International Journal of Plant & Soil Science
8(6): 1-8, 2015; Article no.IJPSS.21331
ISSN: 2320-7035

SCIENCEDOMAIN ***international***
www.sciencedomain.org

NPK Fertilization and Deflowering Increases Leaf Yield and Extends the Vegetative Phase of *Cleome gynandra* L.

Carol M. Mutua[1], Richard S. Mulwa[1] and Joshua O. Ogweno[1*]

[1]Department of Crops, Horticulture and Soils, Egerton University, P.O.Box 536-20115, Egerton, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. Author CMM was responsible for performing experiments, data collection, interpretation of results and manuscript preparation. Authors JOO and RSM conceived and designed the experiments and edited the manuscript. They also provided for the reagents and materials, bench fees and analyzed the data.

Article Information

DOI: 10.9734/IJPSS/2015/21331
Editor(s):
(1) Fatemeh Nejatzadeh, Department of Horticulture, Faculty of Agriculture, Khoy Branch, Islamic Azad University, Iran.
Reviewers:
(1) Willem Jansen van Rensburg, Vegetable and Ornamental Plant Institute, South Africa.
(2) Felix M. Chipojola, Ministry of Agriculture, Malawi.
Complete Peer review History: http://sciencedomain.org/review-history/11626

Original Research Article

Received 12th August 2015
Accepted 21st September 2015
Published 29th September 2015

ABSTRACT

Spider plant (*Cleome gynandra* L.) is among some of the African Leafy Vegetables whose consumption is on the increase in Kenya. Production of the vegetable is constrained by low leaf yields resulting from, among others causes, the short vegetative phase of the plant. In trying to address these problems, a study was conducted at Egerton University, Kenya, in 2014-2015 to investigate the effects of various levels (0, 100, 200, 300 and 400 kg of Nitrogen-Phosphorus-Potassium ha^{-1} fertilizer and deflowering and no deflowering. The experiment was a 5x2 factorial arrangement in Randomized Complete Block Design (RCBD) with 10 treatment combinations. Data collected included number of primary branches, plant height, fresh and dry leaf weight and the harvest period in weeks. Data were analyzed using analysis of variance with the SAS statistical package. Means were separated using Tukey's Honestly Significant Difference. Results indicated that deflowering and NPK fertilization significantly ($P \le 0.05$) influenced the fresh leaf yield, dry leaf weight, number of primary branches, plant height and significantly extended the harvest period.

**Corresponding author: E-mail: ogwenojoshua@gmail.com;*

Application of 300 kg NPK ha^{-1} combined with deflowering gave the highest leaf yield of 1090.32 kg ha^{-1} and 873.24 kg ha^{-1} in season 1 and 2 respectively compared to the other treatment combinations. This combination also gave the highest number of primary branches per plant and extended the harvesting period by eight weeks in both seasons compared to the control. In conclusion the application of 300 kg ha^{-1}of NPK fertilizer and deflowering is a horticultural management solution to the low productivity of spider plant vegetable.

Keywords: Cleome gynandra; deflowering; NPK fertilizer; leaf yield.

1. INTRODUCTION

Cleome gynandra is one of the African Leafy Vegetables (ALVs) that have not been given much attention in horticulture [1]. As a result it has remained a mostly wild, semi- cultivated or under small-scale production [1]. Production and utilization of spider plant is now being encouraged as awareness of its medicinal properties, nutritional value, and economic value increases [2]. The share of ALVs in terms of the domestic value was 5% even though the quantity produced was 11% of all the vegetables produced in Kenya in the year 2012 [3]. Spider plant is used as a vegetable and the tender leaves, flowers, shoots are consumed after boiling them in water or milk alone or in combination with other vegetables and spices [4]. The leaves may be crushed to make a drink which is used to cure diseases such as scurvy [5]. Eating the vegetable is also known to reduce dizzy spells in pregnant women, reduce the length of time taken in labor and helps to regain normal health after child birth [6]. It contains anti-oxidants that scavenge and bind harmful radicals in the body which if left could cause diseases like cancer and diabetes [7]. The leaves of C. *gynandra* have repellant and an acaricidal property for the larvae, nymphs and adults ticks [4]. Intercropping *C. gynandra* with roses in greenhouses at 8.3 plants/m^2 reduced the population of red spider mites (*Tetranychus urticae*), therefore the crop can also be used as a crop protectant [8]. The leaves are used as forage by camels, bovines, equines and game animals and the seeds are feed for birds [4].

