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Effect of fertilizers, time of pinching and harvesting method on growth and yield of spider plant *(Cleome gynandra)*

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Abstract

A study was conducted at Kabete Field Station, University of Nairobi to assess the effect of fertilizers, time of pinching and harvesting method on growth and yield of spider plant. Fertilization options (no-fertilizer control, 200 kg/ha di-ammonium phosphate, 10 t/ha chicken manure and 100 kg/ha di-amonium phosphate + 5 t/ha chicken manure), pinching (early pinching and late pinching) and harvesting method (piecemeal and wholesome harvesting) treatments were evaluated in a randomized complete block design with a factorial arrangement. Data were subjected to analysis of variance using Genstat software and means separated using the least significant difference test at $P \leq 0.05$. Fertilizer application, late pinching and wholesome harvesting significantly ($p<0.05$) increased fresh and dry leaf yield, number of leaves and branches per plant, plant height and canopy span. Application of 100 kg DAP/ha + 5 t/ha manure out-yielded the other treatment combinations in all the measured parameters. For instance, it produced the highest leaf yields of 1803.3 and 1740.9 kg/ha in the first and second season, respectively. Late pinching increased leaf yields by 1419.8 and 1385.2 kg/ha in first and second season, respectively, as compared to early pinched plants. Wholesome harvested plants had significantly higher leaf yields of 1411.1 and 1311 kg/ha than piecemeal harvested ones, in the first and second season, respectively. The results of this study show that growth and leaf yield of spider plant can be substantially increased by practicing fertilizer application, late pinching and wholesome harvesting.

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Introduction

Demand for African indigenous leafy vegetables (AILVs) has been on the increase in the recent times due to sustained sensitization of the public on their health benefits (HCDA, 2012). The AILVs can withstand harsh climatic conditions and are highly tolerant to pest and diseases as compared to the exotic vegetables. Besides, AILVs have high nutritional components that are associated with health benefits (Prasad *et al*., 2008), for instance, spider plant (*Cleome gynandra* L.) is rich in nutrients like vitamin C, β-carotene, protein and minerals like iron, calcium, phosphorus and magnesium (Mbugua *et al.,* 2011). For many years, spider plant grew as a volunteer crop in gardens. The leaves were domesticated and utilized as food. The great increase in demand of spider plant has led to increased leaf yield production in Kenya from 19,428 MT in 2012 to 21,507 MT in 2013 (HCDA, 2014). This trend was associated with increases in acreage under spider plant from 5,634 acres to 8,249 acres in 2013 (HCDA, 2014). The major producing counties in Kenya are Kisii, Nyamira and Kisumu (HCDA, 2012).

Spider plant is an annual herb belonging to *Capparaceae* family (Chweya and Mnzava, 1997). The plant grows in a wide range of environmental conditions and has a high level of diversity with various phenotypic expressions (Wasonga *et al*., 2015). They contain antioxidants that are anti-cancer and anti-diabetes (Mibei *et al*., 2012). It is reported to reduce dizzy spells in pregnant women, time taken in labour, and time taken to regain normal health after childbirth (Kamatenesi *et al*., 2007).

In spite of the very many health benefits associated with spider plant, the leaf yield in Kenya is still in the range of 1-3 t/ha compared to the optimal range of 20-40 t/ha (Abukutsa-Onyango, 2003). This can be attributed to lack of adequate information regarding spider plant best production and management practices. For example, problems such as a short vegetative phase, early flowering behavior and lack of information on the recommended amounts and types of fertilizers to be used have not been adequately addressed. Continuous cultivation on arable land with low or no adoption of fertilizer use has often resulted to reduction in soil fertility thereby reducing crop yields (Ayoola and Makinde, 2007). Organic manure obtained from animals, can supply large quantities of major plant nutrients hence promote growth and leaf yields of spider plant (Materechera *et al*., 2013), however, they are not available in adequate quantities (Tittonell and Giller, 2012). Chemical fertilizers on the other hand, have the potential to increase leaf yields in spider plant (Ogweno *et al*., 2015) but they are costly and easily leached. Adoption of nutrient supplementation to spider plant production whereby chemical and organic fertilizers are combined can lead to increased spider plant yields and improved soil fertility.

