MORPHOLOGICAL CHARACTERIZATION AND RESPONSE OF SPIDER PLANT (*Cleome gynandra* L.) TO NPK FERTILIZER RATES AND DEFLOWERING

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted before in any institution for any other award.

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Recommendation

This thesis has been submitted with our approval as University supervisors for examination according to Egerton university regulations.

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DEDICATION

To all my family members and friends who have encouraged me to aim for the sky in life. I thank you very much and may God bless you all.

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The successful completion of this work was a team effort. Therefore I acknowledge the magnificent support that has brought this study to fruition. I thank the almighty God for giving me good health and sound mind throughout my research work; may all the glory belong to him. I also want to express my sincere gratitude to Egerton University and my supervisors Prof. R. M. S. Mulwa and Prof. J. O. Ogweno for their support by way of suggestions, guidance and advice throughout the study and during writing of this thesis. I wish to acknowledge Prof. J. O. Ogweno and Dr. Nyalala for providing seeds of the ecotypes used in my research work. All Department of Horticulture staff members who were willing and available in offering their technical knowhow in making this work successful are also greatly appreciated.

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ABSTRACT

Spider plant (*Cleome gynandra*) is among traditional leafy vegetables whose consumption is increasing in Kenya. Characterization of spider plant ecotypes has not been exclusively done even though a collection exists at the national museums of Kenya. Production of spider plant as a vegetable is constrained by low leaf yields resulting from lack of improved planting materials and a short vegetative phase of the plant. The objective of this study was to morphologically characterize 36 spider plant ecotypes and to investigate the effect of various NPK (17:17:17) fertilizer rates and deflowering on leaf yield and extension of the vegetative phase of spider plant. The study was conducted at the Horticulture Training Field three of Egerton University, Njoro for two seasons. In the morphological characterization experiment a 6×6 Lattice square design with seven replications and 42 blocks was used. Data was collected on days to first emergence, stem, petiole and main vein pigmentation, number of primary branches per plant, days to 1st, 50% and 75% flowering, flower colour, number of pods per plant, seed yield, 1000 seed weight, leaf yield and dry leaf weight. In the NPK and deflowering experiment a 5×2 factorial arrangement in a Randomized Complete Block Design (RCBD) with 10 treatments and three blocks was used. Data was collected on days to flowering, number of primary branches, plant height, fresh leaf yield, number of harvesting weeks and dry leaf weight. Results in the characterization experiment indicated that ecotypes took six to eight days to first emergence. In terms of stem, petiole and main vein pigmentation, four plants types were identified based on colour combinations amongst the 36 ecotypes studied: green stems - green petioles and green main vein; purple stems - purple petioles and purple main veins; green stems - purple petioles and purple main veins and purple stems - green petioles and green main veins. White and purple flowers were observed among the ecotypes. The best ecotype was IP8 in terms of fresh and dry leaf weight and number of primary branches compared to the other ecotypes. The hierarchical cluster analysis of the qualitative traits done using Unweighted Pair Group Method of Arithmetic Averaging (UPGMA) generated using DARwin software version 5.0 revealed two major clusters (cluster I and II) with cluster II forming two sub clusters(IIA and IIB). In the crop nutrition and deflowering study, the application of 300 kg NPK ha $^{-1}$ in combination with deflowering gave the highest fresh leaf yield, leaf dry weight and extended the harvesting duration by four weeks when compared to the control. The number of days to flowering was not influenced by fertilizer rates. Deflowered plants produced significantly higher numbers of primary branches than non-deflowered treatments. It is concluded that morphological diversity is evident in spider plant ecotypes and that deflowering in combination with NPK fertilization significantly increases vegetable yield by extending spider plant's vegetative phase.

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LIST OF ABBREVIATIONS

AILVs	African Indigenous Leafy Vegetables
ANOVA	Analysis Of Variance
ATP	Adenosine Triphosphate
AVRDC	Asian Vegetable Research and Development Centre
C4	Carboxylic Acid cycle
CAN	Calcium Ammonium Nitrate
DAP	Diammonium Phosphate
Dflw	Deflowering
FAO	Food and Agricultural Organization for United Nations
FYM	Farmyard Manure
HCDA	Horticultural Crops Development Authority
IC_{50}	Half minimal Inhibitory Concentration
KAPAP	Kenya Agricultural Productivity and Agribusiness Project
MT	Metric Tons
NACOSTI	National Council of Science Technology and Innovation
NPK	Nitrogen (N), Phosphorous (P), Potassium (K) fertilizer
No dflw	No deflowering
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
UPGMA	Unweighted Pair Group Method with Arithmetic Mean

CHAPTER ONE
1.0 INRODUCTION

1.1 Background information

Spider plant (*Cleome gynandra)* is one of the African Indigenous Leafy Vegetables (AILVs) that have not been given the attention they deserve. As a result of the neglect most of the popular AILVs such as *Cleome gynandra*, *Amaranthus* and *Solanum* complex grow in the wild, semi- cultivated or under small-scale production. Spider plant belongs to the family Cleomaceae. The production and utilization of these vegetables has been steadily increasing due to awareness created about their medicinal properties, nutritional value, agronomic and economic value (HCDA, 2012). During the year 2012, the share of AILVs on the domestic value for vegetables was 5% although the quantity produced was 11% (HCDA, 2012). Among the AILVs, spider plant is ranked fourth cowpea (*Vigna unguiculata*), African nightshade (*Solanum sp*) and pumpkin leaf (*Cucurbita maxima*) are first, second and third respectively (HCDA, 2012). According to the HCDA report 2012, the area under production of spider plant has been decreasing from 3,306 ha in 2010, to 2,409 ha in 2012 leading to a decline in the quantity produced from 28,222 MT in 2010 to 15,137 MT in 2012. The challenge in spider plant production is the renewing of seeds reducing their yields. Being grown under organic conditions also impact on their productivity (HCDA, 2012).

Spider plant is endemic in many parts of the world but it is a very underutilized weed crop. It is an herbaceous plant with alternate leaf arrangement, compound leaves and it produces white flowers. It grows as a weed in many parts of Sub-Saharan Africa especially in eastern and central Africa (Chweya and Mnzava, 1997). The leaves are tender, sharp and have mustard flavor with antioxidative and anti-inflammatory properties. The tender leaves, flowers, pods and shoots are consumed after boiling them in water or milk alone or in combination with other vegetables and spices. To remove the bitter taste the first cooking water is usually drained and fresh boiling water added. The leaves and stems are covered with glandular hairs (Van Wyk *et al*., 2000) and may have green or purple stems. It is a monoecious plant and possesses the C4 photosynthetic pathway and can therefore withstand high daytime temperatures, intense sunlight and drought, making it highly adapted to tropical and sub-tropical regions in the world (Chweya and Mnzava, 1997).

Nutritionally, spider plant contains high levels of beta-carotene, vitamin C, and moderate levels of calcium, magnesium and iron. It also has high levels of crude protein, lipids and phenolic compounds (Lyimo *et al*., 2003; Mulokozi *et al*., 2004). The leaf yield of spider

plant in Kenya is in the range of 1-3 tons/ha compared to the reported range of 20-40 tons/ha (Abukutsa-Onyango, 2003). This can be attributed to problems such as lack of quality seeds, short vegetative phase of the plant and lack of production packages for the improvement of this crop.

The demand for spider plant is increasing in urban and peri-urban areas sometimes surpassing the supply. Therefore, there is need to increase the production of spider plant which is also a source of income for the rural poor (Schippers, 2000). There is very little information on the cultivation techniques, use, extent and structure of genetic variation and the potential for crop improvement through domestication, selection and breeding. While systematic characterization and evaluation of spider plant has not been done in Kenya, some studies in Kenya and Zimbabwe indicate significant variations in many characteristics among spider plant populations (Chweya, 1990; Kemei *et al*., 1995; Mnzava and Chigumira, 2004). Little information exists to what extent these differences are due to environmental factors such as climate, soil fertility and stress conditions and genetic factors (Mnzava and Chigumira, 2004).

1.2 Statement of the problem

Spider plant is a popular indigenous leafy vegetable in many Kenyan rural communities and is rapidly gaining prominence among urban dwellers. Though a popular vegetable with multiple uses, spider plant is still poorly understood morphologically, has low leaf yields, displays non-uniformity in crop stands, has a short vegetative growth phase, and has no properly defined horticultural production packages in terms of fertilizer use and other manipulations. In addition, the vegetable exhibits early and excessive flowering coupled with prolific seed-set which competes with the leaves for assimilates, resulting in extremely low leaf yields. A common practice by farmers is the use of DAP fertilizer at planting followed by nitrogenous fertilizer top dresses. However, most farmers skip the top dress assuming that enough fertilizer has been applied at planting and that the crop requires no more fertilizer. Thus it is important to conduct studies to develop production packages for this indigenous vegetable.

1.3 Objectives

1.3.1 General objective

To contribute to improved production of spider plant through characterization of ecotypes and development of horticultural management practices.

1.3.2 Specific objectives

The specific objectives of this study were to:

1. Morphologically characterize spider plant ecotypes.
2. Determine the effects of different rates of NPK and deflowering on growth, leaf yield and extension of the vegetative phase of spider plant.

1.4 Hypotheses

The hypotheses for this study were:

1. There are no differences in the morphological traits of spider plant ecotypes.
2. Different rates of NPK fertilizer and deflowering have no effect on growth, leaf yield and the vegetative phase of spider plant.

1.5 Justification

Spider plant is one of the important indigenous leafy vegetables which improves food security, nutrition, health and is a source of income to many rural poor communities. Spider plant is adapted to a wide range of environments and can be produced at altitudes from sea level to 2400 meters above the sea level. Understanding the diversity of spider plant is essential for its conservation, utilization. Despite the great value of spider plant, not much research has been devoted towards its crop improvement especially in the area of morphological characterization. Morphological characterization of spider plant will inform on selection of ecotypes with desirable traits for breeding and conservation purposes. Information on the diversity within and among closely related crop species is essential for their effective use, improvement and management. Characterization of spider plant also promises to increase yield and improve availability of seed leading to more domestication and consumption the crop. Increased production would also lead to production surpluses, which are sold in markets providing reliable and consistent income for the poor farmers. Additionally, there is need to conduct studies on horticultural manipulations of spider plant to improve its productivity as this will help improve livelihoods, health and the economy to the rural poor farmers.

CHAPTER TWO
2.0 LITERATURE REVIEW

2.1 Overview of vegetable production in Kenya

In the year 2012 vegetables contributed 38% to the domestic value of horticulture in Kenya. The area, production and value were 287,000 Ha, 5.3 million tons and Ksh 91.3 Billion respectively, (HCDA, 2012). Traditional green leafy vegetables play an important role in household nutrition particularly in rural areas, as these are the main source of vitamins, minerals and certain hormone precursors in addition to protein and energy (Maundu *et al*., 1999). These vegetables are now being grown in rural and peri-urban areas for consumption among urban and rural population due to their inherent nutritional quality and medicinal values (Kimiywe *et al*., 2007).

With the onset of the market economy and modernization of agriculture in Africa, attention has been given to crops that offer a potential for urban and export market. As a result, exotic vegetables have become more prestigious than traditional vegetables and conventional agronomy has, to a large extent, concentrated on conserving the genetic resources and promotion of exotic high yielding vegetables rather than traditional vegetables (Sato *et al*., 2002). However, spider plant is among the most important traditional vegetables in Kenya (Schippers, 2000). Spider plant is grown mainly for the domestic market (HCDA, 2012). Kisii and Nyamira counties were the largest producers accounting for 60% of the total production and 69% of the value. Other producing counties were Tharaka Nithi and Kisumu (HCDA 2012). Spider plant is an erect herbaceous annual herb, which thrives best from 18 to 25°C and grows well on a range of soils from sandy loams to clay loams (Chweya and Mnzava, 1997). Spider plant grows as a weed in most tropical countries but is a semi-cultivated popular leafy vegetable in many parts of Sub-Saharan Africa especially in eastern and southern Africa (Chweya and Mnzava, 1997). Globally, spider plant is grown and consumed in Nigeria, Malawi, Zaire, Zimbabwe, Botswana, Swaziland, Tanzania, Kenya, Zambia, South Africa, Ghana, and Uganda. In India it is consumed as a pot herb and a flavoring in sauces and in Thailand it is consumed when fermented in a product called ‘pak-sian-dong’ (FAO, 1990).

2.2 Origin of Spider plant

Spider plant (*Cleome gynandra* L.) commonly known as spider flower plant, African spider flower, spider wisp, African cabbage or cats' whiskers, comprises 150-200 species of which 50 are indigenous to Africa (Schippers, 2002). Synonyms of *Cleome gynandra* L. are Gynandropsis gynandra (L.) Briq.), *Cleome pentaphylla* L., *Pedicellaria pentaphylla* (L.) Schrank, *Gynandropsis pentaphylla* (L.) DC, *Gynandropsis denticulata* DC and *Cleome acuta* Schum. (Chweya and Mnzava, 1997). Some of the edible but neglected species include *C. allamani*, *C. hirta* (Klotzsch) Oliv. *C. gynandra* L. Chiov, *C. monophylla* L., *C. rutidosperma* DC, and *C. viscosa* L. The crop belongs to the Cleomaceae family and sub family cleomoideae. According to Jansen (2004) and Mnzava (2004) *C. hirta (*Klotzsch*)* and *C. viscosa* originate from Ethiopia, Somalia, and through Eastern and Central Africa. *C. monophylla* is widespread in tropical and subtropical Africa. The origins of *C. allamani, C. gynandra* and *C. rutidosperma* are not well known.

2.3 Morphological description of spider plant

Spider plant is an erect herbaceous annual herb, which is strongly branched (Figure 1). It can grow up to a height of about 1.5 m based on the environmental conditions but it is usually 0.5 - 1.0m tall (Chweya and Mnzava, 1997). It has a long tap root, with a few secondary roots with root hairs. Stems and leaf petioles are thick and with glandular hairs. The stems may be green or purple in color (Figure 2). Schippers (2002) reported that those cultivars with purple stems are more nutritious, resistant to attack by insects than those with green stems, but they are more susceptible to diseases.

According to Chweya (1990), there are four different spider plant types based on stem and petiole pigmentation: green stem- green petioles, green stems- purple petioles, purple stems- green petioles and purple stems- purple petioles (Figure 2). The leaves are compound and can be alternate, palmate and have a petiole. Each leaf has 3-7 leaflets but most of them have 5 leaflets which are pinnate (Figure 3). The plant is monoecious and has three types of flowers: protandrous and protogynous flowers which allow cross pollination and there are those with flowers with the anthers shedding pollen grains when the stigma is receptive and this allows self-pollination (AVRDC, 2009).

The stem is sticky with glandular hairs and is marked with longitudinal lines. Stem pubescence varies from glabrous to abundant (Figure 4) (Chweya and Mnzava, 1997). The leaf stalk is 20 – 50 cm long with glandular hairs. The inflorescence is a terminal raceme with many flowers and it elongates into a fruit. The flower stalk is 10 – 20 mm long with glandular hairs

and the petals are white, sometimes pink 10 - 20 × 3 – 5 mm and are rounded at the apex. Flowers are bisexual, bracteates, white or tinged with purple. The fruits are in form of capsules which are cylindrical and linear. The fruits can be big and rough or thin and smooth (Figure 5) (Kiebre *et al*., 2015) The seeds are brown, circular, 1.5 mm in diameter with an obscurely netted surface (Mishra *et al*., 2011). Spider plant is a C_4 plant. In a study carried out by Voznesenkaya *et al*. (2007) the analysis of the anatomy, ultra structure of chloroplasts and mitochondria, levels of C_4 enzymes and immunolocalization of carboxylases indicated that *C. angustifolia* and *C. oxalidea*, along with *C. gynandra*, are NAD-ME-type C_4 species.

Figure 1: Spider plant (*Cleome gynandra* L.)
Source: (AVRDC, 2009)

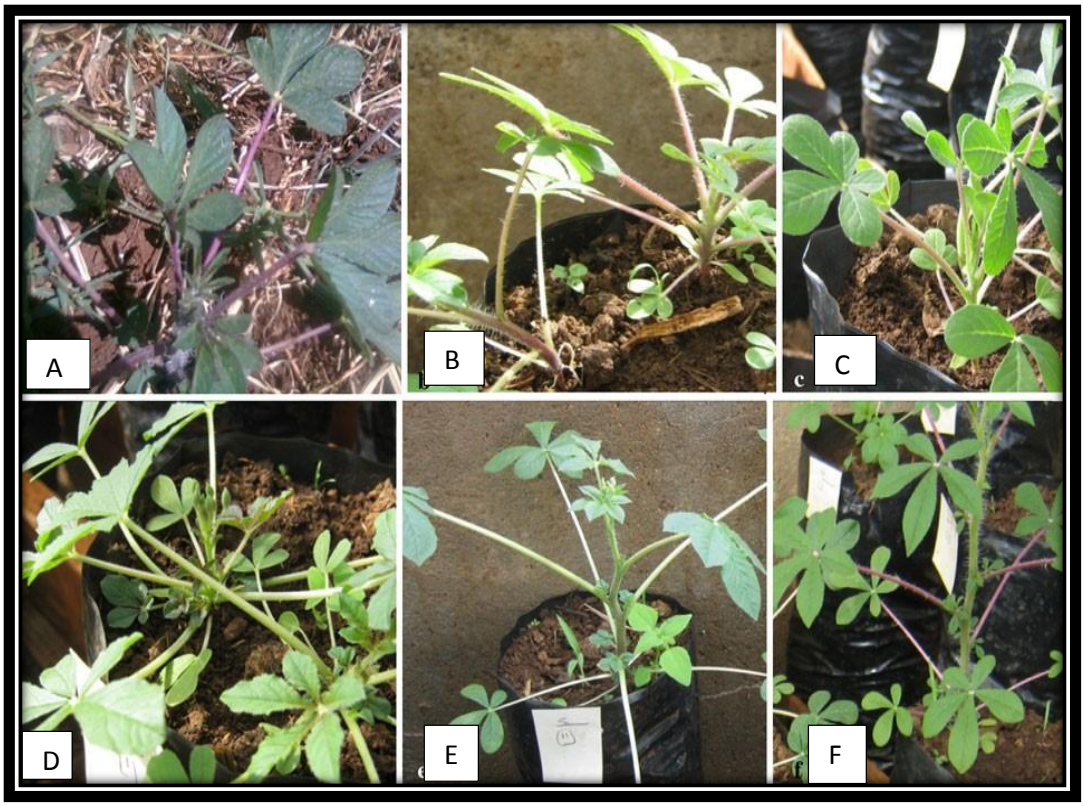


Figure 2: Spider plant types exhibiting variable pigmentation. A - Dark purple stems and leaf petioles, B - Pink stems and leaf petioles, C - Green stems with light pink leaf petioles, D -Green stems with green leaf petioles, E - Green stems with pale pink leaf petioles, F - Green stems with pink leaf petioles.

