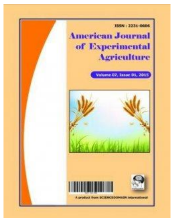

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Effects of Shoot Tip and Flower Removal on Growth and Yield of Spider Plant (*Cleome gynandra* L.) in Kenya

Emily E. Wangolo[1*], Cecilia M. Onyango[1], Charles K. K. Gachene[2] and Peter N. Mong'are[1]

[1]Department of Plant Science and Crop Production, University of Nairobi, P.O.Box 29503, Nairobi, Kenya.
[2]Department of Land Resource Management and Agricultural Technology, University of Nairobi, P.O.Box 29503, Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration between the authors. All authors contributed to the design of the study, and author EEW completed the literature review and implemented the field experiments. Author EEW performed the statistical analysis with support from author PNM. Author EEW composed the first draft of the manuscript and revisions were managed by authors EEW, CMO and CKKG. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Despite spider plant's (*Cleome gynandra* L.) high nutritional value, it has received minimal research attention compared to exotic vegetables and other indigenous vegetables such as amaranth (*Amaranthus* spp.) and cowpeas (*Vigna unguiculata*). This has led to a lack of scientific production recommendations. This study contributes to developing best agronomic practices for spider plant by determining its response to shoot tip and flower removal that can lead to more profitable small-scale commercial production of the vegetable.
Place and Duration of Study: Two field experiments were conducted at the Upper Kabete Field Station of the University of Nairobi, Kenya, during the long rains (February-May) and in the dry

**Corresponding author: E-mail: ebean130@gmail.com;*

season (June-August) 2014.
Methodology: A randomized completed block design with three replications was used. Commercial spider plant seeds were drilled in raised beds with cow manure as nutrient input (50 kg N ha^{-1}). Plants were thinned to 30 x 20 cm, 30 x 15 cm and 20 x 15 cm spacings at six weeks after planting. Shoot tips were removed once when plants were 10-15 cm tall, and flowers were removed at bud formation throughout the experiment.
Results: Flower removal produced significantly (P=.05) greater plant height, leaf yield, and fresh and dry shoot weight than both shoot tip removal and the control. Flower removal plants reached a height of 66 cm, compared to 48 and 49 cm for shoot tip removal and the control, respectively. For total leaf yield, flower removal produced 12.3 t ha^{-1}, which was significantly greater than both shoot tip removal (8.4 t ha^{-1}) and the control (6.5 t ha^{-1}). Fresh shoot weight was 22.1, 15.2 and 14.4 t ha^{-1} for flower removal, shoot tip removal and the control, respectively.
Conclusion: Flower removal during production of spider plant should be practiced in order to increase growth and leaf yield.

Keywords: Spider plant; flower removal; shoot tip removal; yield.

1. INTRODUCTION

Spider plant (*Cleome gynandra* L.) is one of the many African leafy vegetables (ALVs) which have the potential to address a wide variety of problems including malnutrition, food insecurity, low income generation and diminishing crop diversity [1-5]. Spider plant is a herbaceous, erect plant with palmately compound leaves, which grows up to 1.5 m tall and naturally grows in a wide range of soil types [3,6]. Although considered a weed in many locations, spider plant is a valued vegetable in many communities and is consumed in Kenya, Uganda, Botswana, Zambia, Zimbabwe, Malawi, Cameroon, Namibia, Swaziland, Tanzania, Ghana and South Africa [7]. It ranks as one of the leading ALVs in terms of nutritive quality [8,2].

Despite the benefits of spider plant and other ALVs, they gained the reputation of being a “poor man’s food” due to their association with rural areas, causing people to avoid growing and eating them [4,9]. This has contributed to decreasing agrobiodiversity around the globe, as introduced vegetables are given preference over indigenous species in cultivation and consumption [10].