Frequent cutting of leaves has resulted to increased leaf yield in crops like cowpea. Yield response depends on the age of the plant at which the defoliation occurs and the cutting frequencies made (Saidi *et al*., 2007). There is little documentation on how piecemeal harvesting and wholesome harvesting would influence leaf yields in spider plant. In the recent studies, pinching has been reported to increase vegetative yields in spider plant and amaranth (Ogweno *et al*., 2015; Love, 2014), though the best timing for pinching has not been fully documented. Despite all the potential benefits brought about by these management practices, they have not been fully applied to spider plant and, where practiced, they have not been adequately documented. The objective of this study was to evaluate the influence of fertilizers, time of pinching and harvesting method on growth and yield of spider plant.

Materials and methods

Site description

The field experiment was conducted at the University of Nairobi's Kabete Field station, Kenya for two seasons namely: March-July 2015 and October 2015-February 2016. The study site is situated on latitude 1° 15'S, longitude 36°44'E, and at an altitude of 1940 m above sea level (Somroek *et al*., 1982). The area receives mean annual rainfall of 1006 mm with the long rains from early March to late May and short rains from October to December. The site has a mean annual temperature of 18° C (Onyango *et al.*, 2013). The soils are well-drained, dark red to darkish brown humic nitisols (Michieka, 1978). Soils were sampled before planting at 30 cm depth and chicken manure used in the study were analyzed for pH, carbon, nitrogen, potassium, sodium, calcium, magnesium and phosphorous in both seasons (Table 1). The rainfall and temperature data during the experimental period are shown in Table 2.

Field experiment

The study was a 4 × 2 × 2 factorial experiment laid out in a randomized complete block design with three replications. Three factors were studied: (i) fertilizers, (ii) time of pinching and (iii) harvesting method. Fertilizer treatments were four: 200 kg/ha of di-ammonuim phosphate (DAP), 100 kg/ha DAP + 5 t/ha chicken manure, 10 t/ha chicken manure and control (no fertilizer). Time of pinching treatments comprised early pinching and late pinching, while harvesting treatments comprised piecemeal harvesting and wholesome harvesting. The fertilizers were applied in prepared drills and mixed with soil before planting. Early and late pinching involved removal of spider plant apical bud at 3 and 5 weeks after emergence, respectively. Apical and flower buds were removed using pruning shears. Piecemeal harvesting involved manual plucking of all leaves commencing at 5 weeks after emergence and continued weekly till the fifth harvest. Wholesome harvesting entailed uprooting the entire plant and plucking the edible leaves. The early pinched-wholesome harvested spider plants were uprooted and leaves harvested at 5 weeks after emergence. Another planting was done immediately and harvested at 5 weeks after emergence. The late pinched-wholesome harvested spider plants were uprooted and the leaves harvested once at 10 weeks after emergence.

Spider plant seeds sourced from Kenya Seed Company, Nairobi, were drilled along furrows separated at a spacing of 50 cm apart at a seed rate of approximately 54 seeds per m^2, on 2 m by 1.5 m experimental plots. The emerged spider plant seedlings were thinned 3 weeks after emergence to remain with 18 vigorously growing plants per plot at an intra-row spacing of 30 cm. Hand weeding was carried out at 3, 5 and 8 weeks after emergence to ensure weed free plots. Integrated pest management method was used to ensure no incidences of pest infestation occurred.

Data collection

Six plants from the inner rows were tagged for data collection. Data collected included: plant height, number of branches per plant, days to 50% flowering, number of edible leaves, canopy span, fresh leaf yield and dry leaf yield. From these plants, plant height, number of edible leaves per plant, number of branches per plant and canopy span were measured from five weeks after emergence and weekly thereafter till the ninth week. Plant height was determined using a meter rule by measuring the distance between soil surface and the tip of the central shoot in centimeters. Canopy span was determined using a meter rule by measuring the widest span of plant canopy.

The number of branches was obtained through physical counting. Number of edible leaves was determined by counting the fresh leaves harvested that were consumable as a vegetable. Days to 50% flowering were the number of days taken for half of the six-tagged plants to flower in each plot.