Source: Onyango *et al*., 2013.

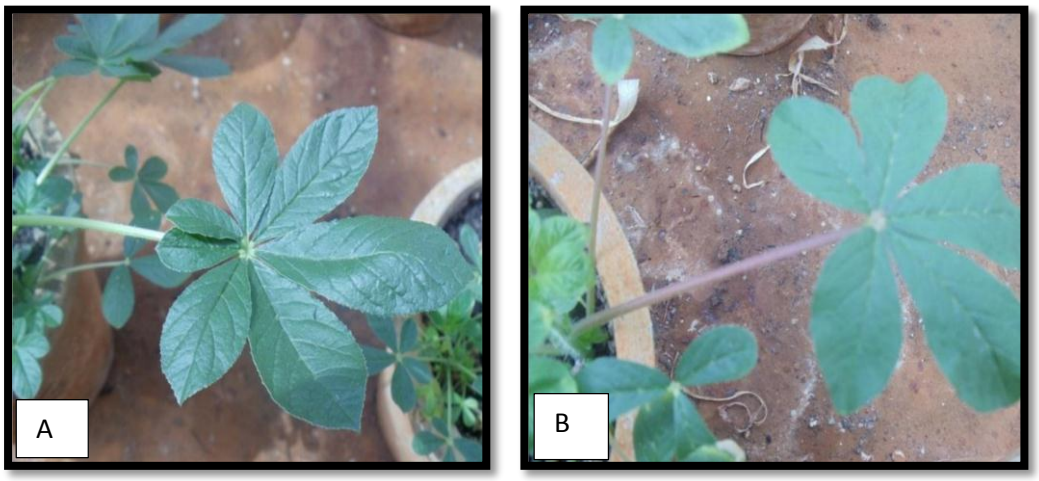


Figure 3: **Variations in number of leaflets per compound leaf of spider plant**
A – Seven leaflets, B – Five leaflets. Source: Masuka *et al*., 2012.

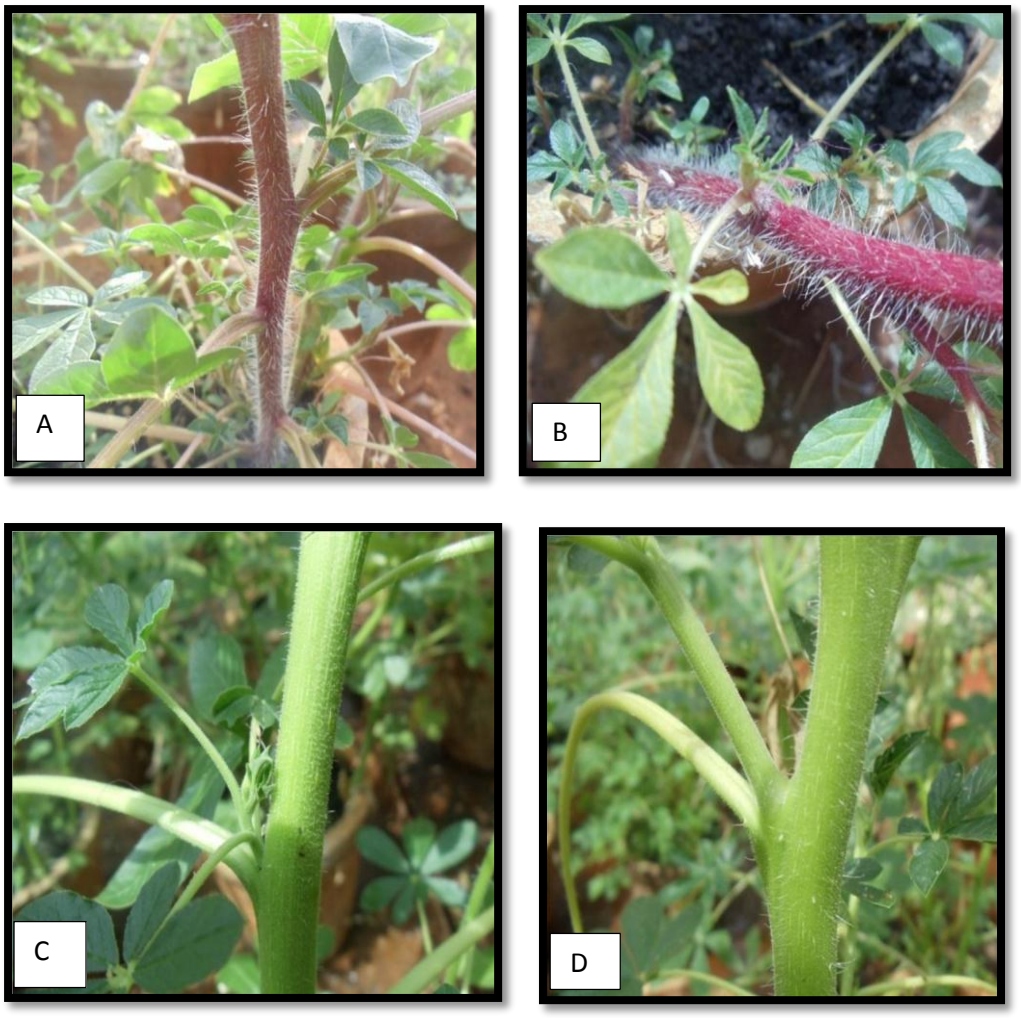


Figure 4: Comparison of stem pubescence of spider plant
A – Moderate pubescence, B – Densely glandular, C – glabrous, D – almost glabrous.

Source: Masuka *et al*., 2012

Figure 5: **Variation of fruit shape of spider plant**. A – Big and rough fruits, B – Small and smooth fruits Source: Kiebre *et al*., 2015.

2.4 Genetic diversity and characterization

In a study carried out by Maundu *et al*. (1999) to show whether the diversity within *Cleome gynandra* had any effect on the nutritional quality, the existence of morphotypes within the species was reported. Morphological characteristics which are easy to identify such as stem and petiole color were used and four morphotypes were identified. An earlier study by Chweya *et al*. (1990) recognized four plant types based on stem and petiole pigmentation which varied from light to deep. Ramaiah *et al*. (1983) defined morphotypes as strains of a species that have established morphological differences and Singh, (1990) defined morphology as the study of forms and features of different plant organs such as roots, stems, leaves, flowers, seeds and fruits. Morphotypes are referred to as strains of a species. Dutta, (1979) described character or trait as a morphological, anatomical or physiological feature of an organism which is usually a product of the action of the environment and the genotype. Characterization and evaluation of spider plant has not been done exhaustively. Chweya, (1993) collected different germplasm from farmers' fields and then determined the differences in plant characteristics, leaf yield and the nutritive quality of plants from the various seed lots. In other studies carried out in Kenya and Zimbabwe significant variations in many characteristics among spider plant populations were observed (Chweya, 1990; Kemei *et al*., 1995; Mnzava and Chigumira, 2004). Variation exists on spider plant because it comprises of 150 – 200 species.

2.5 Uses of spider plant

2.5.1. Leafy Vegetable and Nutritional importance

Studies carried out by Maundu *et al*. (1991) and Abukutsa- Onyango (2003) indicate that the leaves of spider plant are more nutritious than most of the exotic leafy vegetables as shown in table 1. In another study it was reported that increased soil fertility increases crude protein, but decreases β-carotene, ascorbic acid and iron content of the leaves (Chweya and Mnzava, 1997). Calcium and sodium content of the leaves are not affected by increased soil fertility (Opole *et al*., 1995). In Africa, the tender leaves or young shoots, as well as the flowers, are eaten boiled as a pot herb, tasty relish, stew or side dish. In East Africa, fresh leaves are used as ingredients in other mashed foods, and the dried leaves are ground and mixed with weaning foods (Mathenge, 1995). The leaves are rather bitter, and they are often cooked with other leafy vegetables such as cowpea (*Vigna sp*.), amaranths (*Amaranthus sp*.) and black nightshade (*Solanum nigrum* L.*)*. Milk may be added to remove the bitterness and the mixture left overnight in a cooking pot. The leaves may be boiled briefly after which the water is drained

and fresh boiling water added. The vegetable is a rich source of vitamins A and C and minerals such as calcium and iron and it contains some protein (Arnold *et al*., 1985). Boiling the leaves may reduce vitamin C content by up to 81%, while drying reduces the vitamin content by 95% (Sreeramulu *et al*., 1983; Mathooko and Imungi 1994). The other nutrient components are not significantly affected by cooking or drying of the leaves. The leaves contain some antinutrients such as phenolic compounds, which give the vegetable an astringent taste. The phenolic compounds bind proteins and this may lower protein digestibility and quality (Chweya and Mnzava, 1997).

Table 1: Nutrient content of 100g fresh weight edible portion of spider plant (*Cleome gynandra* L.) compared to kale (*Brassica oleracea* var *acephala*).

	Spider plant	Kale
Protein (%)	5.1	3.3
Calcium (mg)	262.0	187.0
Iron (mg)	19.0	32.0
Vitamin A	8.7	7.3
Vitamin C	144.0	93.0

Source: Maundu *et al*., 1999, Abukutsa- Onyango 2003.

2.5.2 Medicinal value

According to ethno-pharmacological surveys, spider plant has a number of medicinal uses. Leaves may be crushed to make a drink which is used to cure diseases such as scurvy (Opole *et al*., 1995). It is a highly recommended meal for pregnant and lactating women in some communities in Kenya (Kokwaro, 1976). Eating the vegetable is believed to reduce dizzy spells in pregnant women, reduce the length of time taken in labor and helps to regain normal heath after childbirth (Kamatenesi *et al*., 2007). Spider plant is also used to cure migraine, vomiting, diphtheria, vertigo, headache, pneumonia, septic ears, stomach ailments, as eyewash and is fed to boys after circumcision (Kokwaro, 1993; Edmonds *et al*., 1997; Schippers, 2002). A study carried out in Tanzania by Gessler *et al*. (1994) to analyze the antimalarial activity of spider plant found that the ethyl acetate extract was most effective at half minimal inhibitory concentration (IC_{50}) of 14 µg/ml. Van puyvelde *et al*. (1986) showed that methanolic extracts of spider plant could be used to inhibit *Candida albicans* and *Mycobacterium smegmatis* at 50 mg/ml. Hamill *et al*. (2003) reported that *Staphylococcus aureus* and *Bacillus subtilis* were

susceptible to inhibition to methanolic extracts. According to AVRDC (2009), free radicals are responsible for "oxidative stress" and often are implicated in the expression of several human diseases including diabetes, cancer, coronary heart diseases, neurodegenerative ailments and rheumatoid arthritis. The human body has an antioxidant defense system that is believed to be strengthened by antioxidant-rich diets. Stangeland *et al*. (2009) analyzed antioxidant activity in 35 Ugandan fruits and vegetables and reported that spider plant had antioxidant activity of 0.53 to 2.92 mmol/100g. Mibei *et al*. (2012) reported that the anti-oxidants in spider plant scavenge and bind harmful radicals in the body which if left to accumulate could cause diseases like cancer and diabetes. In the study it was found that the extracts of *Corchorus olitorius* and *Cleome gynandra* were the most effective since they had higher percentage of radical scavenging activity and lower IC_{50} values (Mibei *et al*., 2012). Spider plant been reported to aid in constipation and facilitate birth (Kokwaro, 1993; Olembo *et al*., 1995).

2.5.3 Crop protectant

The leaves of spider plant have repellant and acaricidal properties against the larvae, nymphs and adult *Rhipicelphalus appendiculatus* and *Amblyomma variegatum* ticks (Chweya and Mnzava, 1997). According to Schipper (2002), spider plant contains insecticidal and insect repellant properties and therefore spraying an aqueous extract of spider plant can reduce aphid and thrip populations. Intercropping spider plant and cabbage reduces diamond back moth (*Plutella xylostella*) as well as thrip attacks. In a study carried out in Kenya, it was reported that intercropping spider plant with roses in greenhouses at 8.3 plants/m^2 reduced the populations of red spider mites (*Tetranychus urticae*) (Nyalala and Grout, 2007). Spider plant contains glucosinolates, which include methylglucosinolates (Hasapis *et al*., 1981) cleomin, and glucocapparin (Mnzava *et al*., 2004); and their hydrolysis gives rise to methyl isothiocyanates, which is a strong antimicrobial compound (Mari *et al*., 1993) that may contribute to insecticidal properties, along with phenolic compounds and an acid volatile oil present in the glandular hairs (which are involved in the characteristic mustard smell). Waiganjo *et al.* (2007) observed that intercropping snap bean with spider plant significantly reduced the population of thrips on the former. Spider plant was also observed to be a host for *Orius spp* which is a natural enemy for thrips. The natural enemy could have played a role in reducing the population of the thrips. Intercropping spider plant with onions significantly reduced the population of thrips (*Thrips tabaci*) Gachu *et al*. (2012).

2.5.4 Fodder

The leaves of spider plant are used as forage by Bovines, camels, equines and game animals and the seeds as feeds for birds (Chweya *et al*., 1997). According to Mnzava, (1990) the seeds of spider plant contain up to 29.6% of polyunsaturated oils. The oil can be extracted by simple pressing and does not require refining. The seed cake can be used as animal feed and the seed itself for feeding birds (Mnzava *et al*., 2004).

2.6 Plant nutrition studies

2.6.1 Effect of farmyard manure on vegetables

Spider plant responds positively to increased fertility of the soil in terms of leaf yield (Chweya and Mnzava, 1997). It responds well to the application of nitrogenous fertilizers whether organic or inorganic. The use of farmyard manure has been observed to give better results than the use of inorganic nitrogenous fertilizers because FYM improves soil structure, cation exchange capacity and water holding capacity. Application of 20 kg FYM/m^2 is recommended (Mnzava, 1986). Where FYM is not available Diammonium Phosphate (DAP) is recommended at a rate of 0.2 kg/m^2 at planting time to promote continuous vegetative growth resulting to good leaf yields. During thinning which is done three weeks after emergence, top dressing is done using calcium ammonium nitrate (CAN) which contains 26% nitrogen (Chweya and Mnzava, 1997). Elevated levels of nitrogen delay flowering and hence extend the vegetative phase. Too much nitrogen makes the stems to become too succulent and regeneration is reduced and this is a disadvantage in places where the leaves are periodically harvested (Mnzava, 1986). According to a study carried out by Ng'etich *et al*. (2012) calcium ammonium nitrate (CAN) and composted farmyard manure increases the growth, fresh edible yield, above ground mass, chlorophyll content and stomatal conductance of spider plant.

Kipkosgei *et al*. (2002) reported that an increase in the amount of FYM or CAN caused a corresponding increase in the leaf yield of *Solanum villosum* but in all the experiments that were carried out the first harvest always gave the greatest yields with a decline in the subsequent harvests. This was attributed to the reduction of the photosynthetic surface hence the reduction in yields. Increasing the rate of fertilizers increased the content of beta- carotene in the edible portions of *Solanum villosum*. Inorganic nitrogen decreased the vitamin C content of the vegetable (Kipkosgei *et al*., 2002). Abukutsa *et al*. (2005) showed that different nitrogen levels increased growth of field grown broad leaved African nightshade up to 40-80 tons ha^{-1}

after which further increase in nitrogen led to stagnation or decrease of growth due to luxury uptake of nitrogen.

2.6.2 Effect of NPK fertilizer on vegetable production

Several studies have been done using NPK fertilizer on different vegetables. Olujide *et al*. (2007) observed substantial difference between the yields of *Amaranthus hybridus* under different levels of NPK (15:15:15) fertilizer. Achebe *et al*. (2013) reported that use of 250 kg ha^{-1} of NPK (20:10:10) fertilizer performed better than the other rates in plant height and total leaf area of okra (*Abelmuschus esculentus*). Application of NPK (20:10:10) at a rate of 300 kg ha^{-1} was recommended for farmers on upland soils of the Northern Guinea Savanna ecological zones of Nigeria (Ainika *et al*., 2012). It was reported that use of NPK fertilizer influenced the growth of pumpkin biomass, number of leaves produced and branches, stem diameter, number of tendrils, plant height and total young leaf yield were highest in those plants that received a higher amount of NPK fertilizer of 180 and 270 kg ha^{-1} as compared to those that received lower levels of NPK fertilizer. It was also noted that pumpkin requires 180 kg NPK ha^{-1} or less for optimal antioxidant activities and concentration of phenolic antioxidant. However, high levels of NPK fertilizer drastically reduced antioxidant activity and phenolic antioxidant concentration (Oloyede, 2012). A research done in Nigeria suggested that the application of NPK 15:15:15 fertilizer at the rate of 200 kg NPK ha^{-1} to eggplant under field conditions with good management practices improves growth, dry matter during pre anthesis and anthesis stages. It was also noted that the application of 200 kg NPK ha^{-1} was optimum for fruit production and leaf area in pot experiment while 300 kg NPK ha^{-1}favoured dry matter production and growth of eggplant (Nafiu *et al*., 2011).