C. gynandra is endemic in many parts of the world and is an erect herbaceous annual plant which is strongly branched and can grow to a height of about 1.5 m depending on the environmental conditions but it is usually 0.5 – 1.0 m [4].

Nutritionally, *C. gynandra* contains high levels of beta-carotene, vitamin C, and contains moderate levels of calcium, magnesium and iron. It also has high levels of crude protein, lipids and phenolic compounds [9,10]. The leaf yield of spider plant in Kenya is in the range of 1-3 tons/ha compared to the optimal range of 20-40 tons/ha [11,12]. This can be attributed to problems such as lack of quality seeds, short vegetative phase of the plant, lack of recommendations on the amount and type fertilizers to be used for optimal yields and premature flowering behavior (Bolting) [13,14]. Bolting has been attributed to responses to temperature extremes and photoperiodic effects in many vegetables [14]. Generally, bolting leads to production losses as the plants flower before they have produced an economic vegetable leaf yield, sometimes just a few weeks after emergence, if directly seeded or soon after transplanting [15]. To mitigate these problems, an experiment was designed to study the effects of different NPK fertilizer rates in combination with deflowering with a view to improving leaf yields and extending the harvest period for the vegetable by increasing the vegetative phase of growth.

2. MATERIALS AND METHODS

The study was conducted at Egerton University, Kenya (0º23' S, longitudes 35º35' E) and lies at an altitude of approximately 2,238 meters above sea level. The average maximum and minimum temperature range from 19ºC to 22ºC and 5ºC to 8ºC, respectively, with a total annual rainfall ranging from 1200 to 1400 mm. The soils are well-drained sandyloam-vintricmollic Andosols [16].

The experiment was designed as a 5×2 factorial arrangement in a Randomized Complete Block Design (RCBD) with 10 treatments replicated three times. The experimental plots measured 2 × 2 m. The fertilizer was applied in the rows and mixed thoroughly with the soil before placing the seeds. Seeds obtained from Simlaws Ltd were drilled in rows spaced at 30 cm apart to give a total of six rows. Thinning was done three weeks later to create a spacing of 10 cms between the plants to provide a total of 20 plants per row for a total of 120 plants per plot. Five rates of NPK (17:17:17) fertilization (0, 100, 200, 300 and 400 kg ha^{-1}) with or without deflowering were tested. Deflowering treatments commenced four weeks after sowing and continued on daily basis until no more harvests were obtainable from the plants during the two seasons.

Data on the number of primary branches, fresh leaf yield, dry leaf weight, plant height and the number of weeks for harvesting were collected from the four middle rows in the plots consisting of 80 plants. Of these 10 plants from each second row were tagged and used to collect morphology data (plant height and number of primary branches). The remaining 70 plants were used for the application of deflowering treatments where applicable and the collection of yield data. The number of primary branches was determined by counts from the plants and the mean number of primary branches per plot computed for each treatment. Leaf harvesting commenced 50 days after sowing and continued at two week intervals. At each harvest the fresh leaf weight was determined and recorded and at the end a summation of leaf yield was computed for each treatment. After each leaf harvest data was collected, the leaf samples were dried in a hot air oven at 70^0C to constant weight. Plant height was measured from the ground level to the top most part of the leaf of the main stem and this was done when the non- deflowered plants produced pods. The length of time taken for each treatment combination to be harvested to the end was also determined in weeks. Data was analyzed using ANOVA with the SAS statistical package and significant means separated using Tukey's Honestly Significant Difference (Tukey's HSD) test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Number of Primary Branches