Fresh leaf yield was determined by harvesting edible leaves through observing green leaves ready for harvesting and consumption, from a set of six plants per plot and measured immediately using a weighing balance. Harvesting was done at weekly intervals starting at 5 weeks after emergence for piecemeal harvested plants till the fifth harvest was obtained. Wholesome harvesting was done thrice, one harvest at 5 weeks after emergence and two harvests after 10 weeks. Dry leaf yield was obtained from the six plants that were harvested for fresh leaf yield by oven drying the leaves at 70° C for 72 hours to a constant weight.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using Genstat Version (15th edition). Where the differences were significant, separation of means was done using Fisher's least significant difference (LSD) test at P≤0.05.

Results and discussion

Effects of fertilizers on spider plant vegetative growth and yield

In both seasons, spider plant treated with fertilizers had significantly (P≤0.05) taller plants, wider canopy spans and higher number of branches per plant, number of leaves per plant, fresh leaf yield and dry leaf yield than plants that did not receive any fertilizer (Table 3). Plants treated with 100 kg/ha DAP + 5 t/ha chicken manure significantly (P≤0.05) outperformed those treated with 10 t/ha manure and 200 kg/ha DAP in all the measured attributes. In the first season, plants subjected to 200 kg/ha DAP out-performed 10 t/ha manure treated plants in plant height, canopy span, fresh leaf yield and dry leaf yield while in the second season, no significant (P≤0.05) differences were noted between 200 kg/ha DAP and 10 t/ha manure in all the measured plant attributes except number of branches.

Table 1. Chemical composition of soil and chicken manure used in the experiment.

	First season			Second season	
Parameters	Soil	Chicken manure	Critical levels	Soil	Chicken manure
pH	5.40	6.80	5.50-7.50	5.89	6.80
C %	2.79	9.61	≥3.50	3.24	9.61
N %	0.28	1.16	0.30-0.50	0.24	1.16
K cmol/kg	1.10	1.60	0.50-0.80	1.10	1.60
Na cmol/kg	0.42	3.30	≤2.00	0.46	3.30
Ca cmol/kg	2.20	1.26	1.00-3.00	6.10	1.26
Mg cmol/kg	5.70	3.65	0.50-1.50	3.65	3.65
P (ppm)	22.80	944.25	10.00-25.00	13.50	944.25

These findings are in agreement with those of Mavengahama *et al.*, (2013) and Ogweno *et al.*, (2015) who found higher yields in spider plant that received inorganic fertilizer supplementation. It is apparent that DAP encouraged growth of spider plant through provision of readily available inorganic N and P, which stimulated root elongation and proliferation together with uptake of other plant nutrients (Ndor *et al.*, 2012). Availability of N also encouraged stem elongation, which correlated to more vegetative growth, thereby leading to increased yields (Kujeke *et al.*, 2017). According to Aguyoh *et al.*, (2012) manure application increased growth parameters and yield of spider plant.

Table 2. Monthly rainfalls and temperatures received in Kabete Field Station during the experimental period in 2015.

Months	Temperature (°C)	Rainfall (mm)
March	22.60	66.04
April	21.00	270.5
May	18.50	87.10
June	16.90	50.50
July	16.60	3.60
September	18.23	29.50
October	20.23	41.70
November	20.16	160.30
December	19.37	69.6

Source: Kenya Meteorological Department, Kabete Agro-met Station (January 2016).

The increase in yields may be due to the effect of chicken manure in improving soil aggregation, soil aeration, water holding capacity and good soil conditions for the spider plant root growth. Furthermore, chicken manure may have ensured slow and steady supply of nutrients throughout the growing period.

Application of 100 kg/ha DAP + 5 t/ha chicken manure outperformed all the other fertilizer treatments in plant height, canopy span, number of branches per plant and leaf yields. These results are consistent with those reported by Alemu and Bayu, (2005) who found an increase in growth parameters and yields of amaranths treated with combinations of manure and inorganic fertilizer as compared to those with sole applications. Similar observations were made by Fusire, (2008) and Love, (2014) on spider plant and grain amaranth, respectively. The increase in growth attributes and yields may be attributed to the greater benefits of manure such as slow and steady supply of nutrients, improvement of soil structure and water holding capacity, coupled to high and fast nutrient release to the crop by DAP.