Scientific research on ALVs has also historically received little attention until their promotion by governments, NGOs and educational institutions began during the past decade [11,4,12]. Recent studies on spider plant have covered topics such as pharmaceutical uses [13,14], plant physiology [15,16], agricultural uses [17,18], genetic diversity [19] and morphological characterization [20]. For production practices, research has focused on germination [21,22] and nutrient input [23-25]. No studies have been carried out on the effect of shoot tip removal on the yield of spider plant. It is generally accepted that removal of the apical bud decreases apical dominance, allowing dormant lateral buds to begin growing [26-28]. The lateral buds will develop into branches, which produce more leaves, leading to an overall yield increase for leafy vegetable production. Mnzava and Masam [29] illustrated this phenomenon by removing the apical shoot tip of vegetable amaranth which significantly increased leaf and seed yield.

Flower removal in plants is a practice that can delay senescence and prolong vegetative growth since reproductive parts are significant resource sinks in plants [30,31]. Two studies have evaluated the effect of flower removal combined with nitrogen input on the growth and yield of spider plant [23,24]. In plants that had bolted, Mavengahama [24] found that subsequent continuous flower removal led to a 46% increase in fresh leaf weight. Similarly, Maumba [23] found that flower removal combined with increased nitrogen input led to increased vegetative growth and significantly higher weekly and cumulative leaf yields. Oluoch et al. [32] reviewed the effect of harvesting methods for spider plant and vegetable amaranth, and demonstrated that a harvesting technique that also removed flowers outperformed other methods. However, research gaps exist in comparison of shoot tip removal as well as flower removal at constant nitrogen application rates. This study addresses these gaps in order to improve best agronomic practices of spider plant thereby increasing the competitiveness of this vegetable in Kenya as a source of food, nutrition and income for small-scale farmers.

2. MATERIALS AND METHODS

2.1 Site Description

Field trials were carried out at the University of Nairobi Field Station, Upper Kabete Campus during the March-May rain season and June-August dry season of 2014. Kabete is located about 15 km to the west of Nairobi city at 1º15'S latitude and 36º44' E longitude, with an altitude of 1930 m above sea level [33]. It lies within the lower highland (LH) 2-3 agro-ecological zones, with average rainfall of 993 mm per annum and a mean annual temperature of 18ºC [34,33]. The site has a bimodal distribution of rainfall, with long rains from early March to late May and the short rains from October to December [35]. The soils in Kabete are humic nitisols, characterized as well-drained, deep, dusky red to dark reddish-brown, friable clay [36,37].

2.2 Field Experiment

A 3 x 3 factorial experiment laid out in a randomized complete block design used. The factors were plant density at three levels (30 x 20 cm, 30 x 15 cm and 20 x 15 cm) and cultural management practices: shoot tip removal, flower removal and the control. Shoot tip removal was performed once when plants were 10-15 cm tall, and flowers were removed at bud stage three times per week throughout the trials. The control had no shoot tip or flowers removed.

Raised beds of 1 m x 2.5 m were prepared by first ploughing the land then hand digging raised beds and raking the surface to a fine tilth [3]. Cow manure was incorporated into the soil by hand implements after bed preparation at the rate of 0.4 kg m^{-2} (wet weight of manure). This was equivalent to 50 kg N ha^{-1}, and was based on current nitrogen recommendations [38,2]. In order to simulate common farming practices, no top dressing or inorganic fertilizer was applied throughout the trials. Supplemental irrigation was utilized whenever necessary to keep the soil moist and avoid water stress on the plants.

Seeds of a commercial spider plant type were planted by drilling in shallow furrows and lightly covering the seed. These were then thinned 4 ½ weeks after planting to spacings of 30 x 20 cm, 30 x 15 cm and 20 x 15 cm. Shallow weeding by hand and with a *panga* (machete) was carried out as needed. The presence of pests and diseases was monitored throughout the experiment, and a broad-spectrum pesticide (lambda-cyhalothrin, active ingredient) was applied once during season 2 due to an infestation of white flies, aphids and scales.