NPK fertilization and deflowering significantly influenced the number of primary branches. Plants which were applied with 300 kg NPK ha^{-1} and deflowered had the highest number of primary branches compared to the control in which no deflowering was done (Table 1). In season one the application of 300 and 200 kg NPK ha^{-1} were not significantly different while the application of 100, 200 and 400 kg NPK ha^{-1}gave similar number of primary branches. The control was not significantly different from the application of 100 and 400 kg NPK ha^{-1} (Table 1). In season two, the application of 300 kg NPK ha^{-1} was significantly different from the other NPK rates while application of 100 and 200 kg NPK ha^{-1}gave similar results. The application of 100, 400 and the control were also statistically identical in season 2 (Table 1). Generally, it was observed that the number of primary branches increased as the fertilizer rate increased from 0 kg to 300 kg NPK ha^{-1}. A further increase of NPK to 400 kg NPK ha^{-1}reduced the number of primary branches from the maximum attained at 300 kg ha^{-1} [17]. The reduced number of primary branches could be attributed to excess nitrogen supply which leads to reduced plant growth [18]. Plants which were deflowered had the highest number of primary branches compared to those which were not deflowered. Deflowered plants had 17.92 and 21.70 primary branches in season one and two respectively (Table 1). In the current study, the initial removal of the first inflorescence led to the production of numerous primary branches and with continued deflowering a profusion of secondary and tertiary branches ensued on which more foliage grew. Similar observations were reported on *C. gynandra* according to [15,19].

Table 1. Main effects of NPK rates and deflowering on number of primary branches of *Cleome gynandra* in season one and two

Number of primary branches		
Treatment	**Season 1**	**Season 2**
NPK (kg ha^{-1})		
0	14c	17c
100	16bc	18bc
200	17b	19b
300	20a	21a
400	15bc	18bc
Flowering type		
Deflowering	18a	22a
No deflowering	15b	17b

**Means followed by the same letter (s) within a column are not significantly different according to Tukey's HSD at P≤0.05*

3.2 Plant Height

NPK fertilization and deflowering had a significant effect on plant height. Plants which were not deflowered were the tallest compared to those which were deflowered. Plants which were applied with 300 kg NPK ha^{-1} and were not deflowered were the tallest with a mean height of 66.07 cm and 104.3 cm in season one and two respectively (Fig. 1). In season one, the plant height of plants applied with 0, 100, 200, 300 and

400 kg NPK ha^{-1} and no deflowering were not significantly different. The application of 0, 100, 200 and 400 kg NPK ha^{-1} and no deflowering were not significantly different from the application of 200 kg NPK ha^{-1} and deflowering. In season two, the plant heights of plants supplied with 0, 100, 200, 300 and 400 kg NPK ha^{-1} and not deflowered had similar heights (Fig. 1). The application of 200 kg NPK ha^{-1} and deflowering was significantly different from the other deflowering treatments (Fig. 1). Deflowering involves the removal of the terminal bud and it imparts stress to the plant and the plant requires time to overcome this condition as growth is hampered. Natural auxin concentration in the tip of the plant causes the plant to grow tall and deflowering temporarily reduces auxin and this takes away the apical dominance as it stimulates the production of side buds which grow into branches [20]. On the other hand, plants which were not deflowered showed normal vegetative growth. The deflowered plants cannot therefore exhibit normal vegetative growth and the ultimate result showed short plants compared to those which were not deflowered.

3.3 Fresh Leaf Yield

NPK fertilization and deflowering had a significant effect on the fresh leaf yield of *C. gynandra.* Plants subjected to 300 kg NPK ha^{-1} and deflowering had significantly higher leaf yields compared to the other treatments in both seasons. Plants subjected to 100, 200 and 400 kg NPK ha^{-1} in combination with deflowering and 300 kg NPK and not deflowered were statistically identical in influencing fresh yield in season one (Fig. 2). The application of 100 and 400 kg NPK ha^{-1} and deflowering gave similar results to the application of 300 kg NPK ha^{-1} and no deflowering (Fig. 1). The fresh leaf yield differences between the treatments were significantly ($P \leq 0.05$) large with about 129% increase in fresh yield when NPK was applied at 300 kg ha^{-1}. A further increase of NPK at 400 kg ha^{-1} had no effect on yield (Fig. 2).