Table 3. Main effects of fertilizers spider plant vegetative growth and yield during 2015 short and long rains at Kabete Field Station.

	P.H (cm)	C.S (cm)	B/P	L.No	FLY(Kg/ha)	DLY (Kg/ha)
Fertilizers						
First season (2015 long rains)						
Control	6.3	9.0	1.0	3.7	281.5	41.4
200 kg/ha DAP	49.0	36.5	8.0	26.5	1717.6	252.3
100 kg/ha DAP + 5 t/ha M	57.0	41.3	9.0	32.0	1803.3	264.5
10 t/ha Manure	43.3	34.1	8.0	25.3	1487.8	218.4
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	5.3	1.9	0.8	1.9	48.2	6.9
Second season (2015 short rains)						
Control	16.4	20.1	1.9	13.5	563.4	80.7
200 kg/ha DAP	43.2	35.3	5.6	32.5	1543.9	219.1
100 kg/ha DAP + 5 tons/ha M	53.4	40.8	6.6	39.6	1740.9	246.1
10 tons/ha Manure	43.3	36.6	6.2	35.5	1555.7	220.6
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	6.7	2.5	0.5	3.6	71.2	9.8

PH=plant height, CS=canopy span, B/P= number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield.

Effects of time of pinching and harvesting method on spider plant vegetative growth and yield

In both seasons, late pinched plants were significantly (P≤0.05) taller, with wider canopy spans and higher number of branches per plant, number of leaves per plant, fresh and dry leaf yields than early pinched plants (Table 4). These observations are in agreement with the findings of Wangolo *et al.*, (2015) and Ogweno *et al.*, (2015) who stated that deflowering increased the number of branches, number of leaves and, consequently, fresh and dry leaf yields in spider plant. When plants begin to bolt, resources are re-allocated to the flowers and fruiting bodies, drawing energy away from vegetative growth (Kriedemann *et al.*, 2010). By removing this resource sink through late pinching, energy and resources continue to supply leaves and shoots. This likely extended vegetative stage, resulting in increased plant growth parameters and vegetative yields. It could also be possible, late pinched had higher sinks than early pinched plants which encouraged more vegetative growth leading to higher yields.

In both seasons, piecemeal harvested plants had significantly ($P \leq 0.05$) taller plants and wider canopy spans than wholesome harvested plants. In contrast, the wholesome harvested plants had significantly higher number of leaves per plant, branches per plant, fresh and dry leaf yields (Table 4).

Table 4. Main effects of time of pinching and harvesting method on spider plant vegetative growth and yield during 2015 short and long rains at Kabete Field Station.

	P.H (cm)	C.S (cm)	B/P	L.No	FLY(Kg/ha)	DLY (Kg/ha)
First season (2015 long rains)						
Pinching						
Early pinching	32.2	28.1	5.0	14.2	612.7	86.1
Late pinching	45.7	32.4	8.0	29.7	2032.5	302.0
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	3.7	1.3	0.5	1.3	34.1	4.9
Harvesting						
Piecemeal H	44.1	31.3	7.0	15.0	617.0	87.9
Wholesome H	33.8	29.2	8.0	28.7	2028.1	300.4
P-value	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	3.7	1.3	0.5	1.3	34.1	4.9
Second season (2015 short rains)						
Pinching						
Early pinching	30.9	30.6	3.9	18.4	658.4	88.2
Late pinching	47.3	35.8	6.3	42.2	2043.6	295.0
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	4.7	1.8	0.4	2.6	50.4	6.9
Harvesting						
Piecemeal H	46.7	35.6	5.7	20.2	695.5	92.5
Wholesome H	31.5	31.8	4.5	40.3	2006.5	290.7
P-value	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	4.7	1.8	0.4	2.6	50.4	6.9

PH=plant height, CS=canopy span, B/P= number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, H=harvesting, M=manure.