2.6.3 Functions of Nitrogen, Phosphorous and Potassium in plant growth

Nitrogen is an essential nutrient and a determining factor in crop production. It is a constituent of many organic compounds, nucleic acids and protein compounds (Madan and Munjal, 2009). Nitrogen affects growth and yield of leafy vegetables through its effect on cell division, expansion, and elongation resulting to large stems, leaves and enhanced quality (Onyango, 2002). Nitrogen also plays a role in chlorophyll synthesis and hence the process of photosynthesis and carbon dioxide assimilation. Nitrogen deficiency results in poor growth rate; earlier maturity and shortened vegetative growth phase (Jasso-Chaverria *et al*., 2005). High nitrogen application results in lush plants with soft tissue and subsequent delay in maturity (Wolf, 1999). On the contrary, most plant growth decreases under excessive nitrogen

supply (Sanchez *et al*., 2004). Under high nitrogen rates, most plant species show reduced growth, smaller leaves and stunted root systems, and in severe cases death of the plant. (Cao and Tibbtts, 1998).

Phosphorus is one of the seventeen essential nutrients required for plant growth (Ragothama, 1999). It is the second most important macronutrient after nitrogen in limiting crop growth. Plant dry weight may contain up to 0.5% phosphorus and this nutrient is involved in plant processes such as in photosynthesis, respiration, in energy generation, in nucleic acid biosynthesis and as an integral component of several plant structures such as phospholipids (Vance *et al.,* 2003). Despite its importance in plants growth and metabolism, phosphorus is the least accessible macro-nutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilizers (Cordell *et al*., 2011) The low availability of phosphorus is due to the fact that it readily forms insoluble complexes with cations such as aluminum and iron under acidic soil condition and with calcium and magnesium under alkaline soil conditions further poor P fertilizer recovery occurs due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations (Cordell *et al*, 2011). Global P reserves are being depleted at a higher rate and according to some estimates there will be no soil P reserve by the year 2050 (Vance *et al.,* 2003; Cordell *et al*., 2011).

Potassium is another macronutrient which is important in crop growth. It is involved in enzyme activation. Potassium activates 60 different enzymes in plants by changing the physical shape of the enzyme molecule and thus exposing the appropriate chemical active site for reaction (Van *et al*, 1998). It also neutralizes organic anions and other compounds in the plant and this helps to stabilize the pH between 7 and 8 which is the optimum pH for most enzymes (Van *et al*., 1998). Potassium regulates the opening and closing of the stomata pores through which leaves exchange carbon dioxide, water vapor and oxygen with the atmosphere. Proper functioning of the stomata is essential for photosynthesis, water and nutrient transport and plant cooling (Thomas and Thomas, 2009). Potassium plays a role in photosynthesis due to the activation of enzymes and its involvement in adenosine triphosphate (ATP) production. It maintains the electrical charge at the site of ATP production (Van Brunt and Sultenfuss, 1998). The plant transport system uses energy in the form of ATP to transport sugars which are produced during photosynthesis to the other parts of the plant for use or storage. If potassium is inadequate, less ATP is available and the transport system breaks down (Van Brunt and Sultenfuss, 1998). The transport of water and nutrients in the xylem is also a role of potassium in conjunction with specific enzymes and plant growth hormones (Thomas and Thomas, 2009).

Without adequate potassium the reading of the genetic code in plant cells to produce proteins and enzymes that regulate all growth processes would not be possible. Plants deficient in potassium will not synthesize proteins even with an adequate amount of nitrogen (Patil, 2011). Potassium is also responsible for the activation of the enzyme starch synthetase which is responsible for starch synthesis (Patil *et al*, 2011). Therefore, inadequate potassium leads to reduction in soluble carbohydrates and nitrogen compounds accumulate in the plant (Patil, 2011).

2.7 Deflowering in vegetables

It has been reported that spider plant flowers prematurely a condition known as bolting. Bolting is common in other vegetables such as spinach (*Spinachea oleracea*), lettuce (*Lactuca sativa*) and mustard rape (*Brassica juncea*). Bolting can be due to temperature extremes, photoperiod or genetic factors and it leads to production losses because the crops flower before they have produced an economic yield (Royal Horticultural Society, 2012). Masarirambi *et al*. (2011) reported that bolting in brassicas is a physiological disorder. Zobolo *et al*. (1999) concluded that flowering was responsible for reduction of leaf and stem growth and that deflowering reduced senescence, hence maintaining the vegetative growth of *Bidens pilosa*. Mwafusi (1992) carried out a study to determine the effect of deflowering on vegetative growth, leaf yield and nutritive quality of *Solanum nigrum* and reported that deflowering did not significantly affect plant height, plant canopy spread and number of branches per plant. However, deflowering increased leaf yield by 40%, with the deflowered plants yielding 2154 kg ha^{-1}. Mavengahama (2013) reported that the removal of flowers and nitrogen application resulted in significant increase in fresh and dry weight of cleome leaves. In the study it was observed that the removal of flowers resulted into a 46% increase in fresh weight of the leaves. The removal of flowers could therefore offer a possible solution to the problem of bolting and hence increase the utilizable leaf yield of spider plant (Mavengahama, 2013). Frequent picking and deflowering encourages lateral growth thus extending the harvesting period of spider plant (Chweya and Mnzava, 1997). Mutoro *et al*. (2012) reported that deflowering of spider plant is important in extending the harvesting period by avoiding early senescence. In the study flowers and young flower buds were removed daily to encourage vegetative growth. Maumba (1993) reported that deflowering significantly reduced plant height, increased number of primary branches per plant and leaf yield of spider plant. Deflowered plants had a fresh leaf yield of 9.5 ton ha^{-1} while non-deflowered plants had 7.5 ton ha^{-1}. It was also noted that deflowering

significantly increased leaf ascorbic acid content but had virtually no effect on leaf β-carotene and total phenolic contents. The removal of the apical shoots in plants is known to stimulate the growth of lateral shoots which develop into branches as confirmed by Masinde and Agong (2011) who removed flowers so as encourage vegetative growth of C. *gynandra*. Abukutsa *et al*., (2003) reported that topping which is the removal of the apical stem could be used to delay flowering in some of the indigenous vegetables that flower early like spider plant and hence increase productivity.

CHAPTER THREE
3.0 MATERIALS AND METHODS

3.1 Site description

The study was conducted at the Horticulture Research and Teaching Field 3 of Egerton University, Njoro. The site lies at latitude 0º 23' South, longitude 35º 35' East in the Lower Highland III Agro Ecological Zone (LH3) at an altitude of approximately 2,238 meters above sea level. The average maximum and minimum temperatures 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-vintric mollic andosols (Jaetzold *et al.*, 2006**).**

3.2 Description of experiments

Two experiments were conducted in this study. The first experiment involved morphological characterization of 35 spider plant ecotypes and one commercial seed type (Simlaw Seeds, Kenya). The second experiment investigated the effect of different rates of NPK fertilizer and deflowering on the productivity of the commercial type.

3.2.1 Experiment one: Morphological characterization of spider plant ecotypes

The 35 ecotypes used in this experiment were collections by Prof. Ogweno and Dr. Nyalala. Specifically the ecotypes were collected from Bungoma (BUG), Kilgoris (KIL), Kwale (KWL), Nyeri (NYR), Baringo (BAR), Molo (MOL), Rangwe (RAN), Vihiga (VIH), Siaya (SIA), Egerton (EGT), Trans - Mara (TAS), Narok (NAR), China (CHINA), Kisumu (KSM), Eldoret (ELD), Kakamega (KKM), Webuye (WEB), Migori (MIG), Kitale (KTL), Kericho (KER), Lugari (LUG), Keiyo (KEY), Luanda (LUA), Homabay (HBY), Kitui (KTU), Embu (EMB), Meru (MRU), Kilgoris (KIL), Kapenguria (KAP), Kabarak (Kenya DF), AVRDC Arusha (IP8), AVRDC Arusha (PS), Suba (SUB), Eldoret equator (EQT), Kiamunyi (Kenya D). In addition, one commercial seed type was sourced from Simlaw Seeds Ltd. In total 36 accessions were used. The experimental design was 6×6 lattice square design with 42 blocks and 7 replications each with the 36 spider plant ecotypes as the treatments. Each experimental plot measured 1.2 m × 1.2 m. The seeds were drilled in 4 rows spaced 30 cm apart. DAP fertilizer was applied at the rate of 120 kg ha^{-1} during planting and thoroughly mixed with the soil before placing the seeds. Three weeks later seedlings were thinned to an

intra-row spacing of 10 cm to give 12 plants per row for a total of 48 plants per plot. Topdressing was done with CAN fertilizer at a rate of 100 kg ha^{-1} after thinning. In each plot the plants were divided into two lots such that plants in one half were harvested for leaf yield data and those in the other half left for morphological trait data collection. The first weeding was done four weeks after planting and continued at an interval of two weeks. Watering was done when rainfall was inadequate. Flea beetles were controlled using an insecticide (Bestox).

3.2.2 Experimental layout and randomization of treatments

Replication 1

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Replication 2

2	7	13	19	25	31
1	8	14	20	26	32
3	9	15	21	27	33
4	10	16	22	28	34
5	11	17	23	29	35
6	12	18	24	30	36

Replication 3

6	8	15	22	29	36
31	2	9	16	23	30
25	32	3	10	17	24
19	26	33	4	11	18
13	20	27	34	5	12
7	14	21	28	35	1

Replication 4

4	23	32	10	13	20
15	2	24	33	11	14
28	16	3	25	34	12
7	29	17	1	26	35
21	8	30	18	6	27
36	22	9	31	19	5

Replication 5

17	30	7	19	27	14
22	2	31	8	20	28
15	23	3	32	9	21
11	6	24	4	33	10
35	12	1	25	5	34
29	36	13	18	26	16

Replication 6

3	18	28	7	13	32
23	2	19	29	8	14
33	24	1	20	30	9
10	34	6	4	21	31
15	11	35	25	5	22
17	16	12	36	27	26

Replication 7

11	12	21	28	33	36
7	2	13	22	29	34
17	8	3	14	23	30
25	18	9	4	1	24
31	26	19	10	5	16
35	32	27	20	15	6

Figure 6: Experimental layout for the morphological characterization experiment.
KEY: 1-BUG, 2-KGR, 3-KWL, 4-NYR, 5-BAR, 6-IP8, 7-PS, 8-MOL
9-RAN, 10-Kenya DF 1, 11-VIH, 12-SIA, 13-EGT, 14-TAS, 15-KAP,
16-SUB, 17- NAR, 18- Kenya D, 19-CHINA, 20- KSM, 21-ELD,
22-EQT, 23-KKM, 24-WEB, 25-MIG, 26- KTL, 27-KER, 28-LUG,
29-KEY, 30-LUA, 31-HBY, 32-KTU, 33-EMB, 34-KIL, 35-MRU,
36- Commercial variety.

3.2.3 Data collection

Data was collected and recorded on the following parameters from a total of 10 plants in the two middle rows of each plot. The outer rows in each plot served as guard rows.

(i) Number of days to first emergence

The mean numbers of days to first emergence were obtained by computing the average number of days to first seedling emergence for each ecotype.

(ii) Stem, petiole and main vein pigmentation

Stem, petiole and main vein pigmentation was determined using standard plant colour charts (Royal Horticultural Society color chart). Additionally, photographs of the various pigmented spider plants were taken and pasted on a chart and compared using standard plant colour.

(iii) Number of primary branches per plant

The number of primary branches was determined by counts from the 10 middle plants selected from each plot and replicate at the peak of vegetative phase, just before flowering. The mean number of branches per plant was computed for each plot from the 10 selected plants. Treatment means were then calculated.

(iv) Days to first, 50% and 75% flowering

The number of days taken for the first flowers to appear in each plot was determined. Additionally the number of days taken by the plants in each plot to attain 50% and 75% flowering was also determined.

(v) Flower color

Flower colour was determined using standard plant colour charts (Royal Horticultural Society color chart). Additionally, photographs of the various flower colours were taken and pasted on a chart and compare using standard plant colour.

(vi) Number of pods per plant

The number of pods per plant was determined by counting pods from the 10 selected plants from each plot in each replicate. The mean number of the pods per plant in each plot was calculated after which the mean number of pods per plant for each ecotype was computed.

(vii) Seed yield

Seeds were extracted from all the pods obtained from the 10 selected plants and their weight taken .For each plot the weight (g/plot) was converted to kilograms per hectare. The average seed yield for the 7 replicates of each ecotype was computed.

(viii) 1000 seed weight

This was determined by counting 1000 seeds from each of the treatment plots for each ecotype and measuring their weight in grams. The mean 1000 seed weight for the 7 replicates was computed to constitute 1000 seed weight for each ecotype which was recorded in grams.

(ix) Leaf yield

Leaf harvesting commenced 50 days after planting from 10 selected plants in each plot. Harvesting continued at intervals of two weeks until no more leaves were available in each plot. The yield was recorded in g/plot. Means for each treatment were computed from the 7 replicates in the experiment and converted to kg ha^{-1}.

(x) Dry leaf weight

The leaves obtained from section 3.2.3 (ix) were placed in an oven at 72^0C and dried to constant weights for 72 hrs. The dry weight of each sample replicate was determined and means computed for each ecotype.

3.2.4 Cluster analysis

Cluster analysis was conducted using the qualitative data to infer genetic relationships among the 36 spider plant ecotypes by Un-weighted Pair Group Method and Arithmetic Average (UPGMA) using DARwin version 5.0 (Perrier and Jacquemond – Collet, 2006) with simple matching coefficient. The dissimilarity coefficients were then used to generate an un-weighted hierarchical dendrogram.

3.2.5 Data analysis

All the quantitative data from the experiment was subjected to Analysis of Variance (ANOVA) and significant means separated using Tukey's honestly significant difference (Tukey's HSD) test at $P \leq 0.05$. The SAS statistical package (SAS Institute, 2005) was used for data analysis.

The basic model fitted for the experiment was:

$Y_{ijkl} = \mu + \alpha_i + \beta_j + \tau_k + \alpha\tau_{ik} + R_l + \varepsilon_{ijkl}$

i= 1, 2; j= 1, 2, 3…..42; k= 1, 2, 3, 4……36; l=1, 2, 3, 4, 5, 6, 7.

Where; Y_{ijkl} – Spider plant response

μ – Overall mean

α_i – Effect due to the i^{th} season

β_j – Effect due to j^{th} block

τ_k- Effect due to k^{th} ecotype

$\alpha\tau_{ik}$- Interaction effect of the i^{th} season and k^{th} ecotype

R_l- Effect due to the l^{th} replication

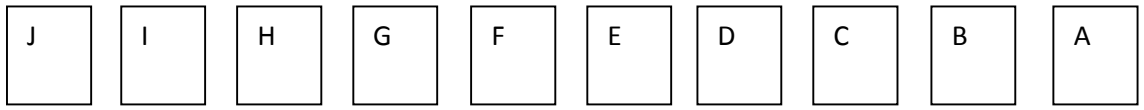
ε_{ijkl} – Random error component which is assumed to be normally and independently distributed about zero mean with a common variance σ^2.

The overall assumption was that the data was normally distributed with means and standard deviations which are not equal to zero.

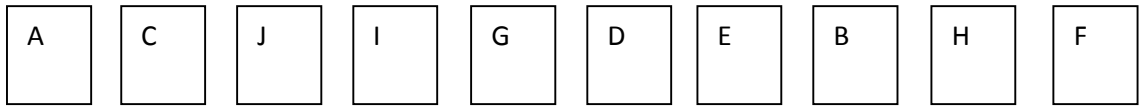
3.2.5 Experiment two: Effect of different NPK (17:17:17) rates and deflowering on the leaf yield and harvest duration of spider plant

Commercial spider plant seeds sourced from Simlaw Seed Company in Kenya were used in this experiment. The experiment was conducted as a 5×2 factorial arrangement in a RCBD with 10 treatments replicated 3 times. The experimental plots measured 2m×2m. Seeds were drilled in rows spaced 30 cm apart to give a total of 6 rows and thinning was done three weeks later to leave a spacing of 10 cm between the plants for a population of 120 plants per plot. Various combinations of NPK rates (0, 100, 200, 300 and 400 kg ha^{-1}) with or without deflowering were tested.

Block 1



Block 2



Block 3

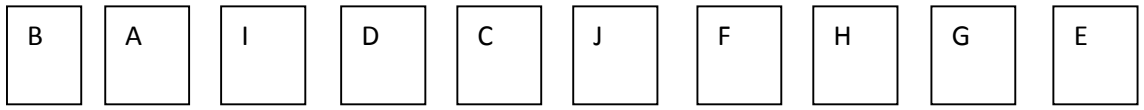


Figure 7: Experimental layout and treatment randomization for experiment 2

KEY: A- 0kg NPK and no deflowering, **B-** 100kg NPK and no deflowering, **C**-200kg NPK and no deflowering, **D**-300kg NPK and no deflowering, **E**-400kg NPK and no deflowering, **F**-0kg NPK and deflowering, **G**-100kg NPK and deflowering, **H**-200kg NPK and deflowering, **I**-300kg NPK and deflowering, **J**-400kg NPK and deflowering.

3.2.6 Data collection

Data was collected from the 4 middle plant rows in the plots consisting of 80 plants. Out of these 10 plants from each second row of a plot were tagged and used to collect plant morphology data (number of days to flowering, number of primary branches and plant height). The remaining 70 plants were used for application of deflowering treatments where applicable and the collection of yield data. The following data was collected:

(i) Number of days to flowering

This was determined by counting the number of days taken by the plants from planting to flowering in each treatment. The mean numbers of days taken to flower were computed and thereafter treatment means computed.

