season one and two

Accessions	Nitrogen rates	Season 1		Season 2
		7	8	6
P6	Manure	11.00ab	12.33b	23.67bc
	2.6 g N/plant	10.00ab	12.00b	19.00bc
	5.2 g N/plant	11.00ab	12.67b	19.00bc
MLSF17	Manure	11.33ab	13.33ab	29.00ab
	2.6 g N/plant	14.00ab	11.67b	16.00bc
	5.2 g N/plant	11.33ab	14.33ab	15.67bc
MLSF3	Manure	12.33ab	13.67ab	35.67bc
	2.6 g N/plant	14.67ab	17.67ab	17.33bc
	5.2 g N/plant	12.33ab	15.00ab	16.67bc
UGSF9	Manure	12.67ab	14.00ab	27.67ab
	2.6 g N/plant	12.67ab	15.00ab	18.67bc
	5.2 g N/plant	11.33ab	13.33ab	19.67bc
UGSF12	Manure	11.33ab	14.00ab	15.33bc
	2.6 g N/plant	10.67ab	12.00b	17.33bc
	5.2 g N/plant	12.33ab	15.33ab	14.67c
UGSF25	Manure	14.33ab	15.33ab	16.00bc
	2.6 g N/plant	12.33ab	14.67ab	21.00bc
	5.2 g N/plant	13.00ab	17.00ab	15.67bc
UGSF36	Manure	12.00a	15.00ab	20.33bc
	2.6 g N/plant	15.67ab	22.00a	16.33bc
	5.2 g N/plant	12.67ab	15.67ab	15.67bc
IP3	Manure	12.00ab	13.33ab	21.33bc
	2.6 g N/plant	13.00ab	16.67ab	23.00bc
	5.2 g N/plant	15.00ab	19.33ab	20.00bc
UGSF14	Manure	15.67a	21.00ab	19.67bc
	2.6 g N/plant	11.67ab	13.00ab	16.67bc
	5.2 g N/plant	12.33ab	14.00ab	21.00bc
LSD		2.68	4.97	21.00bc
AxN		**	*	***

Means in a same column followed by different letter (s) are significantly different at P<0.05 * Significant at α=0.05 ** Significant at α=0.1*** Significant at α=0.01

Accessions UGSF36, IP3, UGSF14, MLSF17 and MLSF3 produced the highest number of leaves under 2.6g N/plant and application of manure (Table 3). Yields are determined based on the number of leaves produced. Improvement through selection of accessions of spider plant has intensified in the recent past (Onim and Mwaniki, 2008; Masinde, 2011), since commercial varieties have shortfalls such as yield, nutrient, and geographical diversity. Limited access to quality seed and shortage of suitable cultivars has been key cause of low spider plant productivity (Abukutsa-Onyango, 2009). Commercial farmers apply nitrogen in order to obtain higher yields of spider plant.

Agong and Masinde, 2006, Mauyo *et al*. (2008) have shown that applying nitrogen significantly increased plant height, number of leaves and shoots, and fresh yields of spider plant which is either organic or inorganic. Use of inorganic and organic fertilizers significantly improved yields of *Brassica oleracea* var *oleracea* (Wambani *et al*. 2006; Yamika and Ikawati, 2012). Although it was not a component of this study, literature has shown that crop higher yields were obtained when organic and inorganic sources were combined (Herman, 2011). Mtambanengwe *et al*. (2006) observed that nitrogen availability from low quality organic materials can be improved with the application of inorganic fertilizer.

There was significant difference between yield from manure and fertilizer. However, there was no significant difference among the two rates of nitrogen fertilizers. Therefore, farmers would rather apply the lower rate of fertilizer nitrogen of 2.6 g per plant or less, in order to save cost and also conserve the environment. Excess nitrogen causes non-point source nitrate pollution of groundwater, when it is lost through leaching and/or runoff that cause eutrophication of water bodies (Alva *et al.*, 2008). It also volatizes into the atmosphere as nitrous oxide that accelerates global warming. When applied at high rates as fertilizer, plants continue to uptake (nitrogen) thus, causing phytotoxity (Mutua, 2015). When eaten, such crops can have high level of nitrogen dosage beyond recommended daily intake. Many plants, especially leafy vegetables, accumulate nitrate under low light conditions as uptake of nitrate exceeds reduction. Plants adapted to higher pH and more aerobic soils prefer nitrate uptake as opposed to ammonium or amino acids (Maathius, 2009). Nitrate may harm the health of the consumer as it is converted to nitrite causing methemoglobinemia or carcinogenic nitrosamines (Blom-Zandstra, 2008). Acceptable daily intake (ADI) for nitrate of 0–3.7mg nitrate ion/kg body weight (WHO/FAO, 2012).