These observations are in line with those of Saidi *et al*., (2007) and Barimavandi *et al*., (2010) who found that frequent leaf cutting resulted to more vegetative growth in cowpea. This could have resulted from redistribution of auxins at the point where leaves were plucked, stimulating the growth of more buds that later developed to branches and leaves resulting to increased plant height, canopy span and branches per plant. Contrary to the earlier findings by Saidi *et al*., (2007) and Barimavandi *et al*., (2010), this study showed significantly higher number of leaves and fresh and dry leaf yields from wholesome harvested plants than piecemeal harvested plants. Similar observations were made in amaranth plant whereby frequent leaf harvesting reduced fresh leaf yields Materechera *et al*., (2013).

The results of this study could be probably due to reduction in photosynthetic capacity caused by heavy defoliation in piecemeal harvested plants that contributed to low light interception due to reduced photosynthetic area.

It could also be due to the diversion of assimilates in healing wounds and developing buds for the frequently harvested plants at the expense of proliferating more leaves (Alleman, 1996).

Interactive effects of fertilizers and time of pinching on spider plant vegetative growth yield

All plants supplied with fertilizer had significantly ($P \leq 0.05$) taller plants, wider canopy spans and higher number of leaves and branches per plant, fresh and dry leaf yields than plants that did not receive fertilizer, irrespective of whether they were early pinched or late pinched (Table 5). In both seasons, late pinched plants treated with fertilizers significantly increased all the measured plant attributes. Plants that received 100 kg/ha DAP + 5 t/ha manure + late pinching had significantly higher records of plant height, canopy span, number of branches per plant, number of leaves per plant, fresh and dry leaf yields than the other treatment combinations (Table 5).

Table 5. Interactive effects of fertilizers and time of pinching on spider plant vegetative growth and yield during 2015 short and long rains at Kabete Field station.

	PH (cm)	CS (cm)	B/P	L.No	FLY(kg/ha)	DLY (kg/ha)
First season (2015 short rains)						
Control + EP	5.6	8.3	1.0	2.5	120.5	17.1
Control + LP	6.9	9.7	2.0	4.8	442.5	65.8
200 kg/ha DAP + EP	41.7	36.1	6.0	17.0	763.3	105.2
200 kg/ha DAP + LP	56.6	36.9	9.0	36.2	2672.2	397.5
100 kg/ha DAP + 5 t/ha M + EP	46.6	37.8	6.0	19.7	879.0	123.6
100 kg/ha DAP + 5 t/ha M + LP	67.4	44.8	11.0	44.2	2727.7	405.3
10 t/ha M + EP	34.7	30.0	6.0	17.5	688.1	96.6
10 t/ha M + LP	51.9	38.1	10.0	33.2	2287.5	340.1
P-value (F × P)	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	5.3	2.6	1.1	2.6	68.1	9.8
Second season (2015 long rains)						
Control + EP	15.4	18.8	1.9	6.9	187.5	25.1
Control + LP	17.3	21.4	1.9	20.1	939.2	136.2
200 kg/ha DAP + EP	36.5	35.4	4.4	21.9	770.2	103.1
200 kg/ha DAP + LP	49.8	35.2	6.8	43.1	2317.7	335.2
100 kg/ha DAP + 5 t/ha M + EP	40.5	37.7	4.6	23.5	918.3	122.9
100 kg/ha DAP + 5 t/ha M + LP	66.3	43.9	8.5	55.7	2563.5	369.2
10 t/ha M + EP	30.9	30.5	4.5	21.1	757.6	101.6
10 t/ha M + LP	55.8	42.7	7.9	49.9	2253.9	339.5
P-value (F×P)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	9.4	3.6	0.8	5.1	100.8	13.9

PH=plant height, CS=canopy span B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, H=harvesting, M=manure, F=Fertilizer, P=pinching.

Research findings by Masinde *et al.*, (2011) reported that a combination of fertilizers and deflowering significantly enhanced spider plant growth and yield attributes. Benefits of fertilizer application in spider plant production are more pronounced when late pinching is carried out since more resources are re-allocated in the tips of late pinched plants than early pinched plants that stimulated more vegetative growth (Kriedemann *et al.*, 2010) because of efficient utilization of the sinks that resulted to improved yields.