(ii) Number of primary branches per plant

The number of primary branches was determined by counting from 10 selected plants in each plot at the peak of vegetative phase just before flowering. The mean number of primary branches per plot was computed for each treatment.

(iii) Plant height

The height of the 10 selected plots in each plot and each replicate was measured using a meter rule from the ground surface to the top most part of the main stem. This was done when the plants had ceased producing pods.

(iv) Fresh leaf yield and number of harvesting weeks

Leaf harvesting commenced 50 days after planting from the 20 selected plants from each plot. Harvesting continued at an interval of two weeks until no more vegetable could be obtained. The yield was recorded in g/plot for each treatment plot. Means for each treatment were computed from the 3 blocks in the experiment and converted to kg ha^{-1}. The number of weeks taken to harvest from each treatment was determined at the end of each harvesting regime for each plot and means of the number of weeks taken computed.

(v) Dry leaf weight

The leaves obtained from section (iv) were dried to a constant weight in an oven at 72^0C and dried to a constant weight for 72 hrs. The dry weight of each plot sample was determined and means computed for each treatment.

3.2.7 Data analysis

Data collected was subjected to Analysis of Variance (ANOVA) and significant means separated using Tukey's honestly significant difference (Tukey's HSD) test at $P \leq 0.05$. The SAS statistical package (SAS Institute, 2005) was used for data analysis.

The basic RCBD model fitted for the experiment was:

$Y_{ijkl} = \mu + \alpha_i + +\tau_k + P_l + \beta_j + \alpha\tau_{ik} + \alpha P_{il} + \alpha\tau P_{ik} + \varepsilon_{ijkl}$

i=1, 2; j = 1, 2, 3; k = 1, 2, 3, 4, 5; l=1, 2

Where; Y_{ijkl} – Spider plant response

μ – Overall mean

α_i – Effect due to the i^{th} season

β_j – Effect due to j^{th} block

τ_k- Effect due to k^{th} fertilizer rate

P_l-Effect due to l^{th} deflowering

$\alpha\tau_{ik}$- Interaction effect of the i^{th} season and k^{th} fertilizer rate

αP_{il}- Interaction effect of the i^{th} season and the l^{th} deflowering

τP_{kl}- Interaction effect of the k^{th} fertilizer rate and the l^{th} deflowering

$\alpha\tau P_{ikl}$- Interaction effect of the i^{th} season, k^{th} fertilizer rate and l^{th} deflowering

ε_{ijkl} – Random error component which is assumed to be normally and independently distributed about zero mean with a common variance σ^2.

The overall assumption for normality of data was made and it was further assumed that was that standard deviations will not be equal to zero.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment 1: Morphological characterization of spider plant ecotypes

4.1.1. Days to first emergence

Significant variation was observed among the ecotypes on the number of days to first emergence. The days to emergence ranged from 6-9 (table 2). Ecotypes IP8, KIL, KKM, KTL, KTU, BUG, CHINA, EMB, NAR, NYR, PS, RAN, SIMLAW and TAS took 6 days to emerge; KENYA DF, KEY, SIA took 7 days; ELD, HBY,KENYA D, KSM and MRU took 8 days. BAR, EGT, EQT, KAP, KER, KGR, LUA, LUG, MIG, MOL, SUB, VIH, KWL and WEB took 9 days to emerge in season 1. In season 2, ecotypes KENYA DF, KEY, SIA, IP8, KIL, KKM, KTL, KTU, BUG, CHINA, EMB, NAR, NYR, PS, RAN, SIMLAW and TAS took 6 days to emerge; ELD, HBY, KENYA D, KSM and MRU took 7 days; BAR, EGT, KAP, KER, KGR, LUA, LUG, MIG, MOL, SUB, VIH, KWL and WEB took 8 days to emerge (table 2).

Table 2: Number of days to emergence in season one and two

	Days to emergence	
Ecotype	Season 1	Season 2
BAR	9a	8a
EGT	9a	8a
EQT	9a	8a
KAP	9a	8a
KER	9a	8a
KGR	9a	8a
LUA	9a	8a
LUG	9a	8a
MIG	9a	8a
MOL	9a	8a
SUB	9a	8a
VIH	9a	8a
KWL	9a	8a
WEB	9a	8a
ELD	8b	7b
HBY	8b	7b
KENYA D	8b	7b
KSM	8b	7b
MRU	8b	7b
KENYA DF	7c	6d
KEY	7c	6d
SIA	7c	6d
IP8	6d	6d
KIL	6d	6d
KKM	6d	6d
KTL	6d	6d
KTU	6d	6d
BUG	6d	6d
CHINA	6d	6d
EMB	6d	6d
NAR	6d	6d
NYR	6d	6d
PS	6d	6d
RAN	6d	6d
SIMLAW	6d	6d
TAS	6d	6d

*Means followed by the same letter(s) within a column are not significantly different according to Tukey's Honestly Significant Difference Test at $P \leq 0.05$.

4.1.2 Stem, petiole and main vein pigmentation

There was a significant variation between the 36 ecotypes in terms of stem, petiole and main vein pigmentation. Four groups of plants were identified based on their vegetative part colour combinations, namely; plants with green stems, green petioles and green main veins;

green stems, purple petioles and purple main veins; purple stems, purple petioles and purple main veins and purple stems, green petioles and green main veins. BUG, KGR, BAR, IP8, KENYA DF, EGT, TAS, CHINA, ELD, KKM, WEB, KTL, KER, LUG, LUA, KTU and EMB ecotypes had some plants with green stems, green petioles and green main veins and others with purple stems, purple petioles and purple main veins and this formed 47.2%. KWL, RAN, SIA, KAP, MIG, KEY, KIL, MRU and SIMLAW had some plants with purple stems, purple petioles and purple main veins while others had green stems, purple petioles and purple main veins and this formed 25%. NYR, PS, MOL, VIH, SUB, KENYA D, KSM and EQT had some plants with purple stems, purple petioles and purple main veins while others had purple stems, green petioles and green main veins and this formed 22.2%. Ecotype NAR had purple stems, purple petioles and purple main veins only forming 2.8%. Ecotype HBY had some plants with green stems, purple petioles and purple main veins while others had green stems, green petioles and green main veins forming 2.8%. These observations are illustrated in Figure 8.

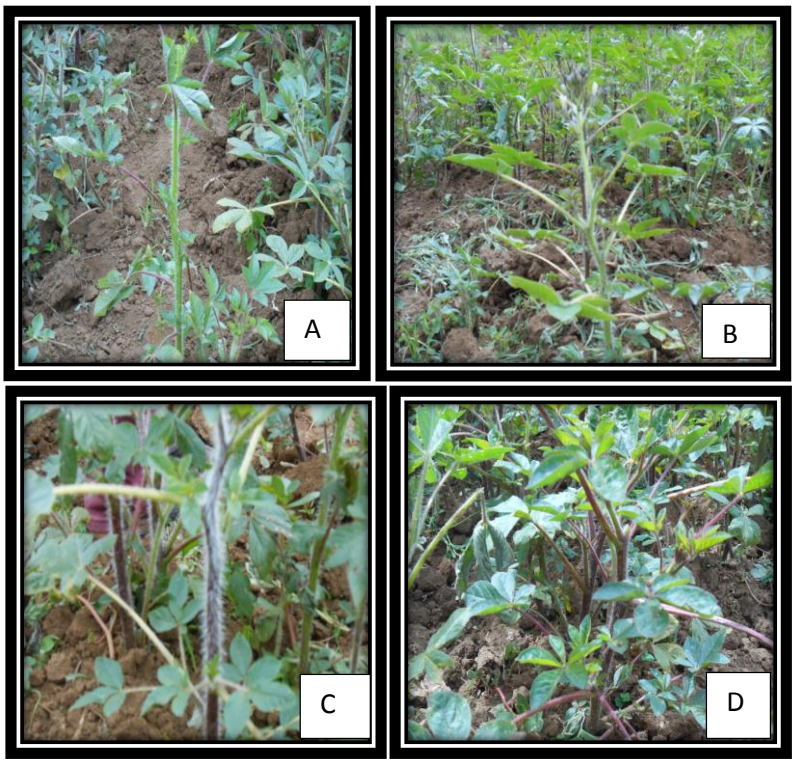


Figure 8: Stem, petiole and main vein pigmentation observed in spider plant ecotypes: **A**- green stem, purple petiole and purple main vein; **B**- green stem, green petiole and green main vein; **C**- purple stem, green petiole and green main vein; **D**- purple stem, purple petiole and purple main vein.

4.1.3 Number of primary branches per plant and number of days to 1st, 50% and 75% flowering

There was significant variation in the number of primary branches formed in the 36 ecotypes studied. Ecotype IP8 recorded the highest number of primary branches in both season 1 and 2 (Table 3). In season 1 ecotype IP8 had a mean of 16.63 primary branches and in season 2 it had 15.36 primary branches compared to the commercial variety SIMLAW which had 12.79 and 10.79 primary branches in seasons one and two, respectively. In season 1 ecotype BAR had 8.18 primary branches per plant and this was the lowest. In season 2 ecotype CHINA had 9.77 primary branches per plant and it's the one which had the lowest number of primary branches in season 2. The other ecotypes were statistically identical in the number of primary branches per plant.

There was no variation among the ecotypes in the number of days to first, 50% and 75% flowering. The days to first flowering ranged from 36 to 47 days while days to 50% flowering ranged from 43 to 50 days and the days to 75% flowering ranged from 47 to 53 days

(Table 3). Ecotypes IP8 and MOL took 47 days to first flowering, 50 days to attain 50% flowering and 53 days to 75 % flowering. Ecotypes IP8 and MOL took the longest time to produce the first flower and to attain 50 % and 75% flowering in both seasons. The commercial variety SIMLAW took 46 days to first flowering, 48 days to 50 % flowering and 51 days to 75 % flowering. Ecotypes KGR and KENYA DF took the shortest time of 35 days to first flowering. Ecotypes BUG, KGR, KWL, PS, KENYA DF, VIH, SIA, TAS, KAP, SUB, NAR and KIL took 43 days to attain 50% flowering and most of the ecotypes took 47 days to attain 75% flowering (Table 3).

Table 3: **Number of primary branches per plant and number of days to 1st, 50% and 75% flowering in season one and two**

	No. of pri branches		Days to : Flowering Season 1 and 2		
Ecotype	Season 1	Season 2	1st flowering	50% flowering	75% flowering
BUG	10.48bc	10.87bc	36	43	47
KGR	11.35bc	11.41bc	35	43	47
KWL	12.52b	11.59bc	36	43	47
NYR	10.75bc	11.74bc	46	49	51
BAR	8.18c	12.00bc	37	44	47
IP8	16.63a	15.36a	47	50	53
PS	11.54bc	10.67bc	38	43	47
MOL	11.60bc	11.79bc	47	50	53
RAN	10.86bc	11.99bc	43	46	49
KENYA DF	12.19b	11.09bc	35	43	47
VIH	11.98b	12.10bc	36	43	47
SIA	11.43bc	11.93bc	36	43	47
EGT	11.66b	11.84bc	40	44	47
TAS	12.46b	10.87bc	38	43	47
KAP	12.32b	12.21b	36	43	47
SUB	12.55b	11.25bc	38	43	47
NAR	11.92b	11.93bc	37	43	47
KENYA D	11.61bc	10.78bc	37	44	47
CHINA	10.71bc	9.77c	40	47	50
KSM	12.02b	10.19bc	39	47	50
ELD	12.22b	10.87bc	41	44	47
EQT	11.08bc	9.98bc	40	47	50
KKM	10.49bc	10.49bc	39	44	47
WEB	12.63b	10.45bc	41	44	47
MIG	10.67bc	10.73bc	40	45	47
KTL	10.95bc	10.93bc	40	44	47
KER	11.02bc	10.81bc	39	44	47
LUG	10.79bc	10.89bc	39	44	47
KEY	12.51b	10.53bc	41	44	47
LUA	11.13bc	11.09bc	41	44	47
HBY	10.27bc	10.17bc	40	47	50
KTU	11.05bc	10.85bc	41	44	47
EMB	10.26bc	10.61bc	42	47	50
KIL	10.10bc	10.98bc	39	43	47
MRU	10.96bc	11.23bc	46	48	51
SIMLAW	12.79b	10.73bc	46	48	51

*Means followed by the same letters in a column are not significantly different according to Tukey's Honestly Significant Difference Test at $P \geq 0.05$

4.1.4 Flower colour

In the current study two main flower colours were identified white and, purple flowers or a mixture of white and purple flowers on the same ecotype. Ecotypes BUG, KGR, NYR, BAR, IP8, PS, MOL, RAN, KENYA DF, SIA, EGT, TAS, KAP, SUB, NAR, CHINA, KSM, EQT, LUA and KTU had only white flowers while VIH, KENYA D, ELD and MIG had purple flowers only. Ecotypes KWL, KKM, WEB, KTL, KER, LUG, KEY, HBY, EMB, KIL, MRU and SIMLAW had a mixture of white and purple flowers in both seasons. These observations are illustrated in the colour plates in Figure 9. The proportion of white flowers was 55.6%, purple 11.1% and mixture of white and purple flowers was 33.3%.

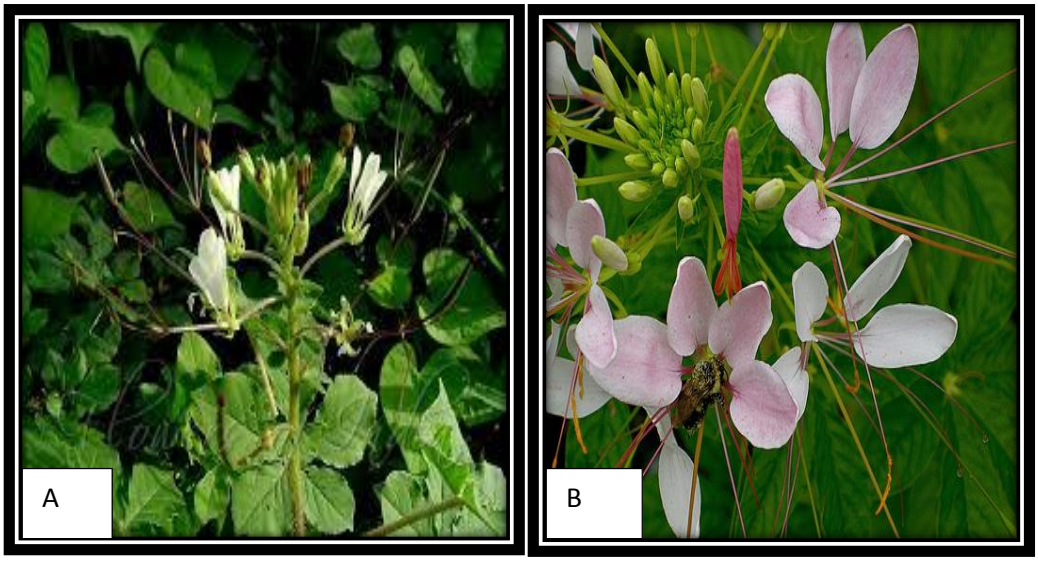


Figure 9: Flower colours observed in spider plant ecotypes. A - White flower, B – Purple flower.

4.1.5 Number of pods per plant and seed yield

There was no significant variation in the number of pods per plant among the ecotypes in both season 1 and 2. The number of pods per plant ranged from 17.57 to 31.82 in season 1 and 22.39 to 45.40 in season 2.

There was significant difference between the seed yields of ecotype SUB and HBY in season one and between NAR and PS in season two. In season one, ecotype SUB had a seed yield of 500.90 kg ha^{-1} while ecotype HBY had a seed yield of 157.85 kg ha^{-1}. In season two, ecotype NAR had a seed weight of 646.25 kg ha^{-1} while PS had 230.35 kg ha^{-1} (Table 4). The

seed yield for ecotype NAR in season one was 410.83kg ha^{-1} and in season two 646.25 kg ha^{-1}. Ecotype CHINA had a seed yield of 238.89 kg ha^{-1} in season 1 while in season 2 the seed yield was 400.49 kg ha^{-1}. Ecotype ELD had a seed yield of 382.36 kg ha^{-1} in season one and 592.78 kg ha^{-1} in season two.

Table 4: Number of pods per plant and seed yield (kg ha^{-1}) in season one and two

	Number of pods/plant		Seed yield (Kg ha^{-1})	
Ecotype	Season 1	Season 2	Season 1	Season 2
BUG	25.64	29.71	290.90ab	222.85b
KGR	26.07	34.37	227.15ab	285.42ab
KWL	21.48	29.45	237.99ab	366.04ab
NYR	29.46	34.37	329.79ab	476.67ab
BAR	29.31	32.23	322.29ab	512.50ab
IP8	18.39	39.00	380.63ab	479.38ab
PS	29.28	32.83	351.88ab	230.35b
MOL	27.21	28.51	317.57ab	402.15ab
RAN	25.27	37.06	459.03ab	537.78ab
KENYA DF	29.49	24.91	344.17ab	544.72ab
VIH	29.09	40.63	265.28ab	408.13ab
SIA	30.98	42.97	300.49ab	497.22ab
EGT	28.14	35.17	294.31ab	411.04ab
TAS	28.07	33.86	364.09ab	410.83ab
KAP	24.61	32.84	282.92ab	286.74ab
SUB	26.95	33.20	500.90a	524.72ab
NAR	26.71	34.94	410.83ab	646.25a
KENYA D	24.82	32.94	356.32ab	497.08ab
CHINA	17.57	31.97	238.89ab	400.49ab
KSM	23.04	35.92	325.49ab	457.57ab
ELD	24.25	45.40	382.36ab	592.78ab
EQT	24.79	36.83	246.18ab	432.22ab
KKM	26.18	24.74	291.94ab	469.44ab
WEB	22.88	29.77	253.89ab	441.18ab
MIG	17.86	40.43	237.99ab	414.79ab
KTL	24.21	34.76	187.78ab	454.93ab
KER	21.57	29.49	322.43ab	421.11ab
LUG	31.82	35.84	241.24ab	483.40ab
KEY	18.32	24.03	314.17ab	445.14ab
LUA	29.07	32.14	239.44ab	386.59ab
HBY	21.00	37.69	157.85b	438.47ab
KTU	25.75	34.04	283.33ab	475.76ab
EMB	22.93	32.51	280.90ab	504.65ab
KIL	26.00	34.83	250.00ab	359.51ab
MRU	23.46	40.40	232.64ab	439.09ab
SIMLAW	20.46	22.39	371.74ab	327.36ab

*Means followed by the same letter (s) in a column are not significantly different according to Tukey's Honestly Significant Difference Test at $P \geq 0.05$.