2.3 Chemical Analysis of Soil and Manure

A chemical analysis of the soil and manure used for the experiment was performed in order to indicate soil nutrient levels before the addition of manure and the quantity of manure required to supply sufficient nutrients. Soil samples were collected from the ploughed land of the study site at depths of 0-30 cm using a soil auger. The samples were air-dried, crushed and passed through a 2 mm sieve [39]. The soil and cow manure were analyzed for pH, total nitrogen, phosphorus, potassium and organic carbon according to methods listed in Table 1.

2.4 Data Collection

Ten plants from the middle two rows in each plot were randomly tagged, and data was collected on a weekly basis on plant height, number of leaves, number of shoots, number and weight of leaves harvested, and fresh and dry shoot weight.

Plant height was measured from the ground surface to the tip of the tallest shoot [40]. The number of fully-expanded leaves and shoots greater than 0.5 cm in length on each plant were counted. Total leaf yield was calculated by adding the weekly harvest weights for an entire growing period. Yield data was calculated per plant then scaled up to tons per hectare. Fresh shoot weight was determined by cutting plants at ground level and weighing the entire plant immediately after cutting. Plants were then dried to a constant weight at 70ºC (approximately 72 hours) in a drying oven after which dry shoot weight was measured [41].

2.5 Data Analysis

Data was subjected to analysis of variance (ANOVA) using the GenStat 15th edition statistical package [42]. Fisher's Protected Least Significant Difference test was used to identify significant differences among treatment means (*P=.05*).

3. RESULTS AND DISCUSSION

3.1 Soil and Manure Analysis

The soil and manure analyses results are shown in Table 1. These results indicate moderate acidity and N content, low phosphorus, adequate potassium and low organic carbon [43].

3.2 Temperature and Rainfall

Mean daily temperature ranged from 15-21ºC and declined over the course of the field trials, which followed typical temperature trends in the study region [34]. Rainfall also generally declined, with the first and second season receiving 302 mm and 213 mm of rain, respectively. Rainfall in April (112 mm) and May (53 mm) fell below normal compared to the average of 234 and 164 mm, respectively [34].

3.3 Plant Height

Plants that had flowers removed reached a height of 66 cm which was significantly taller than both shoot tip removal (48 cm) and the control (49 cm) during season 1 (Table 2). The same trend was observed in the second season with heights of 45, 35 and 38 cm for flower removal, shoot tip removal and the control, respectively (Table 2). Shoot tip removal and the control were not significantly different in any of the seasons.

Maumba's [23] results on spider plant and Mwafusi's [45] on black nightshade were in contrast from findings of this study, with flower removal resulting in shorter plants. However, an increase in plant height due to flower removal should be expected because when plants begin to flower, resources are re-allocated to the flowers and fruiting bodies, drawing energy away from vegetative growth [30,31]. By removing this resource sink, energy and resources continue to supply leaves and shoots. This extends vegetative stage, resulting in taller plants.

3.4 Number of Leaves

Flower removal significantly affected leaf number in season 1, with plants with flower removal averaging 35 leaves per plant throughout the data collection period, which was significantly more than the control plants with 24 leaves (Table 2). Plants with shoot tip removal had 27 leaves per plant, which was not significantly different than flower removal or the control (Table 2).

While no studies have been undertaken on the number of leaves produced in response to flower removal, this variable is connected to leaf yield, which agrees with previous research that showed that spider plant and black nightshade produced significantly higher leaf yields when flowers were removed [23,24,45]. This demonstrates the significance of flowers as resource sinks in plants. When flowers are removed, resources continue to be utilized for vegetative growth of the plant, whereas if flowers are left intact, resources are re-allocated to the reproductive structures, decreasing vegetative growth [30,31]. The marked effects of flower removal during the first season (Table 2) may be linked to abundant rainfall and sunshine which supported significant increase of vegetative growth, compared to season 2 when environmental factors allowed for only minimal increase in growth.