Interactive effects of fertilizers and harvesting method on spider plant vegetative growth and yield

In the first season, fertilizer treated + piecemeal harvested plants were significantly ($P \leq 0.05$) taller and had more number of branches per plant than wholesome harvested plants treated with fertilizers (Table 6). Plants subjected to 100 kg/ha DAP + 5t/ha manure + piecemeal harvesting resulted to significantly ($P \leq 0.05$) taller plants than plants supplied with 200 kg/ha DAP + piecemeal harvesting which, in turn, had taller plants than plants supplied with 10 t/ha manure + piecemeal harvesting (Table 6). Wholesome harvested plants, treated with fertilizer significantly increased the number of leaves, fresh and dry leaf yields in both seasons.

Table 6. Interactive effects of fertilizers and harvesting method on growth and vegetative yield of spider plant during 2015 short and long rains at Kabete Field Station.

	PH (cm)	B/P	LNo	FLY(kg/ha)	DLY (kg/ha)
First season (2015 short rains)					
Control + P	6.7	1.0	2.0	143.6	20.6
Control + W	5.9	1.0	5.3	419.5	62.3
200 kg/ha DAP + P	56.8	8.0	19.0	760.6	108.4
200 kg/ha DAP + W	41.6	7.0	34.2	2674.7	396.3
100 kg/ha DAP + 5 t/ha M + P	63.9	10.0	21.8	872.0	124.1
100 kg/ha DAP + 5 t/ha M + W	50.1	7.0	42.0	2734.7	404.8
10 t/ha M + P	49.0	9.0	17.3	692.1	98.6
10 t/ha M + W	37.6	6.0	33.2	2283.5	338.1
P-value (F × H)	0.034	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	5.3	1.1	2.6	68.1	9.8
Second season (2015 long rains)					
Control + P	21.7	2.2	6.9	187.5	25.1
Control + W	11.1	1.5	20.1	939.2	136.2
200 kg/ha DAP + P	51.8	6.1	21.9	770.2	103.1
200 kg/ha DAP + W	34.5	5.1	43.1	2317.7	335.2
100 kg/ha DAP + 5 t/ha M + P	63.3	7.3	23.5	918.3	122.9
100 kg/ha DAP + 5 t/ha M + W	43.5	5.8	55.7	2563.5	369.2
10 t/ha M + P	50.0	7.0	21.1	757.6	101.6
10 t/ha M + W	36.7	5.4	49.9	2253.9	339.5
P-value (F × H)	0.29	0.42	<.001	<.001	<.001
$LSD_{(p=0.05)}$	NS	NS	5.1^{**}	100.8^{**}	13.9^{**}

PH=plant height, C.S=canopy span, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, P=piecemeal harvesting, W=wholesome harvesting, F=fertilizer, H=harvesting method, M=manure.

In both seasons, wholesome harvested plants that received 100 kg/ha DAP + 5 t/ha manure had significantly higher number of leaves, fresh and dry leaf yields than wholesome harvested plants treated with other fertilizer combination. This is possibly due to synergistic effects of inorganic fertilizers and organic fertilizers, which increased soil available macro- and micro- nutrients that are readily available for plant uptake thus promoting vegetative growth and yields (Singh *et al.*, 2006).

Interactive effects of fertilizers, time of pinching and harvesting method on spider plant vegetative growth and yield

In the first season, no significant difference was observed in plant height, canopy span and number of branches per plant among the plants grown in no fertilizer plots irrespective of time of pinching and harvesting method. However, in both seasons, plants that received no-fertilizers + late pinching + wholesome harvesting had significantly the highest number of leaves per plant, fresh and dry leaf yields (Table 8). Plants that received a combination of fertilizer treatments, late pinching and wholesome harvesting had significantly (P≤0.05) taller plants, wider canopy spans, number of leaves and branches per plant, fresh and dry leaf yields than the other treatment combinations. Combination of 100 kg/ha DAP + 5 t/ha manure + late pinching and wholesome harvesting resulted to higher number of leaves per plant, fresh leaf yield and dry leaf yield than all the other treatment combinations.

Table 7. Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of spider plant during 2015 long rains at Kabete Field Station.