4.1.6 1000 Seed weight

There was no significant difference in the ecotypes in terms of 1000 seed weight in both seasons (Table 5). The 1000 seed weight ranged from 1.33g to 1.60g. Generally the 1000 seed weight was higher in season 2 compared to season 1. In season one ecotypes BAR and KKM had the highest 1000 seed weight of 1.50 g while KWL had the lowest 1000 seed weight of

1.31 g. In season 2 ecotypes KENYA DF, KIL and KTL had the highest 1000 seed weight of 1.60 g while SIMLAW the commercial variety had the lowest 1000 seed weight of 1.36 g (Table 5).

Table 5: 1000 Seed weight (g) of the ecotypes at the end season one and two

	1000 seed weight (g)	
Ecotype	Season 1	Season 2
BUG	1.33	1.44
KGR	1.40	1.37
KWL	1.31	1.43
NYR	1.40	1.54
BAR	1.50	1.57
IP8	1.44	1.51
PS	1.36	1.44
MOL	1.43	1.51
RAN	1.40	1.54
KENYA DF	1.44	1.60
VIH	1.49	1.44
SIA	1.44	1.46
EGT	1.41	1.53
TAS	1.46	1.57
KAP	1.46	1.50
SUB	1.43	1.46
NAR	1.40	1.46
KENYA D	1.40	1.51
CHINA	1.41	1.55
KSM	1.41	1.49
ELD	1.39	1.50
EQT	1.47	1.50
KKM	1.50	1.47
WEB	1.49	1.53
MIG	1.46	1.51
KTL	1.37	1.60
KER	1.39	1.46
LUG	1.47	1.54
KEY	1.40	1.54
LUA	1.40	1.50
HBY	1.46	1.44
KTU	1.46	1.57
EMB	1.41	1.54
KIL	1.43	1.60
MRU	1.47	1.54
SIMLAW	1.44	1.36

*Means followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference Test at $P \leq 0.05$.

4.1.7 Fresh leaf yield

Significant variation was observed between ecotype IP8 and the other ecotypes in both seasons. Ecotype IP8 had the highest fresh leaf yield in both seasons (Table 6). In season 1 IP8 had a total fresh leaf weight of 1419.51 kg $ha^{-1}$and 2364.79 kg ha^{-1}in season 2. In season 1 ecotype HBY had the lowest total fresh leaf weight of 264.17 kg $ha^{-1}$and in season 2 ecotype KIL had the lowest total fresh leaf weight of 1000.17 kg ha^{-1}. Generally, the fresh leaf weight was higher in season 2 as compared to season 1. In season two the rainfall received at the site was 410.3 mm while season one the rainfall was 332.5 mm. The harvesting intervals ranged from 50 days to 106 days after planting. It was observed that fresh leaf weight increased gradually from 50 days after planting and reached its peak 78 days after planting and then decreased in the subsequent harvests. Ecotype HBY had the lowest fresh leaf weight at all the harvesting intervals in season one (Figure.10). In season two, 50 days after planting ecotype KGR had the lowest fresh leaf weight of 103 kg ha^{-1}. At 64 and 78 days after planting ecotype BUG had the lowest fresh leaf weight of 172.22 and 287.43 kg ha^{-1} respectively. Ecotype KAP had the lowest fresh leaf weight of 214.17 kg ha^{-1} and 152.71 kg ha^{-1} at 92 and 106 days after planting respectively (Figure 11).

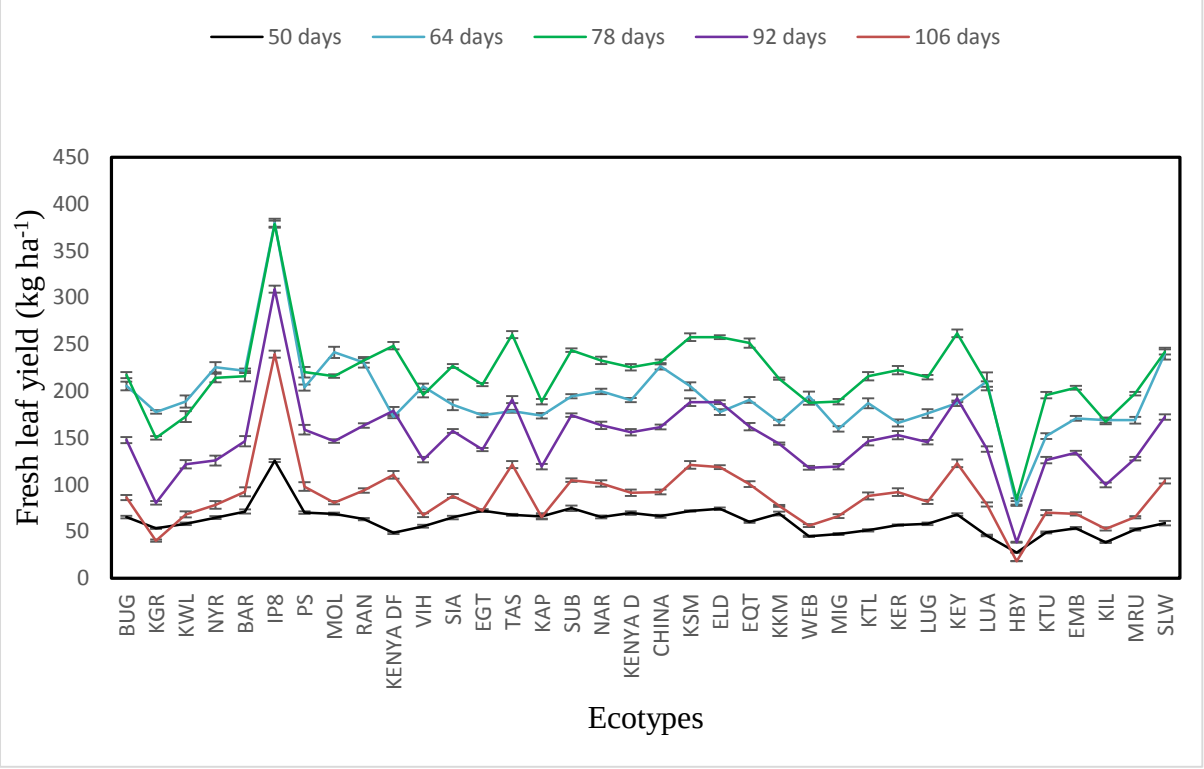


Figure 10: Fresh leaf yield of the 36 ecotypes at successive harvesting intervals from 50 to 106 days after planting in season one

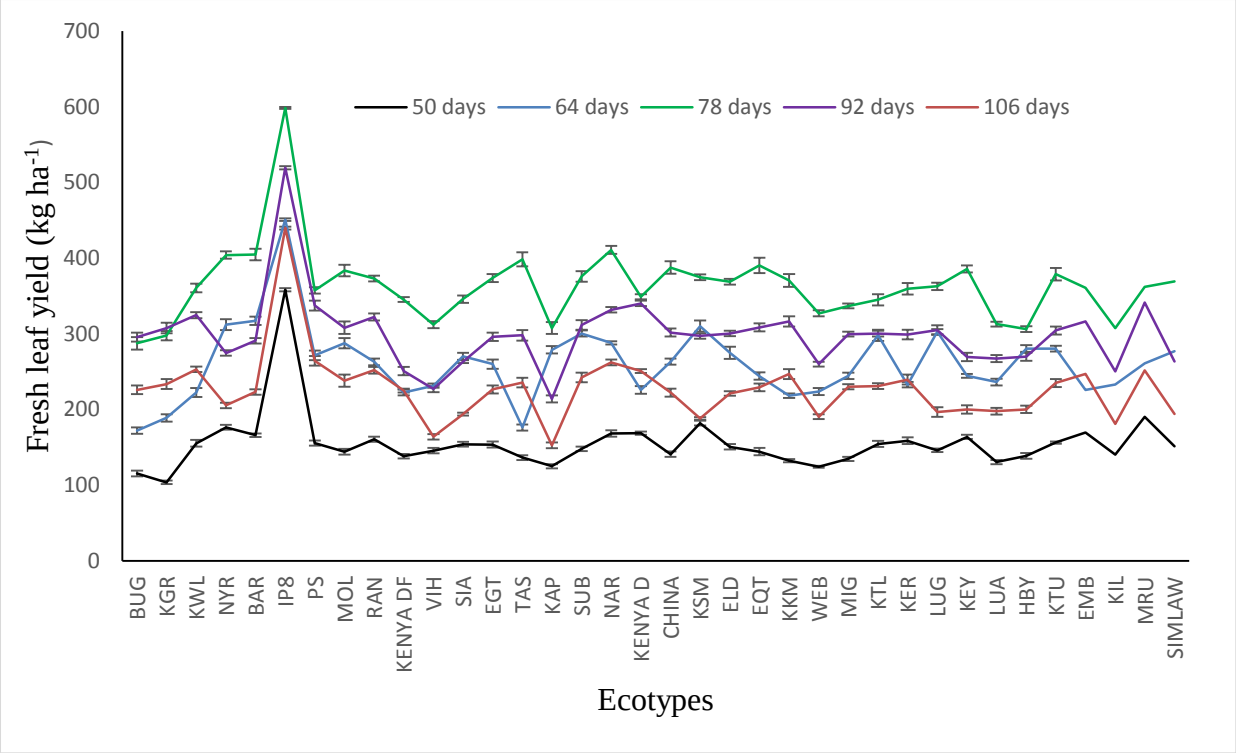


Figure 11: Fresh leaf yield of the 36 ecotypes at successive harvesting intervals from50 to 106 days after planting in season two

Table 6: Total fresh leaf yield (kg ha^{-1}) of the ecotypes in season one and two

ECOTYPE	Season 1	Season 2
BUG	830.42b	1365.00b
KGR	623.96bc	1176.53b
KWL	543.82b	1254.79b
NYR	708.89b	1349.09b
BAR	721.67b	1301.81b
IP8	1419.51a	2364.79a
PS	816.59b	1532.15b
MOL	835.14b	1360.97b
RAN	759.09b	1300.28b
KENYA DF	767.71b	1147.71b
VIH	674.79b	1019.38b
SIA	728.68b	1178.40b
EGT	675.28b	1370.90b
TAS	846.11b	1271.78b
KAP	601.81bc	1034.65b
SUB	789.44b	1301.04b
NAR	713.96b	1380.63b
KENYA D	718.96b	1320.69b
CHINA	787.15b	1351.04b
KSM	869.03b	1320.20b
ELD	783.19b	1269.38b
EQT	784.58b	1313.40b
KKM	700.35b	1252.36b
WEB	584.17bc	1046.18b
MIG	567.57b	1216.25b
KTL	695.91b	1240.63b
KER	642.85bc	1224.24b
LUG	675.07b	1329.65b
KEY	864.24b	1243.33b
LUA	669.65b	1082.57b
HBY	264.17b	1218.19b
KTU	616.39bc	1362.71b
EMB	622.78bc	1288.13b
KIL	516.81b	1009.17b
MRU	579.31bc	1343.13b
SIMLAW	825.76b	1295.76b

*Means followed by the same letter(s) within a column are not significantly different according to Tukey's Honestly Significant Difference Test at $P \leq 0.05$.

4.1.8 Dry leaf weight

There was significant variation in the dry leaf weights of the ecotypes. Ecotype IP8 had the highest dry leaf weight of 290.07 kg ha^{-1} and 305.56 kg ha^{-1} in seasons 1 and 2 respectively. In season 1ecotype HBY had the lowest total dry leaf weight of 61.11 kg ha^{-1} while in season 2 ecotype KAP had the lowest total dry leaf weight of 128.68 kg ha^{-1}. Ecotype IP8 had the highest dry leaf weight in both seasons 1 and 2 from 50 to 106 days after planting. It was observed that the dry weight was increasing from 50 days after planting and was highest at 78 days after planting and decreased at 92 and 106 days after planting in both seasons. In season 1, at 50 days after planting ecotype KIL had the lowest dry weight of only 4.79 kg ha^{-1} and from 64 days to 106 days after planting ecotype HBY had the lowest dry leaf weight of 16.46, 20.21, 13.26 and 6.94 kg ha^{-1}respectively in season 1 (Figure 12).In season 2, at 50 days after planting ecotype KGR had the lowest dry leaf weight of 55.35 kg ha^{-1}, at 64 days ecotype BUG had the lowest dry leaf weight of 26.59 kg ha^{-1}. From 78 to 106 days after planting ecotype KAP had the lowest dry leaf weight of 31.32, 28.54 and 21.46 kg ha^{-1}(Figure 13). Generally, it was observed that the total dry leaf weight was higher in season 2 compared to season 1 (Table 7). This could be due to the high rainfall received at the site in season two (410.3 mm) while in season one the rainfall was 332.5 mm.

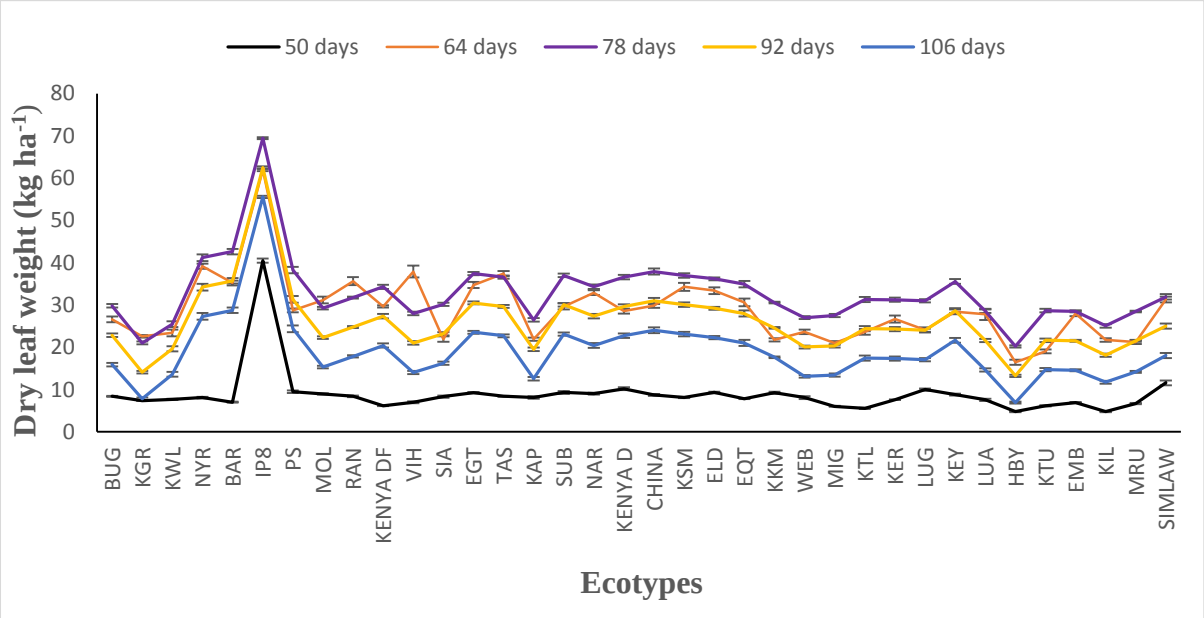


Figure 12: **Dry leaf weight of the 36 ecotypes at successive harvesting intervals from 50 to 106 days after planting in season one.**

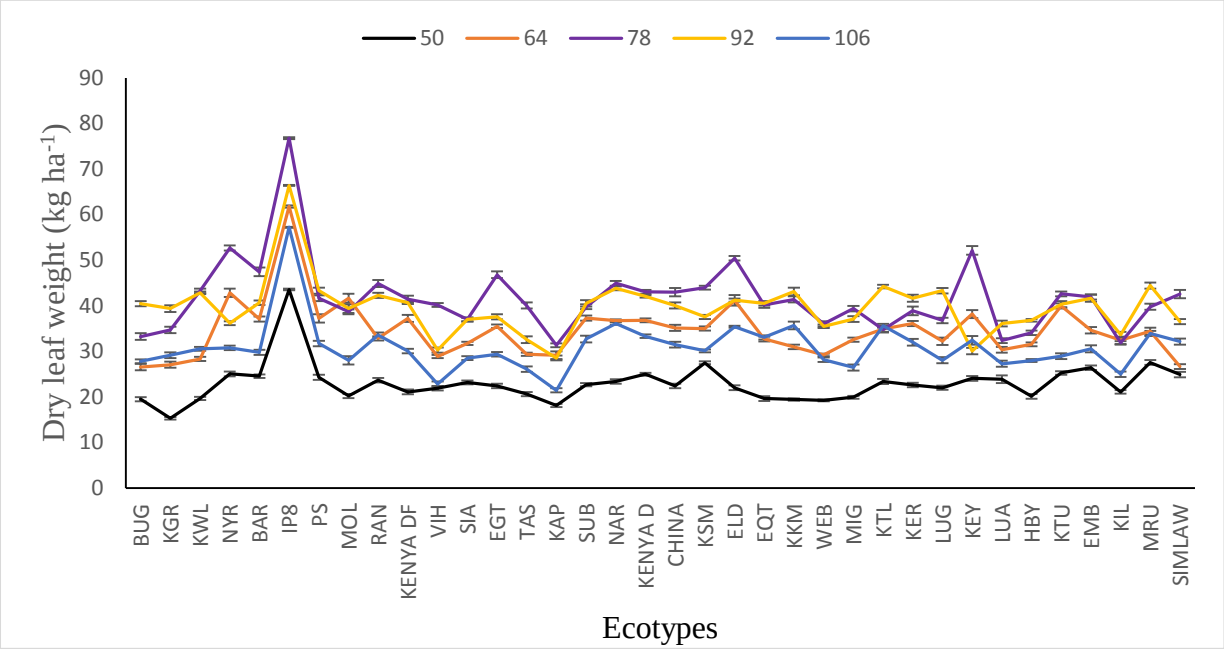


Figure 13: Dry leaf weight of the 36 ecotypes at successive harvesting intervals from 50 to 106 days after planting in season two.