Table 1. Chemical properties and analysis methods of experimental soil (0-30 cm) and manure

Particulars	Soil	Manure	Methods
pH (1:2.5 :: Soil:Water)	5.75	8.80	Glass Electrode pH Meter [41]
Total N (%)	0.31	1.87	Micro-Kjedahl Method [44]
Available P (ppm)	16.0	920	Colorimetric Determination with Double Acid Method [41]
Exch. K (cmol kg^{-1})	1.05	44.0	Flame-photometer [41]
Organic Carbon (%)	3.12	18.5	Walkley-Black Wet Oxidation Method [41]

Table 2. Effect of shoot tip and flower removal on plant height and number of leaves

Treatments	Plant height (cm)		No. of leaves ($plant^{-1}$)	
	Season 1	Season 2	Season 1	Season 2
Shoot tip removed	47.7b	34.7b	27.3ab	19.3
Flowers removed	66.2a	45.0a	34.5a	21.9
Control	48.7b	37.5b	24.4b	19.5
Significance	**	**	*	ns
l.s.d.	11.2	5.6	7.7	ns
s.e.d.	5.28	2.57	3.64	1.54

*** Highly significant at P<.01, * significant at P<.05, ns=not significant at P>.05. Figures down the same column followed by the same letter are not significantly different (P≤.05). Season 1, N=243; season 2, N=216*

3.5 Number of Shoots

Significant differences in shoot production appeared when analyzed on a weekly basis (Fig. 1). During season 1, plants with flowers removed had 22 and 33 shoots on weeks 10 and 11 respectively, which was significantly higher than the control at 15 and 20 shoots for the same weeks, respectively (Fig. 1). Shoot tip removal had 24 shoots on week 11, which was also significantly lower than flower removal (Fig. 1). The same trend occurred in the second season, with flower removal (29 shoots) having significantly more shoots than both shoot tip removal (23 shoots) and the control (22 shoots) on week 13 (Fig. 1).

These findings concur with Maumba's [23] study on spider plant, where plants with flowers removed produced significantly more branches than those with flowers remaining, but stand in contrast to Mwafusi's [45] findings where flower removal in black nightshade did not affect the number of branches. According to Kriedemann et al. [31], flower removal could cause increased shoot growth due to maintaining resources available for vegetative growth. Additionally, flower removal mimics shoot tip removal and would thereby act as an additional mechanism to encourage lateral growth [27].

3.6 Yield

3.6.1 Leaf yield

During both seasons, flower removal yielded significantly greater leaf yield per plant than shoot removal and the control, neither of which was significantly different from each other (Table 3). Flower removal yielded 12.3 t ha^{-1}, compared to 8.4 t ha^{-1} for shoot removal and 6.5 t ha^{-1} for the control in season 1 (Table 3). Season 2 followed the same trend with yields of 9.0, 5.7, and 6.4 t ha^{-1} for flower removal, shoot removal and the control, respectively (Table 3).

The influence of flower removal on leaf yield is further understood when viewed across the harvesting period (Fig. 2). Significant differences occurred on weeks 10-14 of season 1, with leaf yield for flower removal plots peaking at 1.9 t ha^{-1} on week 12, compared to only 1.1 and 0.7 t ha^{-1} for shoot removal and the control, respectively (Fig. 2). During season 2, flower removal maintained significantly greater yields than both shoot removal and the control by a margin of 0.3-0.5 t ha^{-1} during weeks 12-17 (Fig. 2). In both seasons, the significant yield differences began approximately 3 weeks after flower buds appeared, linking yield changes to the presence or absence of flowers which are significant resource sinks in plants [30,31]. Fig. 2 shows that the benefits of flower removal appear in the later weeks of harvesting, which must be considered when selecting a harvesting time frame and crop management practices.

The drastic yield increase for flower removal from week 11-13 of season 1 (Fig. 2) coincides with weather conditions during that time, particularly good rains (56 and 38 mm) on the 11th and 13th WAP, respectively. In Fig. 2, leaf yield in the second season decreased markedly during weeks 7-9 (the first three harvests). This was caused by the greater number and larger size of leaves that were able to grow in the weeks preceding the first harvest. Weather patterns, particularly minimal precipitation on weeks 7-9 and decreasing temperature, did not provide conditions which allowed plants to grow quickly enough to match the yields of the first harvest.