The level of management is a critical factor influencing spider plant fresh leaf yields. Besides the genetic influence, growing conditions and management practices undertaken during growth have important bearing on crop nutritional status (Hutchinson *et al.*, 2006). Application of manure and/or mineral fertilizer and the stage of maturity of spider plant are critical in determining the nutritional, phytochemical and sensory characteristics of the vegetable (Kebwaro, 2013). The improvement in yields for the second season in Ruiru was also attributed to better management coupled with lessons learnt from the previous season. Irrigation was done on a regular basis to keep top soil at field capacity is key, since absorbing roots occupy the top 2-3 cm of soil. Spider plant is highly susceptible to water stress (Masinde, 2003). Regular deflowering of young flower buds as they form is important in extending harvesting duration. This practice delays early plant senescence and is usually done by hand (Mutua, 2015; Wangolo, 2015).

CONCLUSION AND RECOMMENDATIONS

Spider plant accessions when interacted with various nitrogen rates significantly influence both qualitative and quantitative traits of the crop. UGSF36, IP3, MLSF17, MLSF3 and UGSF14 produced more leaves when 2.6g N/plant and manure was applied than all other accessions. Similarly, plant heights depended on the accession in question, and accessions UGSF9, MLSF3, P6 and MLSF17 produced tallest plants compared to all other accessions under manure application. Manure application results in tall plants and more leaves than application of mineral Nitrogen. Farmers should apply no more than 2.6g N/plant as opposed to doubling the rates that would otherwise increase cost of spider plant production, thus making it unsustainable.

In conclusion, the study recommends adoption of accessions MLSF17, UGSF14, UGSF9, IP3, MLSF3, P6 and UGSF36 for adoption by breeders for future selection and commercialization. The seven accessions exhibited outstanding positive effect on phenotypic traits of number of leaves and stem height. To enhance yield levels of spider plant, the study recommends adoption of accessions UGSF36, IP3, UGSF14, MLSF17 and MLSF3 for production in Kiambu County because they produce more leaves than all other accessions including the control P6. However, it is recommended to undertake phytochemical analysis for each accession in order to determine the effect of applying different rates of nitrogen on plant toxin accumulation.

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CONFLICT OF INTEREST
The author declares no conflict of interest in this paper. The content presented in this paper is the responsibility of the author and does not necessarily reflect the views of NACOSTI, WVC or JKUAT.

REFERENCES
Abukutsa-Onyango, M. (2007). The diversity of cultivated African leafy vegetables in three communities in western Kenya. *African Journal of Food, Agriculture, Nutrition and Development,* 7 (3).

Alva, A. K., Paramasivam, S., Fares, A., Delgado, J. A., Mattos, D. Jr. and Sajwan, K. (2008). Nitrogen and irrigation management practices to improve nitrogen uptake efficiency and minimize leaching losses. *Journal of Crop Improvement*. 15: (2) 369-80.

Chadha, M. L., Oluoch, M.O. & Silue, D. (2007). Promoting indigenous vegetables for health, food security, and income generation in Africa. *Acta Hort. (ISHS)* 762:253-62.

Chweya, J.A. and Mnzava, N.A. (1997). Cat's whiskers, Spider plant: Promoting the conservation and use of underutilized and neglected crops. *Institute of plant Genetics and crop plant Research, Gatersleben/International Plant Genetic Resources Institute,* Rome, Italy.

Cronquist, A. (1988). The evolution and classification of flowering plants (2nd ed). The New York Botanical Gardens, USA.

FAO. (2006). World reference base for soil resources 2006: A framework for international classification, correlation and communication, World Soil Resources reports No. 103. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fletcher, R. (1999). *Cleome gynandra* (Cat's whiskers). *The Australian New Crops Newsletter,* Issue No. 11, January, 1999.

Hall, J.C., Sytsma, K.J. and Iltis, H.H. (2002). Phylogeny of Capparaceae and Brassicaceae based on chloroplast sequence data. *American Journal of Botany.* 89: 1826–1842

Herman, M. (2011). Inorganic fertilizer vs. cattle manure as nitrogen sources for maize (*Zea mays L.*) in Kakamega, Kenya. *JUROS.* 2: (22).

Iltis, H.H. (1967). Studies in the *Capparidaceae.* XI. *Cleome afrospina*, a tropical African endemic with neotropical affinities. *American Journal of Botany*. 54: 953-962.

Kebwaro, D.O., Onyango, C.A., Sila, D.N., Masinde, P.W., Nyaberi, M. N. and Mutoro, K. (2013). Influence of nitrogen application on total phenolics and flavonoids during growth of five selected accessions of spider plant (*Cleome gynandra* L.). *JKUAT online repository*.

Kipkosgei, L. (2004). Response of African nightshades (*Solanum villosum*) and spider plant (*Cleome gynandra* L.) to farmyard manure and calcium ammonium nitrate fertilizer and pest infestation in Keiyo District, Kenya. M. Sc. Thesis, University of Nairobi, Kenya.