Table 7: Total dry leaf weight (kg ha^{-1}) of the ecotypes in season one and two

ECOTYPE	Season 1	Season 2
BUG	103.47bcde	147.71b
KGR	72.85de	145.76b
KWL	89.86cde	164.51b
NYR	150.00b	187.57b
BAR	149.38b	179.51b
IP8	290.07a	305.56a
PS	132.36bc	178.26b
MOL	107.01bcde	168.06b
RAN	118.47cd	177.29b
KENYA DF	117.99bcd	170.63b
VIH	108.06bcde	141.94b
SIA	99.93bcde	157.57b
EGT	135.35bc	171.74b
TAS	134.79bc	148.68b
KAP	88.68cde	128.68b
SUB	129.17bcd	173.13b
NAR	124.09bcd	185.00b
KENYA D	127.78bcd	180.28b
CHINA	131.46bc	172.01b
KSM	132.64bc	174.24b
ELD	130.56bc	190.28b
EQT	122.43bcd	164.09b
KKM	103.75bcde	170.63b
WEB	91.94cde	148.19b
MIG	88.13cde	155.49b
KTL	102.50bcde	172.99b
KER	107.15bcde	171.32b
LUG	106.18bcde	162.50b
KEY	123.19bcd	177.01b
LUA	100.21bcde	150.00b
HBY	61.11e	150.63b
KTU	90.35cde	177.29b
EMB	99.51bcde	175.21b
KIL	81.46cde	144.17b
MRU	92.08cde	180.14b
SIMLAW	117.99bcd	162.50b

*Means followed by the same letter (s) within a column are not significantly different according to Tukey's Honestly Significant Difference Test at $P \leq 0.05$.

4.1.9 Cluster analysis

The dendrogram generated from qualitative and quantitative morphological traits based on Euclidean Distance Coefficient and Unweighted Pair Group Method using Arithmetic Average (UPGMA) summarized the 36 ecotypes into two major clusters I and II with cluster II forming two sub clusters; IIA and IIB. Cluster I had one ecotype IP8 (AVRDC, Arusha) while cluster II had 35 ecotypes namely: BUG, KGR, KWL, NYR, BAR, PS, MOL, RAN, KENYA DF, VIH, SIA, EGT, TAS, KAP, SUB, NAR, KENYA D, CHINA, KSM, ELD, EQT, KKM, WEB, MIG, KTL, KER, LUG, KEY, LUA, HBY, KTU, EMB, KIL, MRU and SIMLAW. Sub cluster IIA comprised of 16 ecotypes which include: HBY, LUA, KIL, WEB, KGR, SIMLAW, KTU, KER, EGT, KEY, VIH, EMB, MIG, KKM, KAP and KWL. Sub cluster IIB comprised of 19 ecotypes namely: KTL, KSM, TAS, LUG, ELD, CHINA, SUB, RAN, NYR, KENYA D, MOL, NAR, KENYA DF (KDF), EQT, PS, BAR, MRU, SIA, and BUG (Figure 10). The genetic distance scale ranged from 0-120. Cluster I formed 2.8%, cluster IIA formed 44.4% and cluster IIB formed 52.8% of the 36 ecotypes studied.

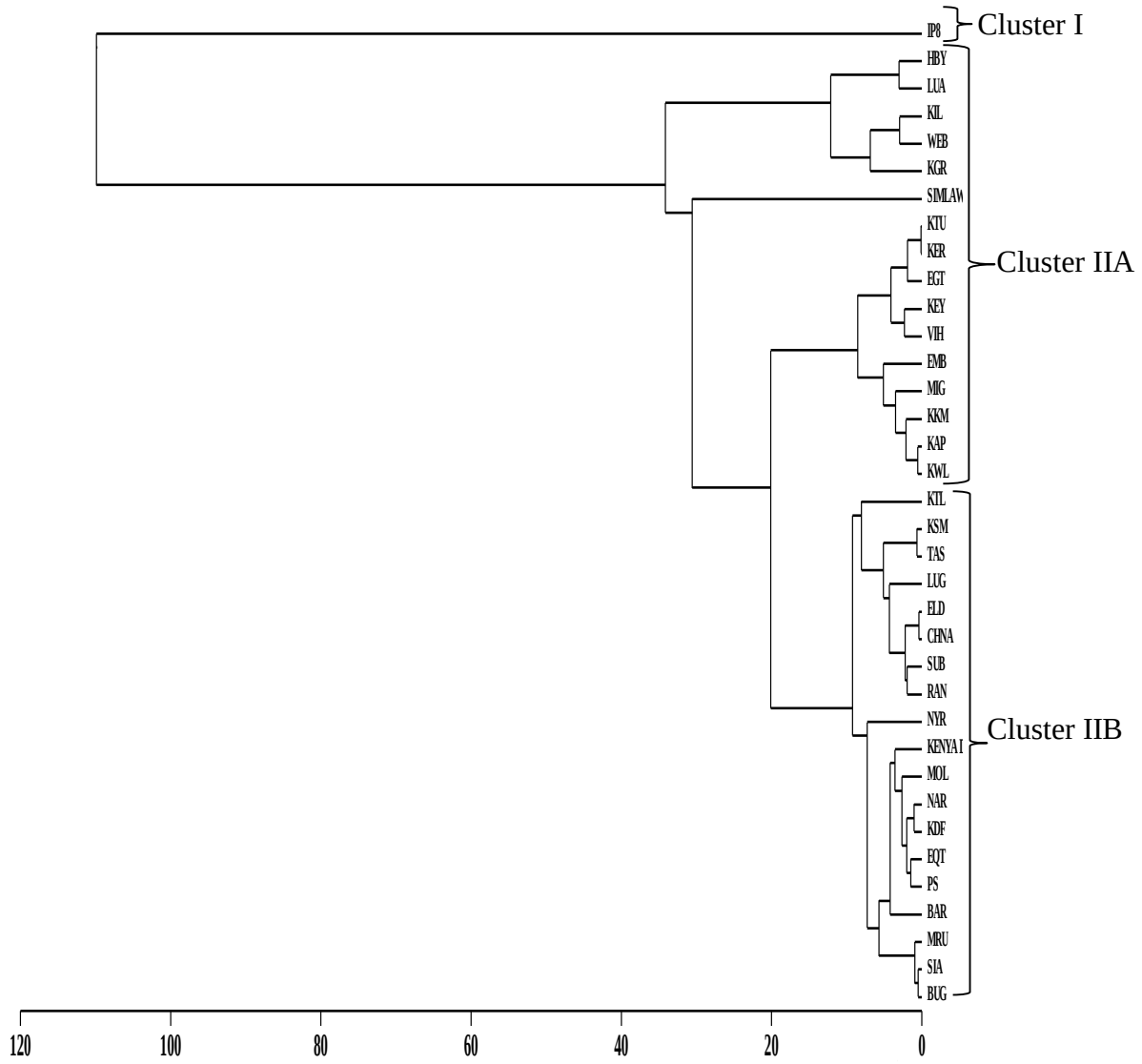


Figure 14: A dendrogram of Genetic relationships generated by Jaccard's similarity coefficients among 36 spider plant ecotypes.

4.2. Interaction effects of different NPK rates and deflowering on the leaf yield and harvest duration of spider plant

4.2.1 Interaction effect of NPK rates and deflowering on fresh leaf yield and number of harvesting weeks

Significant interaction between NPK rates and deflowering was observed on the fresh leaf yield of spider plant (Figure 11). Plants which received 300 kg NPK ha^{-1} in combination with deflowering gave the highest total leaf yield of 1090.32kg ha^{-1} and 873.24 kg ha^{-1} in seasons 1 and 2 respectively compared to the control with no deflowering which had a total fresh leaf yield of 310.45 kg ha^{-1} and 404.12 kg ha^{-1} in seasons 1 and 2 respectively. Generally the deflowered treatments gave the highest yields compared to the non-deflowered and treatments. It was noted that application of 300 kg NPK ha^{-1} in combination with deflowering gave the highest leaf yield from 50 to 106 days after planting while control (no fertilizer and no deflowering) had the lowest leaf yields from 50 to 106 days in both seasons. The fresh leaf yield increased from 50 days after planting and reached its peak at 78 days after planting and then decreased 92 and 106 days after planting in both seasons. It was also noted that application of 400 kg NPK ha^{-1} whether deflowered or not did not result to a significant increase in the fresh leaf yield of spider plant. Generally, the fresh leaf yield was higher in season 1 compared to season 2.

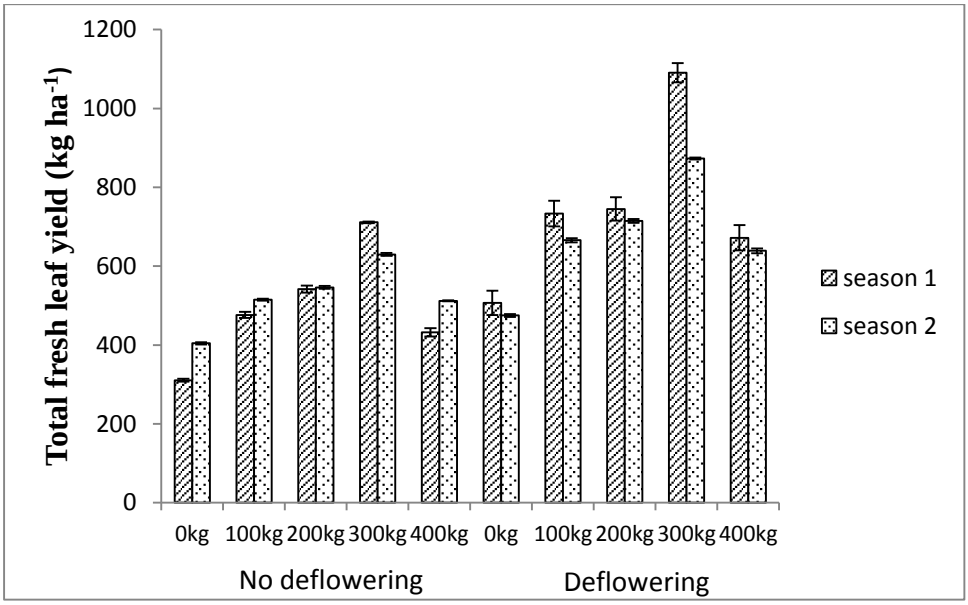


Figure 15: **Effect of NPK rates and deflowering on total fresh leaf yield in season one and two.**

NPK fertilizer rates and deflowering had a significant effect on the number of harvesting weeks. It was observed that the deflowered treatments had a longer harvesting period compared to the non-deflowered treatments at all the fertilizer rates. The application of 300 kg ha^{-1} NPK together with deflowering had the longest harvesting period of 13 weeks in season 1 and 12 weeks in season 2 while the application of 100, 200 and 400 kg NPK ha^{-1} and deflowering had an harvesting period 11 and 10 weeks in season 1 and 2 respectively. The control in which no fertilizer was applied and deflowering was done had the shortest harvesting period of 10 and 9 weeks in season 1 and 2 respectively. In all the non- deflowered treatments, the harvesting period was short. The application of 100, 200, 300 and 400 kg NPK ha^{-1} and no deflowering had a harvesting period of 8 weeks and 7 weeks in season 1 and 2 respectively while the control and no deflowering had a harvesting period of 9 and 8 weeks in season 1 and 2 respectively (Table 8). From the results it is clear that the application of 300 kg NPK ha^{-1} together with deflowering extended the harvesting period by 4 weeks compared to the control and no deflowering in both seasons 1 and 2.

Table 8: **Effect of NPK rates and deflowering on the number of harvesting weeks in season one and two**

Treatment combination	Number of harvesting weeks	
	Season 1	Season 2
NPK 0 kg + dflw	10.00c	9.00c
NPK 0 kg + no dflw	9.00e	8.00e
NPK 100 kg + dflw	11.00b	10.00b
NPK 100 kg + no dflw	8.00d	7.00d
NPK 200 kg + dflw	11.00b	10.00b
NPK 200 kg + no dflw	8.00d	7.00d
NPK 300 kg + dflw	13.00a	12.00a
NPK 300 kg + no dflw	8.00d	7.00d
NPK 400 kg + dflw	11.00b	10.00b
NPK 400 kg + no dflw	8.00d	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 $P \leq 0.05$.

4.2.2 Effect of NPK rates and deflowering on dry leaf weight

NPK fertilizer rates and deflowering interaction had a significant effect on the dry leaf weight (Figure 12). Plants which were deflowered and supplied with 300 kg NPK ha^{-1} had the highest total dry weight of 115.47 kg ha^{-1} and 155.05 kg ha^{-1} in seasons 1 and 2 respectively compared to the control with no deflowering which had a total dry leaf weight of 43.29 kg ha^{-1} and 40.19 kg ha^{-1} in seasons 1 and 2, respectively. Generally, the deflowered treatments exhibited high dry leaf weight when compared to the non-deflowered treatments in both seasons. It was observed that the dry leaf weight increased from 50 days after planting and reached its peak 78 days after planting and decreased at 92 and 106 days after planting in both seasons. Generally, the dry leaf weight was higher in season 1 compared to season 2.

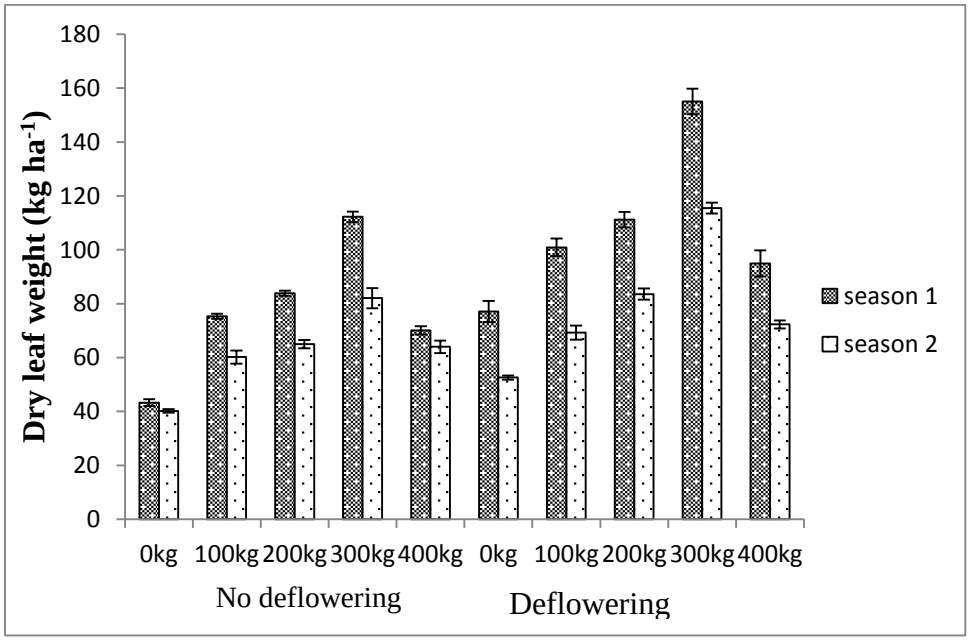


Figure 16: **Interaction effect of NPK rates and deflowering on total dry leaf weight in season one and two**

4.2.3 Effect of NPK rates and deflowering on plant height and number of primary branches

Combination of deflowering and NPK fertilizer had a significant effect on plant height. Plants which were not deflowered were the tallest compared to those which were deflowered. Plants which were supplied with 300 kg NPK ha^{-1} without deflowering were the tallest with a mean height of 66.07 cm and 104.3 cm in season 1 and 2 respectively. In season 1 the shortest plants were those that were supplied with 400 kg NPK ha^{-1} and were deflowered with a mean height of 33.70 while in season 2 plants supplied with 300 kg NPK ha^{-1} had a mean height of 59.73 cm. Generally, the plants were taller in season 2 compared to season 1 (Figure 13).