Table 3. Effect of shoot tip and flower removal on leaf yield and shoot weight

Treatments	Leaf yield (t ha^{-1})		Shoot weight (t ha^{-1})			
			Fresh		Dry	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Shoot tip removed	8.4b	5.7b	15.2b	8.7b	3.2ab	1.9b
Flowers removed	12.3a	9.0a	22.1a	13.7a	4.2a	2.6a
Control	6.5b	6.4b	14.4b	9.2b	2.2b	2.0b
Significance	**	**	**	**	**	**
l.s.d.	2.0	1.4	3.8	2.1	1.1	0.5
s.e.d.	0.92	0.65	1.81	0.94	0.54	0.21

*** Highly significant at P<.01, * significant at P<.05, ns=not significant at P>.05. Figures in the same column followed by the same letter are not significantly different (P≤.05). Season 1, N=243; season 2, N=216*

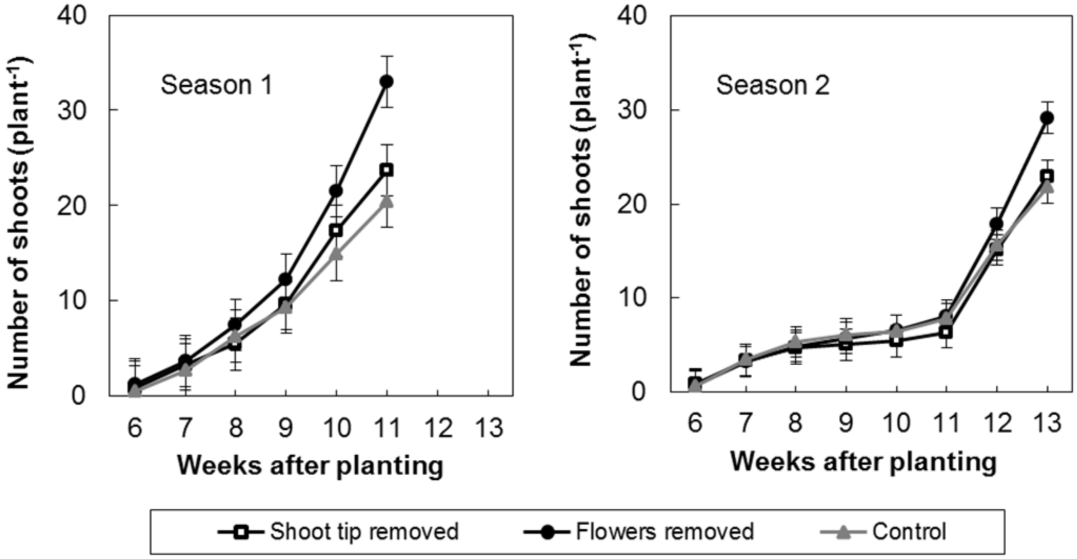

Fig. 1. Effect of shoot tip and flower removal on number of shoots per plant

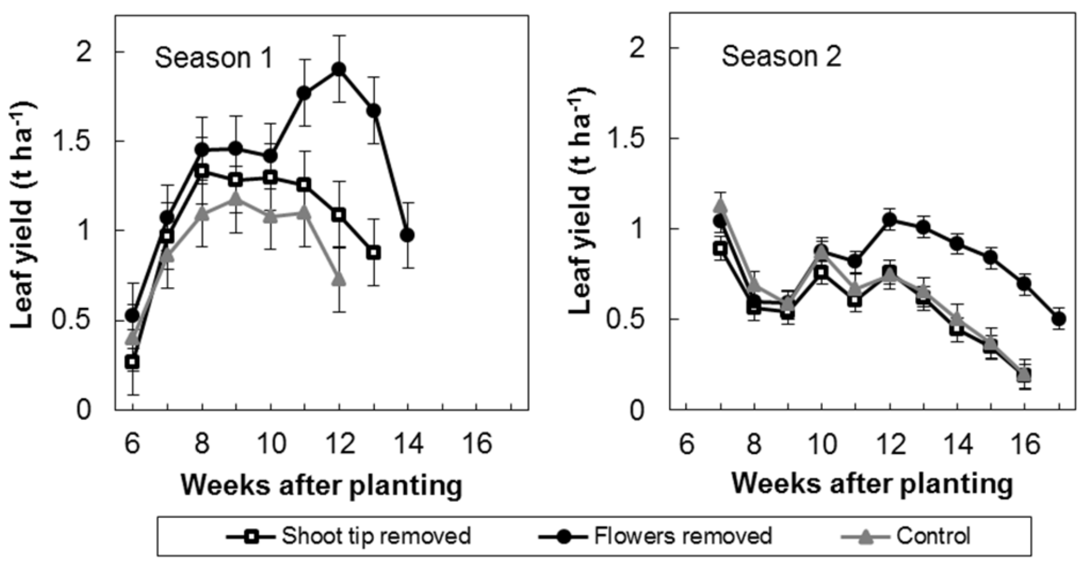

Fig. 2. Effect of shoot tip and flower removal on leaf yield throughout the harvesting period

A number of studies on yield related to flower removal agree with the current study in which flower removal caused significantly greater leaf yield when compared to plants with flowers intact [23,32,45]. These findings demonstrate the importance of reproductive structures as resource sinks in plants which, when removed, can increase vegetative yield [30,31].

The positive effect of flower removal on leaf yield reveals a simple, accessible method that any farmer can utilize to increase yield. Flower removal does require considerable time investment, the cost of which should be weighed against the benefit. Additionally, the first five harvests of both seasons (Fig. 2) yielded similar amounts for shoot tip removal, flower removal and the control, which should be considered if the crop is grown for young foliage or will be removed before the entire season is finished.

Fig. 3 illustrates the effects of flower removal on plant senescence during both seasons, where plants that underwent flower removal maintained