	PH (cm)	CS (cm)	B/P	LNo	FLY(kg/ha)	DLY (kg/ha)
First season (2015 short rains)						
Control + EP + P	6.2	9.1	1.0	2.0	141.7	20.3
Control + LP + P	7.1	9.8	2.0	1.8	145.4	20.8
Control + EP + W	5.1	7.6	1.0	2.8	99.3	13.9
Control + LP + W	6.7	9.7	2.0	7.8	739.6	110.7
200 kg/ha DAP + EP + P	55.7	44.4	8.0	18.7	786.2	111.1
200 kg/ha DAP + LP + P	57.9	31.9	9.0	19.3	741.0	103.4
200 kg/ha DAP + EP + W	27.7	27.8	4.0	15.2	745.9	105.6
200 kg/ha DAP + LP + W	55.4	41.9	10.0	53.0	4603.5	689.3
100 kg/ha DAP + 5 t/ha M + EP + P	60.4	42.9	8.0	21.3	912.5	129.8
100 kg/ha DAP + 5 t/ha M + LP + P	67.4	44.0	12.0	22.5	831.4	117.3
100 kg/ha DAP + 5 t/ha M + EP + W	32.7	32.7	4.0	18.2	845.5	118.3
100 kg/ha DAP + 5 t/ha M + LP + W	67.5	45.6	11.0	65.8	4623.9	692.3
10 t/ha manure + EP + P	46.1	33.7	8.0	18.2	698.0	99.2
10 t/ha manure + LP + P	51.9	34.6	10.0	16.5	686.2	94.0
10 t/ha manure + EP + W	23.3	26.4	3.0	16.7	678.2	97.9
10 t/ha manure + LP + W	51.9	41.5	9.0	49.8	3888.9	582.3
P-value (F×P×H)	0.046	<.001	0.034	<.001	<.001	<.001
$LSD_{(p=0.05)}$	10.6	3.7	1.5	3.7	96.4	13.9

PH=plant height, CS= canopy span, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, EP=early pinching, LP=late pinching, P=piecemeal harvesting, W=wholesome harvesting, M=manure, F=fertilizers, P=pinching, H=harvesting.

This could be possibly due to the synergistic effects of combined organic and inorganic fertilizers (Alemu and Bayu, 2005), and increased photosynthetic area due to wholesome harvesting and late pinching which may have led to increased photosynthesis and, consequently, plant growth and final leaf yield (Materechera *et al.*, 2013).

Effects of fertilizers and time of pinching on spider plant days to 50% flowering, pod length and 1000 grain yield

Fertilizer applications significantly accelerated time to 50% flowering in both seasons. Plants that received 200 kg/ha DAP took significantly fewer days to flower than plants that were treated with 10 t/ha manure.

In the first season, there was no significant difference in pod length and 1000 seed weight between plots that received 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure (Table 9). Similar observations were made in the second season (Table 9).

Late pinched plants took significantly (P≤0.05) longer time to reach 50% flowering than early pinched plants in both seasons (Table 9). In the first season, there was no significant effect of pinching on pod length and 1000 grain weight, while in the second season, early pinching resulted to significantly longer pods than late pinching (Table 9).

Reductions of number of days to 50% flowering with fertilizer treatment were observed by Uarrota (2010) in cowpea. Increases in pod length and grain weight with fertilizer treatment have also been reported by Singh *et al.*, (2011) in French beans and Love, (2014) in grain amaranth. These observations could be attributed to the availability of nutrients from both organic and inorganic fertilizers which stimulated both vegetative and reproductive growth. Incorporation of manure ensured slow and steady release of nutrients while the inorganic fertilizers readily availed the nutrients. Phosphorous is a key nutrient in plants involved in stimulating and enhancing bud development and set, seed formation and blooming as well as quickening plant maturity (Bender *et al.*, 2015).

In addition, phosphorous release from the fertilizers encouraged extensive and deep root system that may have played a significant role in nutrient absorption, photosynthesis, pod development and elongation (Rathi and Singh, 1976).

Table 8. Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of spider plant during 2015 short rains at Kabete Field Station.