This is indicative of an optimum level of NPK at 300 kg ha^{-1} beyond which further increase in fertilizer application becomes inhibitory to vegetative production. This could also be due to the luxury consumption of nutrients by plants. Application of nitrogen fertilizers has been reported to increase the vegetative growth and consequently the fresh leaf yields in many different vegetable crops including spider plant [17,21,22]. These studies reported further that incremental application of nitrogen as calcium ammonium nitrate increased plant height, number of shoots produced and the overall utilizable leaf and shoot yield of spider plant. On the contrary, lowest yield recorded from control plots was due to possible depletion of nitrogen and other nutrients in the soil. In the present study, the responses recorded on spider plant with NPK fertilizer could also be attributable to the effect of the nitrogen in the fertilizer. The increasing leaf yields with deflowering are supported by the increased number of primary branches (Table 1). Removal of flowers encourages vegetative growth of *C. gynandra* [17]. In *Bidens pilosa* flowering was responsible for reduction of leaf and stem growth and deflowering reduced senescence, hence maintaining vegetative growth [23]. Similarly, deflowering increased the leaf yield of *Solanum nigrum* by 40% with deflowered plants giving a leaf yield of 2154 kg ha^{-1} [24]. Continuous removal of the flowers leads to increased utilizable leaf yield of *C. gynandra* [15]. The results according to [15,17,23,24] are in agreement with our findings, that deflowering and application of NPK fertilizer increases the vegetative phase of the vegetable.

3.4 Dry Leaf Weight

NPK fertilizer rates and deflowering also had a significant effect on dry leaf weight. Plants subjected to 300 kg NPK $ha^{-1}$and deflowering had significantly higher dry leaf weight in both seasons. In season one, plants applied with 100, 200 and 400 kg NPK ha^{-1} and deflowering had similar dry weights but were not different from the results of plants applied with 200 and 300 kg NPK ha^{-1} in combination with no deflowering (Fig. 3). In season two, plants subjected to 100, 200 and 400 kg ha^{-1} and deflowering had statistically similar results, (Fig. 3). Control had the lowest dry leaf weight. In the study, incremental application of NPK also enhanced dry matter production in spider plant similar to results reported by [25] that average dry yield increases with an increase in the amount of nitrogen fertilizer applied up to a point of stagnation and a decrease in dry matter production for nitrogen deficient soils. Observations showed a general increase in the dried leaf weight as the rate of NPK increased with a maximum at 300 kg ha^{-1} (Fig. 3).

This was three times the dried leaf weight recorded in the control treatment, indicating that NPK indeed has an effect in dry matter accumulation in spider plant. The application of 3.12 g N per plant in C. *gynandra* resulted in three times higher dry leaf weight compared with treatments where nitrogen was not applied [17]. In this study, it was observed that the dry leaf weights increased with increasing NPK levels, reaching a peak at 300 kg ha^{-1} and a sudden drop when 400 kg ha^{-1} NPK was applied. The increased vegetative growth indicated by high leaf yields with increasing NPK applications also resulted in larger photosynthetic surfaces where more carbohydrate metabolites were produced and therefore contributing to high dry matter content in the leaves.

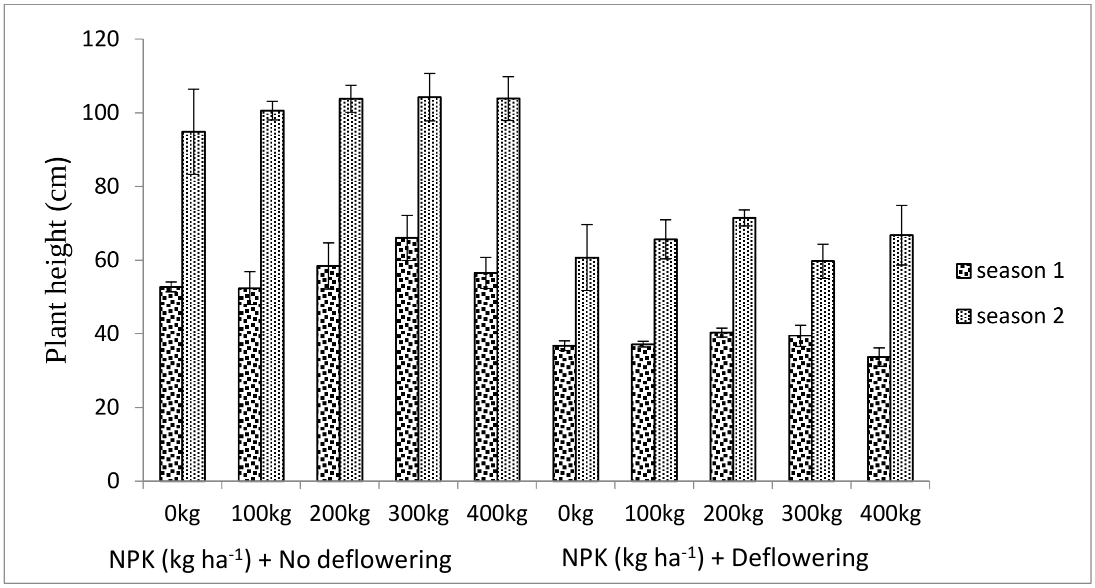

Fig. 1. Interaction between NPK rates and deflowering on plant height of *Cleome gynandra* in season one and two