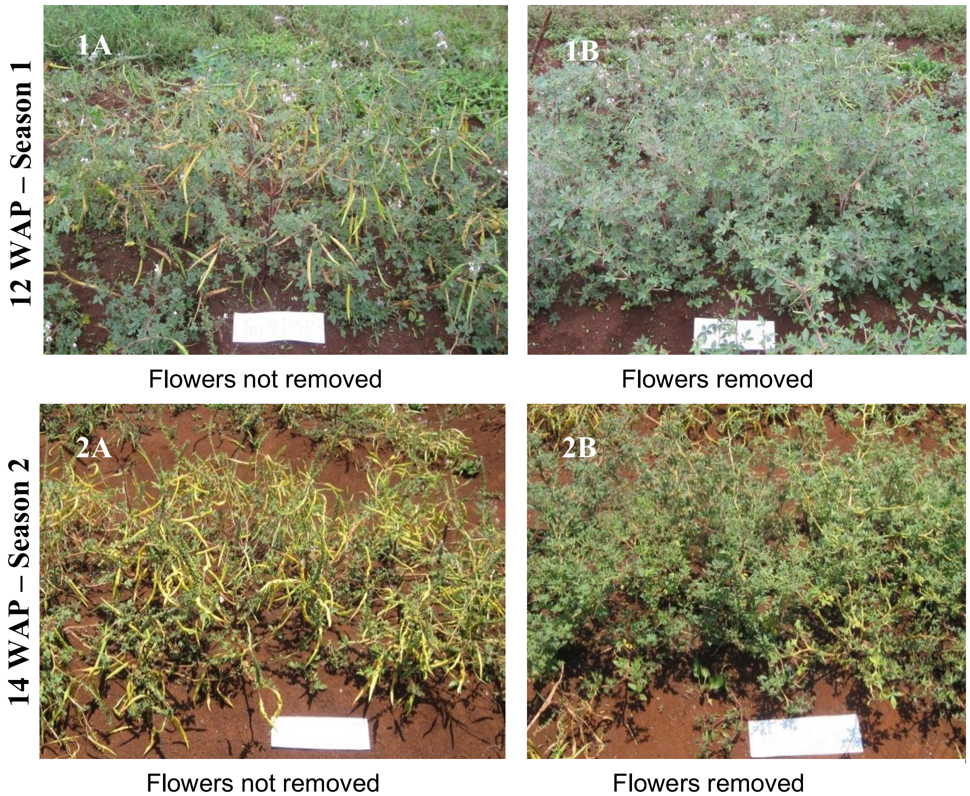

Fig. 3. Effect of flower removal on plant senescence during the first and second season
Plates 1A & AB: season 1, flowers not removed (1A) and flowers removed (1B). Plates 2A & 2B: season 2, flowers not removed (2A) and flowers removed (2B)

greener and denser foliage for a longer period than plants that had flowers intact. Yellowing of foliage for these plants was observed as early as week 12 in season 1 and 13 WAP in season 2 (Fig. 3).

3.6.2 Fresh shoot weight

During season 1, flower removal yielded 22.1 t ha^{-1} fresh shoot weight, which was significantly greater than both shoot tip removal (15.2 t ha^{-1}) and the control (14.4 t ha^{-1}) (Table 3). Shoot tip removal was not significantly different from the control (Table 3). The same pattern was observed in season 2 with fresh shoot weights of 13.7, 8.7 and 9.2 t ha^{-1} for flower removal, shoot tip removal and the control, respectively. This outcome is expected, given that other parameters that contribute to fresh shoot weight produced the same results. A study on spider plant by Oluoch et al. [32] corroborates these findings, with harvesting techniques that removed flowers resulting in significantly greater biomass yield (239.0 g $plant^{-1}$) than those where flowers remained (70.0 g $plant^{-1}$).

3.6.3 Dry shoot weight

In the first season, flower removal yielded 4.2 t ha^{-1} dry shoot weight which was significantly greater than the control at 2.2 t ha^{-1}, while in season 2, flower removal was significantly greater than both shoot tip removal and the control with yields of 2.6, 1.9 and 2.0 t ha^{-1}, respectively (Table 3). Shoot tip removal and the control were not significantly different from each other in either season (Table 3).

No studies have reported on dry shoot weight in response to flower removal. However, Oluoch et al.'s [32] study on fresh biomass where flower removal on spider plant yielded 239.0 g $plant^{-1}$ with flower removal and 70.0 g $plant^{-1}$ with flowers remaining, suggests that significant differences would also occur between dry shoot weights.

In addition to the increased performance of plants with flowers removed, it is noteworthy that the control in both seasons produced very similar weights of dry biomass: 2.2 and 2.0 t ha^{-1} in seasons 1 and 2, respectively (Table 3). The same phenomenon is seen with total leaf yield (6.45 and 6.41 t ha^{-1}, Table 3) and to a lesser extent the number of leaves (24.4 and 19.4 leaves $plant^{-1}$, Table 2). Because the control plots performed similarly for these variables during both seasons, the greater margin between the control and flower removal plants in season 1 came primarily from the higher performance of flower removal plants, not a lower performance from the control. The significance of this observation lies with the varying weather conditions between each season. Season 1 was hot and largely watered by natural rainfall, while the second season was cool and dry, being primarily watered by hand irrigation. From this observation, it can be extrapolated that the removal of flowers and shoot tips benefit the plant most significantly when there is adequate moisture and sunlight to support increased vegetative growth.

4. CONCLUSION

The results of this study have shown that flower removal significantly affected the growth and leaf yield of spider plant. Flower removal resulted in taller plants, more shoots and leaves per plant, higher leaf yield, and greater fresh and dry shoot weight compared to shoot tip removal and the control. From these results it is recommended that flower removal should be practiced in the production of spider plant to increase yield and profitability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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