	PH (cm)	CS (cm)	BP	L.No.	FLY(Kg/ha)	DLY (Kg/ha)
Second season (2015 long rains)						
Control + EP + P	25.8	27.2	2.6	7.9	277.0	36.8
Control + LP + P	17.6	17.4	1.8	8.0	224.5	29.9
Control + EP + W	5.3	10.5	1.1	5.9	97.9	13.4
Control + LP + W	17.0	25.4	2.0	32.2	1654.0	242.6
200 kg/ha DAP + EP + P	52.8	43.3	5.6	24.9	829.0	110.2
200 kg/ha DAP + LP + P	50.9	29.6	6.7	20.0	704.0	93.7
200 kg/ha DAP + EP + W	20.2	27.5	3.3	19.0	711.3	95.9
200 kg/ha DAP + LP + W	48.8	40.9	6.9	66.3	3931.4	576.7
100 kg/ha DAP + 5 t/ha M + EP + P	57.0	42.9	5.8	26.5	960.2	127.8
100 kg/ha DAP + 5 t/ha M + LP + P	69.5	42.2	8.9	29.1	994.0	132.1
100 kg/ha DAP + 5 t/ha M + EP + W	24.1	32.5	3.5	20.6	876.4	118.1
100 kg/ha DAP + 5 t/ha M + LP + W	63.0	45.6	8.0	82.3	4133.0	606.3
10 t/ha manure + EP + P	45.6	34.4	6.0	21.6	725.0	96.6
10 t/ha manure + LP + P	54.3	39.6	8.0	24.0	849.9	113.1
10 t/ha manure + EP + W	16.1	26.7	3.1	20.7	790.3	106.7
10 t/ha manure + LP + W	57.2	45.7	7.8	75.7	3857.8	565.9
P-value (F×P×H)	0.3	0.011	0.4	<.001	<.001	<.001
$LSD_{(p=0.05)}$	13.3	5.0	1.1	7.3	142.5	19.6

PH=plant height, CS= canopy span, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, EP=early pinching, LP=late pinching, P=piecemeal harvesting, W=wholesome harvesting, M=manure, F=fertilizers, P=pinching, H=harvesting.

Late pinched plants took significantly a longer time to reach 50% flowering than early pinched plants. Gnyandev, (2006) reported that late pinching or deflowering delayed the reproductive phase of plants. These observations are also in agreement with those of Love, (2014) in grain amaranth. Late pinched plants took a longer time to flower probably due to the destruction of the already developed flower buds. Early pinched plants had adequate time to develop new buds that later developed to flower buds.

Table 9. Main effects of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain yield of spider plant during 2015 short and long rains at Kabete Field Station.

	Days to 50% Flowering	Pod length (cm)	1000 grain weight (g)
First season (2015 short rains)			
Fertilizers			
Control	64.2	12.0	1.4
200 kg/ha DAP	49.8	16.3	2.0
100 kg/ha DAP + 5 t/ha M	51.0	16.3	2.0
10 t/ha Manure	51.3	15.4	2.0
P-value	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.3	0.9	0.1
Pinching			
Early Pinching	52.6	15.1	1.8
Late Pinching	55.6	14.9	1.8
P-value	<.001	0.54	0.761
$LSD_{(p=0.05)}$	0.2	NS	NS
Second season (2015 long rains)			
Fertilizers			
Control	59.3	13.9	2.0
200 kg/ha DAP	54.2	13.8	1.9
100 kg/ha DAP + 5 t/ha M	53.4	13.2	2.0
10 t/ha Manure	54.9	14.1	2.0
P-value	<.001	0.275	0.912
$LSD_{(p=0.05)}$	0.9	NS	NS
Pinching			
Early Pinching	54.3	14.1	2.0
Late Pinching	56.6	13.4	2.0
P-value	<.001	0.021	0.637
$LSD_{(p=0.05)}$	0.6	0.7	NS

NS=not significant.

Conclusion

The study revealed that combinations of fertilizer applications with late pinching and wholesome harvesting increased leaf yields in spider plant. Specifically, applications of combined inorganic fertilizer (100 kg/ha DAP) and organic fertilizer (5 t/ha chicken manure) resulted in the highest spider plant yields.

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