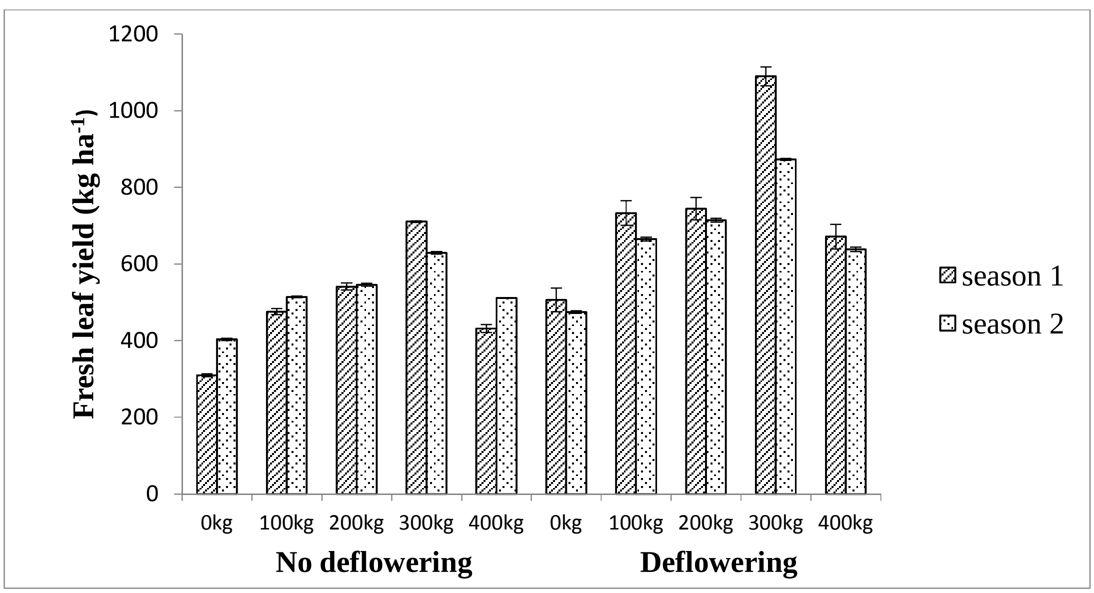

Fig. 2. Interaction between NPK rates and deflowering on fresh leaf yield of *Cleome gynandra* in season one and season two