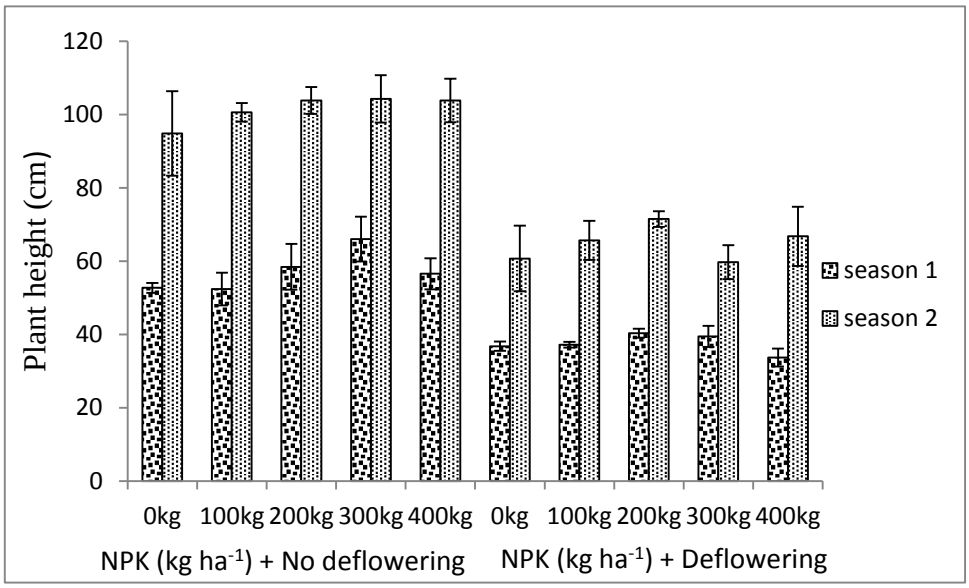


Figure 17: Effect of NPK rates and deflowering on plant height of spider plant in season one and two

NPK rates and deflowering had a significant effect on the number of primary branches. Plants which were supplied 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 9) in both seasons. Generally, it was observed that the number of primary branches increased as the fertilizer rate increased from 0 kg to 300 kg in both the deflowered and non- deflowered plants but at 400 kg the number of primary branches decreased in both seasons. Plants which were deflowered had the highest number of primary branches compared to those which were not deflowered in all the fertilizer rates (Figure 14). In season 1 plants supplied with 300 kg NPK $ha^{-1}$and deflowering had 22.03 primary branches and in season 2 they had 24.83 primary branches. In season 1 the number of primary branches in the plants supplied with 100, 200 and

400 kg NPK ha^{-1} and deflowering were not significantly different with 17.49, 18.44 and 16.18 primary branches respectively. Similarly, the number of primary branches in plants that were not supplied with any fertilizer but were deflowered were not significantly different from the plants that were supplied with 400 kg NPK ha^{-1}. The number of primary branches following the application of 100, 200 and 400 kg NPK ha^{-1} and no deflowering were not significantly different while the number of primary branches from the application of 300 kg NPK ha^{-1} and no deflowering were not significantly different from the number of primary branches when 300 kg NPK $ha^{-1}$and deflowering was applied in season 1. In season 2, plants supplied with 300 kg NPK ha^{-1} and deflowered had similar number of primary branches as plants supplied with 200 kg NPK ha^{-1}. Plants which were not supplied with any fertilizer and not deflowered had the lowest number of primary branches in season 2.

Table 9: Effect of NPK fertilizer rates and deflowering on the number of primary branches in season one and two

	Number of primary branches	
Treatment combinations	Season 1	Season 2
NPK 0 kg + dflw	15.47bc	20.48bc
NPK 0 kg + no dflw	11.76c	14.72g
NPK 100 kg + dflw	17.49ab	21.52b
NPK 100 kg + no dflw	15.57bc	15.71fg
NPK 200 kg + dflw	18.44ab	22.60ab
NPK 200 kg + no dflw	16.43bc	16.75efg
NPK 300 kg + dflw	22.03a	24.83a
NPK 300 kg + no dflw	18.93ab	18.55cde
NPK 400 kg + dflw	16.18bc	19.08cd
NPK 400 kg + no dflw	14.57bc	17.02de

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

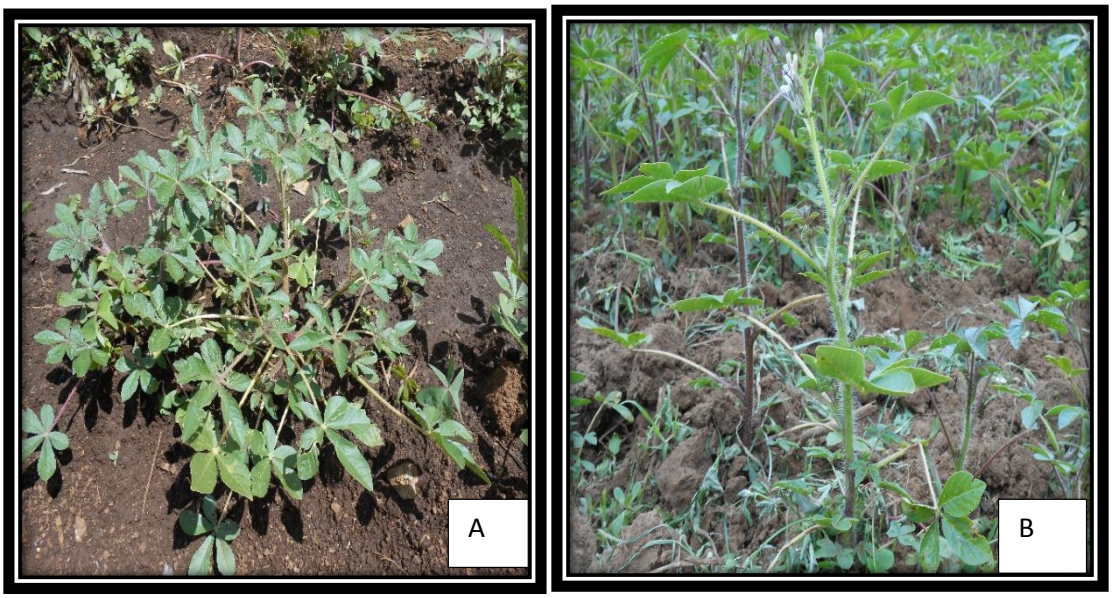


Figure 18: Effect of deflowering on number of primary branches: A- deflowered plants; B-non-deflowered plants.

4.2.4 Effect of NPK rates and deflowering on number of days to flowering

NPK fertilizer rates and deflowering combination did not have a significant effect on the number of days to flowering (Table 10).

Table 10: Effect of NPK rates and deflowering on the number of days to flowering in season one and season two

	Number of days to flowering	
Treatment combinations	Season 1	Season 2
NPK 0 kg + dflw	45.67	45.67
NPK 0 kg + no dflw	45.00	48.00
NPK 100 kg + dflw	42.33	45.33
NPK 100 kg + no dflw	43.67	46.33
NPK 200 kg + dflw	43.67	46.67
NPK 200 kg + no dflw	45.67	46.33
NPK 300 kg + dflw	43.67	46.67
NPK 300 kg + no dflw	41.33	44.33
NPK 400 kg + dflw	47.00	50.00
NPK 400 kg +no dflw	45.00	47.67

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

CHAPTER FIVE
5.0 DISCUSSION

5.1 Morphological characterization of spider plant ecotypes

5.1.1 Number of days to first emergence

Spider plant ecotypes in this study took 6-9 days to emerge. The results of this study are in agreement with those of Chweya and Mnzava (1997) and Masuka *et al*. (2012) who reported that the seeds of spider plant take between 4- 8 days to emerge. The results of the current study are also in agreement with those of Herta (2001) who reported that the seedlings of spider plant take 6 – 8 days to emerge after sowing. Chweya and Mnzava (1997) reported that germination is erratic occurring over an extended period especially during the rainy season. This could explain why the seeds in this study took long to emerge as planting was done during the rainy season. The seeds are negatively photoblastic and this plant species has been shown to exhibit poor germination (Borhinger *et al.,* 1999; Chweya and Mnzava, 1997).

5.1.2 Stem, petiole and main vein pigmentation

In this study four types of stems, petioles and main vein pigments were observed. Green stems, green petioles and green main vein, green stems, purple petioles and purple main veins, purple stems, purple petioles and purple main veins and purple stems, green petioles and green main veins. Similar results were reported by Chweya and Mnzava (1997), in which four colour combinations of the stem and petiole of spider plant were observed. Green stems and green petioles, green stems and purple petioles, purple stems and green petioles and purple stems and purple petioles. Masuka *et al*. (2012) also reported green and purple stems of spider plant in a study that was carried out in Zimbabwe. Chweya and Mnzava (1997) also reported green, pink, violet and purple petiole colours of spider plant. On the contrary, Wasonga (2014) reported the occurrence of violet stems, pink and violet petioles among 32 accessions of spider plant. The proportion of the studied accessions in the field and glasshouse with pink petioles was 37.5%, green petioles 37.5%, purple petiole 18.8%, and violet petioles 6.2%.

The polymorphism in colour observed in stem, petiole and main veins which ranged from green to purple is due to the accumulation of anthocyanins in the plant tissues (Dasgupta and De, 2007). Anthocyanins are glycosides and acylglycosides of anthocyanids and belong to the general class of flavonoids (Dasgupta and De, 2007). These plant pigments are responsible

for a variety of red, blue, and purple colours in fruits and vegetables. These pigments which occur in flowers are very useful to plants and have been reported to be a key component of pollination and subsequent fruit production (Dasgupta and De, 2007). These plant pigments have anti-inflammatory, antitumor, antioxidant, and antihepatotoxic properties in human (Opole *et al.*, 1995), hence providing the vital health promoting bioactive compounds when spider plant is consumed. The accumulation of anthocyanins in plant tissues is controlled by environmental factors such as temperature, nutrients, and stress. Hence ability of spider plant ecotypes to grow under diverse environmental conditions is enhanced in those ecotypes that have anthocyanin accumulation on both stems and petioles rather than on either stem or petiole only, or even no accumulation on both the plant parts (K'opondo, 2011).

5.1.3 Number of primary branches per plant and days to 1st, 50% and 75 % flowering

There was a significant variation in the number of primary branches of the ecotypes. Ecotype IP8 produced the highest number of primary branches in this study. Chweya and Mnzava (1997) reported that the number of primary branches of spider plant ranges from 2 – 7 but significant variations occur among populations due to seasonal differences in environmental conditions. Branching of spider plant tends to be dictated by environmental factors. Good moisture supply in the early stages of growth promotes fast vegetative growth with reduced branching while plant stress promotes early branching (Chweya and Mnzava, 1997). A high number of primary branches was recorded in season 1 compared to season 2. In season 2 the amount of rainfall received at the site was 410.3 mm and this resulted to reduced branching hence few primary branches while in season 1 it was dry with a rainfall of 332.5 mm thus plant stress led to early branching and hence high number of primary branches. Wasonga (2014) observed significant variation in the number of primary branches of spider plant. In the study the number of primary branches ranged from 4.0 - 8.6 for the field grown accessions and 4.0 - 12.0 for the greenhouse grown accessions of spider plant which is lower compared to the results of the current study.

In this study the ecotypes took 35 - 47 days to first flowering, 43 – 50 days to 50% flowering and 47 – 53 days to 75%. Similar results were reported by Wasonga (2014) in which the number of days to first flowering ranged from 33 -51. The findings of this study are similar to those of Chweya and Mnzava (1997) who reported that spider plant took 28 – 42 days to first flowering and 17 – 35 days to attain 50% flowering. Masuka *et al*. (2012) also reported that spider plant morphs took 17 - 36 days to first flowering. Flowering can be as a response to

temperature extremes and photoperiod variation (Royal Horticultural Society, 2012). However, in *C. gynandra* the problem of early flowering seems to be induced by other factors besides temperature and day length, most likely genetic factors. This is due to the observation that even when established throughout the year *C. gynandra* there was variation in flowering (Mavengahama, 2013).

5.1.4 Flower color

Two types of flower color were observed i.e. white flowers or purple only or a mixture of white and purple flowers. Similar observations by Mishra *et al*. (2011) and Masuka *et al*. (2012) reported that spider plant flowers were white or tinged with purple. It was noted that white corolla was from the Zimbabwean morphs and purple tinged inflorescence was observed in Kenyan morph (Masuka *et al*., 2012). In contrast, studies by AVRDC (2009), reported additional flower colours such as mauve-pink, lilac-pink and violet. This may be attributed to varying environmental factors such as temperature, nutrients and stress where the evaluations were conducted (Chweya and Mnzava, 1997). On the contrary, Wasonga (2014) reported pink flowers among 10 accessions of the 32 accessions of spider plant studied. Among plant pigments that are responsible for a variety of red, blue and purple colours are anthocyanins, which accumulate in certain plant tissues at specific developmental stages. The accumulation is controlled by various environmental factors such as light, temperature, nutrients and stress (Beggs *et al*., 1994).

5.1.5 Number of pods per plant and seed yield

The 36 ecotypes studied had no significant difference in the number of pods per plant. Masuka *et al*. (2012) reported that spider plant morphs had 3 - 21 pods per plant which is contrary to the current study in which the number of pods per plant ranged from 17 – 36 within the 36 ecotypes. On the contrary, Wasonga (2014) reported 4 - 53 pods per plant among 32 accessions of spider plant. In the glasshouse, the number of pods per plant was low with an average of 13 pods per plant compared to the average number of pods in the field of 29 pods per plant. It was also observed that field grown accessions had higher pod counts per plant than the glasshouse grown accessions. This variations could be due to differences in environmental conditions (Chweya and Mnzava, 1997).

There was significant difference in the seed yield of the 36 ecotypes in this study. The seed yield ranged from 157.85 kg ha^{-1} to 646.25 kg ha^{-1}. Chweya and Mnzava (1997) reported that the seed yield of spider plant is 500 kg ha^{-1} while Abukutsa *et al*. (2005) reported a higher seed yield of spider plant is 700 kg ha^{-1} than the one obtained in this study. From the results it was observed that the seed yields of ecotypes NAR, ELD AND CHINA were almost double in season two compared to season one. This could be due to the high rainfall which was recorded at the site in season two (410.3mm) compared to season one (332.5 mm).

5.1.6 1000 Seed weight

Results in this study indicate that the 1000 seed weight of the 36 ecotypes ranged from 1.3 – 1.6 g. The results are consistent with those reported by K' Opondo (2011) in which the 1000 seed weight for four morphotypes of spider plant from western Kenya ranged from 1.503 – 1.800g.

5.1.7 Fresh leaf yield

Significant variation was observed among the fresh leaf yields of the ecotypes. In the current study the highest fresh leaf yield of 1419.51 kg ha^{-1} and 2364.79 kg ha^{-1} was recorded in ecotype IP8 in season 1 and 2 respectively. In season 1 the site received a rainfall of 332.5 mm and 410.3 mm in season 2. Therefore the high yields recorded in season 2 could be attributed to high rainfall. Cumulative yields of 30,000 kg ha^{-1} per season may be obtained (Chweya and Mnzava, 1997). Machakaire *et al*. (2000) reported that the average fresh yield of spider plant is 500 kg ha^{-1}. In contrast, Ng'etich *et al*. (2012) reported that the fresh leaf weight of spider plant was 11,150 kg $ha^{-1}$with the application of 150 kg N ha^{-1} from Calcium Ammonium Nitrate. In the current study, topdressing was done using calcium ammonium nitrate at a rate of 100 kg ha^{-1} (14.4 g/ plot). Contrary results were reported by AVRDC (2009) in which 29 accessions of spider plant were grown in colder conditions than which it is produced. Accession ST 94-3 gave the highest fresh leaf yield of 59,130 kg ha^{-1} while accession CLME-SP had the lowest yield of 23,860 kg ha^{-1}. Accession IP8 had a fresh leaf yield of 32,730 kg ha^{-1} (AVRDC, 2009). The other studies reported higher yields of spider plant compared to those obtained in this study because the other studies included growing points (shoots) as part of the yield; in this study only the leaf weight was included and not the weight of shoots. From the results of this study, it is evident that the commercial variety SIMLAW

was outperformed by ecotype IP8. Similar observations were made by Masinde and Agong (2011) who reported that the commercial varieties such as Simlaw seeds have short comings such as low yield, nutrient and geographical diversity.

5.1.8 Dry leaf weight

Significant variation was observed among the dry leaf weights of the ecotypes. Ecotype IP8 had the highest dry leaf weight of 290.07 kg ha^{-1} and 305.56 kg ha^{-1} in seasons 1 and 2 respectively. Takebe *et al*. (1995) reported that increments in leaf dry weight may be due to a combination of nitrogen with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids and protein. Spider plant is a C_4 species which are generally characterized by rapid growth and high dry matter production which is three to five times more per unit leaf area and unit time than C_3 plants (Waithaka and Chweya, 1991). Plant populations from hot, semi-arid areas tend to have shorter leaves and lower dry leaf weights than those from high-rainfall areas. The plants may, therefore, adapt to shorter growing periods which may be accompanied by low biomass production (Chweya and Mnzava, 1997). From the results, the ecotypes from hot and dry areas had low dry leaf weight compared to those from high rainfall areas. The higher vegetative biomass results can be attributed to the role of nitrogen in creating the plant fresh and dry matter as well as many energy-rich compounds which regulate photosynthesis and plant production (Wu *et al*., 1998). Nitrogen has been reported to govern plant growth by virtue of being a major constituent of chlorophyll, protein, amino acids and which plays a crucial role in photosynthetic activity (Sumeet *et al*., 2009).

5.1.9 Cluster analysis

The dendrogram generated by UPGMA cluster analysis illustrated two major clusters (cluster I and II) with cluster II forming two sub clusters. There were significant overlaps in the clustering of the accessions based on site of collection and morphological traits such as flower colour, stem, petiole and main vein pigmentation. This is attributed to the widespread occurrence of spider plant species as most people have now turned to the consumption of indigenous vegetables in a bid to improve nutritional status of communities and livelihoods. The fusion of accessions to form sub cluster IIA and sub-cluster IIB depicts close genetic similarity between the two sub-clusters. Ecotype IP8 was in its own cluster, it had some plants with green and purple stems, green and purple petiole and main vein pigmentation and white flowers.