K'opondo F.B.O., Muasya R.M., Kiplagat O.K. (2010), A review on the seed production and handling of indigenous vegetables (spider plant, jute mallow and African nightshade complex) In: M.O. Abukutsa- Onyango., A.N Muriithi., V.E. Anjichi., K. Ngamau., S.G. Agong., A. Fricke., B. Hau., H. Stutzel. (Eds). (2004). Proceedings of the third horticulture workshop on sustainable horticultural Productions.

Letting, F., Ochuodho, J.O, O. and Omami, E. (2018). Influence of Fertilizer Types on Seed Quality Aspects of Indigenous Vegetables. *African Journal of Education, Science and Technology*, 4(3), 101-111. Retrieved from http://www.ajest.info/index.php/ajest/article/view/111.

Masinde, W. P. (2003). Effects of water stress on growth of spider plant [*Gynandropsis gynandra* (L.) Briq.] and African nightshade (*Solanum* spp.), two traditional leafy vegetables in Kenya. PhD thesis, Institute of Fruit and Vegetable Production, University of Hannover, Germany. pp 1-9.

Masinde, W. P. and Agong, G. S. (2011). Plant growth and leaf N of spider plant under varying nitrogen supply *African Journal of Horticultural Science*. 5: 36-49.

Mtambanengwe, F., Mapfumo, P. and Vanlauwe, P. (2006). Comparative short-term effects of different quality organic resources on maize productivity under two different environments in Zimbabwe. *Nutrient cycling in Ecosystems.* 76: 271-284.

Mutua, M.C. (2015). Morphological characterization and response of spider plant (*Cleome gynandra* L.) to NPK fertilizer rates and deflowering. MSc Thesis, Department of Crops, Horticulture and Soils. Egerton University. Kenya. pp 15.

Murage, E. W., Karanja, N. K., Smithson, P. C. and Woomer, P. L. (2000). Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. *Agriculture, Ecosystems & Environment.* 79: (1) 1-8.

Mwaura, S. N., Muluvi, A. S. and Mathenge, M. K. (2013). African leafy vegetables and household wellbeing in Kenya: A disaggregation by gender. Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, 22-25 September, 2013. Hammamet, Tunisia.

Ng'etich, O. K., Aguyoh, J.N. and Ogweno, J. O. (2012). Effects of composted farmyard manure on growth and yield of spider plant (*Cleome gynandra*). *International Journal of Science and Nature*. 3: (3) 512-20.

Oniang'o, R. and Shiundu K. (2008). Marketing African Leafy Vegetables: Challenges and Opportunities in the Kenyan Context. African Journal of Food, Agriculture, Nutrition and Development. 7 (4).

Onim, M. and Mwaniki, P. (2008). Cataloguing and evaluation of available community/farmers-based seed enterprises on African indigenous vegetables (AIVs) in four ECA countries. *Lagrotech Consultants*. Kisumu. pp 18-21.

PSC. (2018). Eye on the Big Four. Parliamentary Service Commission. Parliament of the Republic of Kenya. 11th Edition of the Budget Watch (2018/19). pp 21-4.

Rosin, C. and Campbell, H. (2009). Beyond bifurcation: Examining the conventions of organic agriculture in New Zealand. *Journal of Rural Studies*. 25: 35-47.

Sawyer, J. (2009). Manure nutrient values. Iowa State University. Agronomy Extension Soil Fertility.

Schippers, R.R. (2000). African indigenous vegetables: an overview of the cultivated species. Chatham, UK: Natural Resources Institute/ACP-EU Technical

Centre for Agricultural Rural Cooperation, pp. 25-31.

Schoenau, J. J. (2006). Benefits of long-term application of manure. *Advances Pork Production*. 17: 153.

Vorster, H.J. and Jansen van Rensburg, W.S. (2005). Traditional vegetables as a source of food in South Africa: Some experiences. African Crop Science Conference Proceedings. 2005; 7: 669-671.

Wambani, H., Nyambati, E. M. and Kamidi, M. (2008). Evaluation of legumes as components of integrated soil nutrient management for kale production. *African Journal of Horticultural Science*. 1: 91-9.

Wangolo, E. E., Onyango, C. M. Gachene, C. K. K. and Mong'are, P. N. (2015). Effects of shoot tip and flower removal on growth and yield of spider plant (*Cleome gynandra* L.) in Kenya. *American Journal of Experimental Agriculture.* 8: (6) 367-76.

WHO/FAO. (2012). Report of the Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization of the UN/WHO and the European Commission's Scientific Committee on Food. pp 3.

Yafan, H. and Barker, A.V. (2004). Effect of composts and their combinations with other materials and their combinations with other materials on nutrient accumulation in tomato leaves. Communications in *Soil Science and Plant Analysis*, 35: (19-20) 2809- 2823.

Yamika, W.S.D. and Ikawati, K.R. (2012). Combination of inorganic and organic fertilizer increased yield production of soybean in rain-field Malang, Indonesia. *American-Eurasian Journal of Sustainable Agriculture.* 6: (1) 14-7.

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