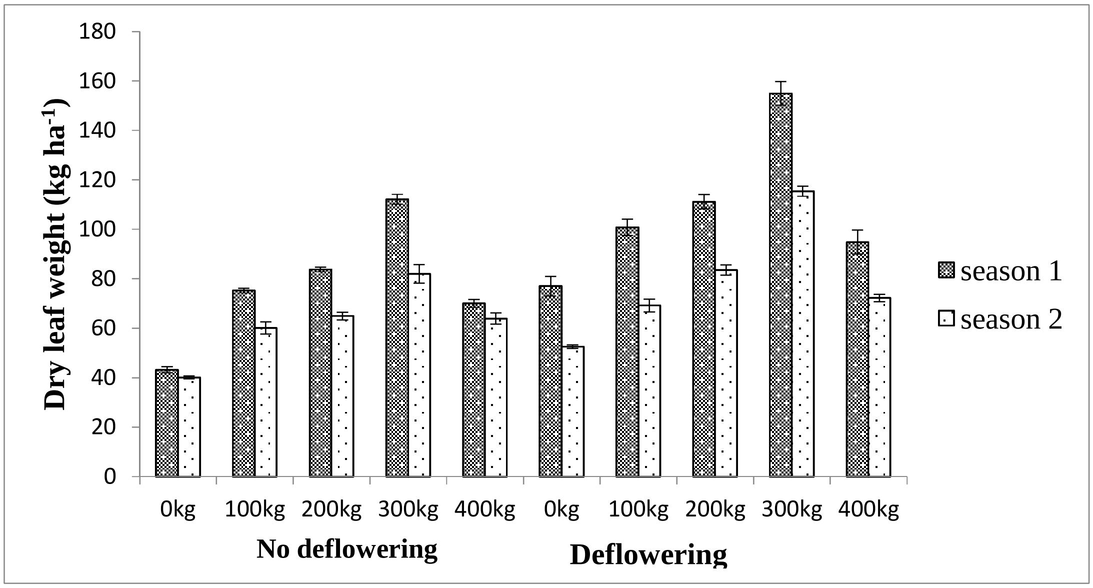

Fig. 3. Effect of NPK rates and deflowering on dry leaf weight of *Cleome gynandra* in season one and season two

3.5 Length of Harvesting Period

NPK fertilization and deflowering had a significant effect on the length of harvesting period. Combinations of deflowering and NPK fertilizer rate at 300 kg ha^{-1} extended the harvest period by eight weeks in both seasons when compared to the control where no NPK or deflowering was done (Table 2). From the foregoing, and considering the observations made with *C. gynandra* in this study, it is apparent that frequent deflowering encouraged continuous growth of lateral shoots resulting in many branches on the plants, thus increasing biomass and also extending the vegetative period. In effect, this response also helped to significantly extend the harvest periods by reducing the chances of bolting where deflowering was done.

The positive response of leaf yield due to NPK and deflowering offers a possible way to deal with the problem of low productivity in spider plant. However, it should be noted that deflowering is quite labour intensive and would only be applicable where production is on a small scale. In Kenya, this practice is well adaptable by farmers as spider plant production is carried out in small patches of land that are used to supply both domestic vegetables and some little extra to sell in the local markets. The practice can also be applied to enhance production on commercial scales but with adoption of phased planting done at intervals of 2-3 weeks to allow deflowering practice to be carried out on different small planting blocks at a time. However another study on the frequency of deflowering is recommended.

Table 2. Interaction between NPK rates and deflowering on length of the harvest period of *Cleome gynandra* in season one and two

Treatment combination	Number of harvesting weeks	
	Season 1	Season 2
NPK 0 kg + dflw	9.00c	10.00c
NPK 0 kg + no dflw	5.00e	6.00e
NPK 100 kg + dflw	10.00b	11.00b
NPK 100 kg + no dflw	6.00d	7.00d
NPK 200 kg + dflw	10.00b	11.00b
NPK 200 kg + no dflw	6.00d	7.00d
NPK 300 kg + dflw	13.00a	14.00a
NPK 300 kg + no dflw	6.00d	7.00d
NPK 400 kg + dflw	10.00b	11.00b
NPK 400 kg + no dflw	6.00d	7.00d

**Means followed by the same letter (s) within a column are not significantly different according to tukey's honestly significant difference Test at P≤0.05*

4. CONCLUSION

The problem of premature flowering and too short vegetative phase that eventually leads to a drastic reduction in utilizable vegetable leaf yield of spider plant can be resolved by adoption of an

NPK fertilizer regime of 300 kg ha^{-1} in combination with deflowering as observed in this study. This regime maximizes quality leaf yields at more than one ton per hectare and also extends the harvesting period by eight weeks.

ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation and thanks to Kenya Agribusiness Productivity Project (KAPAP), National Commission for Science, Technology and Innovation (NACOSTI), and Egerton University for the financial support of this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abukutsa-Onyango MO, Onyango JC. Conservation and seed production of African leafy vegetables at Maseno University botanic garden, Kenya. African Crop Science Conference Proceedings. 2005;7:1237-1240.
2. HCDA. Horticulture data validation report. Horticultural Crop Development Authority; 2010.
3. HCDA. Horticulture performance. Horticultural Crop Development Authority; 2010-2012.
4. Chweya JA, Mnzava NA. Cat's whiskers. *Cleome gynandra* L. 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; 1997.
5. Opole M, Chweya JA, Imungi JK. Indigenous vegetables of Kenya: Indigenous knowledge, agronomy and nutritive value. Field and Laboratory Experience Report; 1995.
6. Kamatenesi- Mugisha M, Oryem-Oringa H. Medicinal plants used to induce labor during childbirth in Uganda. J. of Ethn. Pharmacol. 2007;109:1-9.
7. Mibei EK, Ojinjo NKO, Karanja SM, Kinyua JK. Phytochemical and antioxidant analysis of methanolic extracts of four indigenous leafy vegetables. Annals Food Sc. and Technol. 2012;13(1):37-42.
8. Nyalala S, Grout B. African spider flower (*Cleome gynandra* L.)/ *Gynandropsis gynandra* (L) Briq.) As a red spider mite (*Tetranychus urticae* Koch.) repellant in cut flower rose (*Rosa hybrida* L.) cultivation. Scientia Hort. 2007;114:194-198.
9. Van Wyk B, Gericken N. People's plants. A Guide to useful plants of Southern Africa. Briza publications. Pretoria, South Africa. 2000;352.
10. Lyimo M, Temu RPC, Mugula JK. Identification and nutrient composition of indigenous vegetables in Tanzania. Plant Foods for Human Nutri. 2003;58:85-92.
11. Mulokozi G, Hedren Svanberg EU. *In vitro* accessibility and intake of β-carotene from cooked green leafy vegetables and their estimated contribution to vitamin A requirements. Plant Foods for Human Nutri. 2004;59:1-9.
12. Abukutsa-Onyango MO. Unexploited potential of indigenous African vegetables in Western Kenya. Maseno J. of Ed. Arts and Sci. 2003;4(1):103-122.
13. Abukutsa MOA. African indigenous vegetables in Kenya: Strategic repositioning in the horticulture sector. Second inaugural lecture of Jomo Kenyatta. University of Agriculture and Technology. 2010;63.
14. Masarirambi MT, Oseni TO, Shongwe VD, Mhazo N. Physiological disorders of Brassica / Cole crops found in Swaziland. A review. African J. Plant Sci. 2003;5(1): 8-14.
15. Mavengahama S. Yield response of bolted spider plant (*Cleome gynandra*) to deflowering and application of nitrogen topdressing. J. Food Agric. and Environ. 2013;11:1372-1374.
16. Jaetzold R, Schmidt H. Farm management handbook of Kenya. Natural conditions and farm management information. Ministry of Agriculture Kenya; 2006.
17. Masinde PW, Agong S. Plant growth and leaf N of spider plant (*Cleome gynandra* L.) genotypes under varying nitrogen supply. African J. Hort. Sci. 2011;5:36-49.
18. Sanchez E, Rivero RM, Ruiz JM, Romero L. Changes in biomass, enzymatic activity and protein concentration in roots and leaves of green bean plants (*Phaseolus vulgaris* L. cv. Strike) under high NH_4NO_3 application rates. Scientia Hort. 2004;99: 237–248.

19. Maumba MK. The effect of nitrogen application and deflowering on vegetative growth, yield and quality and postharvest storage stability of *Gynandropsis gynandra* (L.) Briq. MSc Thesis, Univ. Nairobi; 1993.
20. Habiba SU, Islam MS, Jamal AFMU. Influence of terminal bud pinching on growth and yield of Chrysanthemum (*Chrysanthemum indicum* L.). J. Bangladesh Academy of Sci. 2012; 36(2):251-255.
21. Mauyo LW, Anjichi VE, Wambugu GW, Omunyini ME. Effect of nitrogen fertilizer levels on fresh leaf yield of spider plant (*Cleome gynandra* L.) in Western Kenya. Scientific Research and Essey. 2008; 3(6):240-244.
22. Ng'etich OK, Aguyoh JN, Ogweno JO. Growth, yield and physiological responses of spider plant (*Cleome gynandra* L.) to calcium ammonium nitrate rates. International J. Agro. and Plant Prodn. 2012;3(9):346-355.
23. Zobolo AM, Van Staden J. The effects of deflowering and de-fruiting on growth and senescence of *Bidens pilosa* L. South African J. Bot. 1999;65(1):86-88.
24. Mwafusi CN. Effects of propagation method and deflowering on vegetative growth, leaf yield, phenolic and glycoalkaloid contents of three black nightshade selections used as vegetable in Kenya. MSc Thesis. University of Nairobi; 1992.
25. Greef JM. Productivity of maize (*Zea mays* L.) in relation to morphological and physiological characteristics under varying amounts of nitrogen supply. J. Agro. Crop Sci. 1994;172:317-326.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/11626