Cluster analysis revealed the existence of diversity among the 36 spider plant ecotypes for the morphological traits studied. The genetic distance between the clusters ranged from 0-120. Cluster two had the smallest genetic distance ranging from 0-40 and this shows that the ecotypes in this cluster have similar genes and this indicates that they are closely related and have a recent common ancestor. Ecotype IP8 in cluster one had the biggest genetic distance of 110 and this indicates that it is not closely related with the other 35 ecotypes

Several authors have concluded that additive gene action is responsible for much of the genetic variation of qualitative traits (Lal *et al*., 1976; Mak and Yap, 1980; Zaveri *et al*., 1980). Other reports, however, indicate that action by non-additive genes and interactions between genotype and environment are important in some instances for the variations (Singh and Rachie, 1985). The close relationship reported among spider plant accessions may also be due to it being a self-pollinated crop (Omondi, 1990). Similarly, Wasonga (2014) reported the occurrence of two clusters among 32 spider plant accessions grown in the field. In the study cluster I comprised of 7 accessions from South Africa while cluster II had 23 Kenyan accessions and 2 South African accessions. The variations shown among the spider plant ecotypes studied could partly be attributed to different evolutionary pathways of development among the accessions. It is suggested that while genes interact with other genes, the way they are expressed is influenced by their environment (Phillips, 2006). The variations could also be due to the selection pressure being effected by farmers especially in Kenya for those characters they consider to be of importance to them, as they continue putting spider plant under domestication through cultivation (K'Opondo, 2011). Results also revealed that most of the qualitative characteristics like flower colour, stem, petiole and main vein pigmentation differed within the two sub clusters.

Ecotype IP8 from AVRDC (Arusha) can therefore be used for breeding purposes to improve the other ecotypes from Kenya which had few primary branches, low leaf yields and dry leaf weight. Furthermore, a big genetic distance was observed among ecotype IP8 and the other 35 ecotypes presenting a great possibility for the development of suitable varieties for the various agro ecological zones of Kenya by making use of the available potential of the germplasm. Relatively high level of dissimilarity was observed among the ecotypes for most of the traits evaluated. This indicates potential for genetic diversity that can be utilized for crop improvement in spider plant. The use of materials from different geographical origins in any cross breeding programme aimed at developing suitable varieties with specific characters would avoid the use of material with a similar genetic background, as well as avoid spending time, money and other resources on materials not having the best

chance to produce the best result. For example the use ecotype IP8 in a breeding programme to improve ecotype BAR and CHINA for number of primary branches. Morphological traits alone may not be reliable when characterizing spider plant under different environments and therefore genetic studies would provide more accurate genetic distances.

5.2 Effect of different NPK (17:17:17) levels and deflowering on the leaf yield and harvest duration of spider plant

5.2.1 Effect of NPK rates and deflowering on fresh leaf yield and number of harvesting weeks

Application of 300 kg NPK ha^{-1} combined with deflowering gave the highest fresh leaf yield as compared to the control in which no fertilizer was used and deflowering was not done. There was no significant difference in the fresh leaf yields of the plants which were supplied with 100, 200 and 400 kg NPK ha^{-1}combined with deflowering and no deflowering in both seasons. The observed effect of NPK fertilizer on yield of spider plant is attributed to the role of nitrogen in enhancing vegetative growth of plants hence influencing yield of most leafy vegetables. On the contrary, lowest yield recorded from control plots was due to possible depletion of nitrogen and other nutrients in the soil. The results of the present study are similar to those of Boroujerdia *et al*. (2007) who reported that the application of 120 kg N ha^{-1} increased the fresh weight of lettuce leaves while control had the lowest yields. Similar results were obtained by Mavengahama (2013) who reported that the application of 300 kg ha^{-1} of Lime Ammonium Nitrate led to 88% increase in fresh yield of spider plant. The results of this study revealed that the application of NPK (17:17:17) increases the fresh yield of spider plant to a point where further increase led to a decrease in productivity. Greef, (1994) reported that the average fresh weight of maize increased with increase in nitrogen fertilizer applied up to a point of stagnation. Similarly, Ainika *et al*. (2012) also reported that the application of 300 kg ha^{-1} of NPK (20:10:10) resulted to the best edible yield of *Amaranthus caudatus*. Similar results were obtained by Mauyo *et al*. (2008), Masinde and Agong (2011) and Ngetich *et al*. (2012) who reported that incremental application of nitrogen from CAN source resulted to increase in plant height, number of shoots and utilizable leaf yield of spider plant. The low yields obtained following application of 400 kg ha^{-1} could be attributed to excess nitrogen which leads to reduced plant growth, small leaves, stunted root systems and in severe cases death (Cao and Tibbitts, 1998; Sanchez et al, 2004).

The deflowered plants gave the highest fresh leaf weight compared to the non-deflowered plants at all the fertilizer rates. The non-deflowered plants produced flowers coupled with prolific seed set hence lowering the leaf yields. The non- deflowered plants also had few primary branches and therefore few leaf count. It would appear that deflowering stimulates vegetative growth as the removal of the apical shoots in plants is known to stimulate the growth of lateral shoots which develop into lateral branches hence higher leaf yields. These results are similar to those of Zobolo *et al*. (1999) who concluded that flowering was responsible for reduction of leaf and stem growth and deflowering reduced senescence, hence maintaining vegetative growth of *Bidens pilosa*. Similarly, Mavengahama (2013) concluded that continuous removal of the flowers led to increased utilizable leaf yield of spider plant and resulted to 46% increase in fresh weight. Similar results were reported by Maumba (1993) in which deflowered spider plants had a fresh leaf yield of 9.5 t ha^{-1} compared to non- deflowered plants that yielded 7.2 t ha^{-1}. This is higher compared to the yield obtained in the current study because the current study only included the leaves and not the shots and growing points.

The interaction of NPK fertilizer rates and deflowering interaction had a significant effect on the number of harvesting weeks. It was observed that the deflowered treatments had an extended vegetative phase compared to the non-deflowered treatments at all the fertilizer rates. This is because of the role of nitrogen in enhancing vegetative growth in leafy vegetables and the fact that flowering is responsible for senescence. The removal of flowers therefore reduces senescence and hence maintains the vegetative phase. Control and no deflowering treatments had the shortest harvesting duration of 9 and 8 weeks in season one and two respectively and this is due to the possible depletion of nitrogen and other nutrients in the soil. The non- deflowered treatments senesced early and were also coupled with prolific pod formation and seed set therefore there were no more leaves to be harvested hence harvesting was stopped. Similarly, Mavengahama (2013) reported that frequent picking and deflowering of spider plant encourages growth of many shoot apices on a plant and this extends the vegetative phase. In *Bidens pilosa*, another wild species utilized as a vegetable in South Africa, deflowering resulted in tall plants with a higher shoot weight (Zobolo and Van Staden, 1999). The authors concluded that flowering was responsible for reduction of post-flowering leaf and stem growth and that deflowering reduced senescence, thus maintaining vegetative growth.

5.2.2 Effect of NPK rates and deflowering on dry leaf weight

The use of 300 kg NPK ha^{-1} in combination with deflowering gave the highest dry leaf weight while control without deflowering had the lowest dry leaf weight. Similar results were reported by Nafiu *et al*. (2011) who found out that the application of 300 kg NPK ha^{-1} favored dry matter production and growth of eggplant. Boroujerdnia *et al*. (2007) reported that the application of 120 kg N ha^{-1} resulted in the highest dry matter while the lowest dry leaf weight was observed in the control. The results of this study are in agreement with those of Greef, (1994) reported an increase in average dry leaf yield of maize with an increase in the amount of nitrogen fertilizer applied up to a point of stagnation beyond which a decrease in dry matter production was observed in nitrogen deficient soils. In the present study, an increase in dry matter with increasing NPK rates was observed, reaching a peak at 300 kg NPK ha^{-1} and a sudden drop when 400 kg NPK ha^{-1} was applied. In physiological terms, the increased vegetative growth, indicated by the high leaf yields with increasing NPK applications also result in larger photosynthetic surfaces where more carbohydrate metabolites are produced and therefore contributing to high dry matter content in the leaves. Takebe *et al*. (1995) reported that increments in leaf dry weight may be due to a combination of nitrogen with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids and protein. Tei *et al*. (2000) reported that increasing the rate of nitrogen fertilizer significantly increased the dry weight of leaves.

Similar results were reported by Mavengahama (2013) in which deflowered plants had a dry weight of 4.61 g / plant while those which were not deflowered had a dry weight of 3.26 g / plant. Deflowered plants had a higher dry weight when compared to the non-deflowered plants at all the fertilizer levels in both seasons. This is because deflowering involves removal of the apical shoots which bear the terminal bud and this leads to the reduction in the concentration of auxin and the apical dominance is ceases leading to the formation of more lateral branches hence more leaves for harvesting when compared with the non-deflowered plants which had normal vegetative growth with few lateral branches hence few leaves for harvesting resulting to the low dry leaf weight. The control (no fertilizer applied) whether deflowered or not recorded the lowest dry leaf weight due to possible depletion of nutrients.

5.2.3 Effect of NPK rates and deflowering on plant height and number of primary branches

The application of 300 kg NPK ha^{-1} alone gave the tallest plants. Results of the current study concur with those of Maumba (1993) who reported that deflowering significantly decreases plant height of spider plant, in the study deflowered plant had a height of 65 cm while non- deflowered plants had a height of 75 cm. Achakzai (2012) reported similar results in which the tallest plants had a plant height of 200.4 cm in the plots which were supplied with 50 kg pure nitrogen ha^{-1}. In a similar study, Moraditochaee *et al*. (2012) the height of tomatoes increased with increased levels of nitrogen. Application of 180 kg N ha^{-1} produced taller plants than the lowest dose of 120 kg N ha^{-1}. The same results were observed by Oliniyi (2008) who reported an increase in plant height, number of leaves and internodes length of amaranth varieties applied with increasing nitrogen rates from 0 - 60 kg Nha^{-1}. Similar findings were reported by Mauyo *et al*. (2008) when spider plant was subjected to different nitrogen rates. Ng'etich *et al*. (2012), also reported an increase in plant height of spider plant with an increase in the amount of CAN fertilizer applied. The plant height of spider plant ranges from 25 to 72 cm (Chweya and Mnzava (1997). In the current study the plant height was high and this could be due to deflowering.

Removal of the apical shoots 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. Removal of the apical shoots while deflowering, temporarily reduces auxin and this interferes with apical dominance as it stimulates the production of side buds which grow into branches. On the other hand, plants that were not deflowered showed normal vegetative growth by growing vertically as the apical dominance was not removed. The non-deflowered plants were taller compared to those that were deflowered. This is because the removal of the apical shoots leads to more lateral growth rather than vertical growth (Masinde and Agong, 2011) hence the decrease in plant height.

The application of 300 kg NPK ha^{-1} and deflowering gave the highest number of primary branches compared to the other fertilizer rates while control and no deflowering had the lowest number of primary branches. The number of primary branches is a measure of a crop's resilience to water stress and reflects its vegetative productivity (Nkouannessi, 2005). Plants with more primary branches have more leaves for harvesting hence high yields. In this 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. Thus deflowered plants had more branch strata than plants that were not deflowered. Achakzai (2012) reported that nitrogen fertilizer doses significantly increased the number of primary and secondary branches of pea (*Pisum sativum* L.). Mauyo *et al*. (2008), Masinde and Agong (2011) and Ng'etich *et al*. (2012) reported that incremental application of nitrogen from CAN source resulted to an increase in plant height, number of shoots and utilizable leaf yield of spider plant.

The removal of the apical shoots in plants is known to stimulate the growth of lateral shoots which develop into branches as confirmed by Masinde and Agong (2011) who removed flowers to encourage vegetative growth of C. *gynandra.* Similar results were obtained by Mavengahama (2013) who reported that deflowered plants had more branches than the plants which were not deflowered. Mavengahama (2013) also reported that deflowering led to the formation of more lateral shoots resulting into many branches on a plant thus increasing biomass and extending the vegetative period. The results are consistent with those of Maumba (1993) who reported that deflowering increases the number of primary branches of spider plant in which deflowered plants had 14 primary branches while the non- deflowered plants had 13 primary branches. Frequent picking and deflowering encourage growth of lateral resulting in many active shoot apices on a plant (Mavengahama, 2013)

5.2.4 Effect of NPK rates and deflowering on number of days to flowering

There was no significant difference in the number of days to flowering in all the fertilizer rates whether the plants were deflowered or not deflowered in both seasons 1 and 2. The results of the present study are similar to those of Masuka *et al* (2012) who reported that spider plant takes 17-35 days to first flowering and this was contrary to the present study in which the number of days to flowering ranged from 41 to 50. Aboyeji *et al*. (2011) reported that increasing fertilizer rate from 0 - 400 kg NPK ha^{-1} did not positively affect the number of days to flowering of *Thevetia peruviana* and it was observed that the number of days to flowering and number of days to fruit maturity from flowering increased with increasing nitrogen fertilizer rates although not significant.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

A range of observations were made in the current analyses of morphological characteristics of spider plant using both their qualitative and quantitative traits. A high level of similarity was observed in the cluster analysis. Ecotype IP8 (AVRDC, Arusha) was different from the other ecotypes for important traits such as number of primary branches, fresh leaf yield and dry leaf weight and it was in its own cluster showing its uniqueness when compared to the other 35 ecotypes.

Different rates of NPK fertilizer and deflowering have an effect on growth, leaf yield and extension of the vegetative phase of spider plant. The interaction of 300 kg NPK ha^{-1} and deflowering gave the highest fresh leaf yield, dry leaf weight and extended the harvesting period of spider plant by four weeks.

6.2 RECOMMENDATIONS

In the morphological characterization of the 36 ecotypes it was observed that the morphological characteristics of spider plant differ. Significant differences were observed indicating that apart from stem, petiole, main vein pigmentation and flower colour other characters of importance also differ. Given that morphological characteristics are affected by environmental influences, it is recommended that molecular markers be used to supplement this work by identifying the genetic polymorphism that may exist in the ecotypes because these are not subject to environmental influences. It is also recommended that ecotype IP8 be evaluated further with a view to release it as a variety because of its high yields and the fact that it branches profusely and takes longer to flower.

It is recommended that growers will benefit from the application of 300 kg NPK ha^{-1} and deflowering for high leaf yield of spider plant and extension of the vegetative phase of spider plant. While the findings from the present study provide a good foundation for understanding deflowering and NPK fertilizer rates on spider plant performance, it is further recommended that studies on nutritional composition of the ecotypes be conducted.

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APPENDICES

Appendix I: Publication

Carol M. Mutua, Richard S. Mulwa and Joshua O. Ogweno. (2015). NPK Fertilization and Deflowering Increases Leaf Yield and Extends the Vegetative Phase of *Cleome gynandra* L. International Journal of Plant and Soil Science 8 (6): 1-8.

Appendix II: **Days to emergence ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	717.11	1.43	503		
Ecotype	592.83	16.94	35	3.11	<.0001*
Rep	3.60	5.90	6	0.00	
Row	6.60	1.30	5	0.00	
Column	1.30	2.20	6	0.00	
Season	47.06	47.06	1	8.64	<.0001*
Ecotype*Season	29.94	0.86	35	1.57	<.0001*
Error	2.26	5.44	415		

Appendix III: **Fresh leaf yield ANOVA 50 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	51959.54		503		
Ecotype	5281.01	150.89	35	4.10	<.0001*
Rep	3562.62	593.77	6	16.15	
Row	872.35	174.47	5	4.74	
Column	593.33	98.89	6	2.69	
Season	22805.80	22805.80	1	620.19	<.0001*
Ecotype*Season	2315.24	66.15	35	1.79	0.0043*
Error	15260.38	36.77	415		

Appendix IV: **Fresh leaf yield ANOVA 64 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	97512.95		503		
Ecotype	16273.10	464.95	35	4.73	<.0001*
Rep	20837.60	3472.94	6	35.33	
Row	1822.97	364.59	5	3.71	
Column	485.37	80.89	6	0.83	
Season	11748.90	11748.90	1	119.51	<.0001*
Ecotype*Season	4755.38	135.87	35	1.38	0.07670
Error	40798.41		415		

Appendix V: **Fresh leaf yield ANOVA 78 days after planting**

Source	SS	MS	DF	F Ratio	Prob > F
Total	152477.10		503		
Ecotype	18156.00	518.74	35	3.63	<.0001*
Rep	10524.10	1754.02	6	12.28	
Row	3140.54	628.11	5	4.39	
Column	559.36	93.23	6	0.65	
Season	56269.60	56269.60	1	393.92	<.0001*
Ecotype*Season	2634.71	75.28	35	0.53	0.98870
Error	59280.83	142.85	415		

Appendix VI: **Fresh leaf yield ANOVA 92 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	134182.89		503		
Ecotype	15513.80	443.25	35	4.01	<.0001*
Rep	6187.96	1031.33	6	9.32	
Row	2108.22	421.64	5	3.81	
Column	361.94	60.33	6	0.55	
Season	59306.10	59306.10	1	535.99	<.0001*
Ecotype*Season	4137.32	118.21	35	1.07	0.3680
Error	45918.38	110.65	415		

Appendix VII: **Fresh leaf weight ANOVA 106 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	113970.74		503		
Ecotype	12536.70	358.19	35	3.76	<.0001*
Rep	5418.95	903.16	6	9.47	
Row	1662.43	332.49	5	3.49	
Column	189.78	31.63	6	0.33	
Season	50720.50	50720.50	1	531.79	<.0001*
Ecotype*Season	2930.66	83.73	35	0.88	0.6710
Error	39581.76	95.38	415		

Appendix VIII: **Total fresh yield ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	2158920.00		503		
Ecotype	239656.00	6847.32	35	98.01	<.0001*
Rep	297.52	49.59	6	0.71	
Row	456.13	91.23	5	1.31	
Column	90.23	15.04	6	0.22	
Season	1601253.00	1601253.00	1	22920.00	<.0001*
Ecotype*Season	265256.00	7578.73	35	108.48	<.0001*
Error	28993.00	69.90	415		

Appendix IX: **Dry leaf weight ANOVA 50 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	1180.98		503		
Ecotype	163.23	4.66	35	5.90	<.0001*
Rep	49.03	8.17	6	10.44	
Row	14.20	2.84	5	3.63	
Column	19.58	3.26	6	4.17	
Season	513.03	513.03	1	655.64	<.0001*
Ecotype*Season	30.14	0.86	35	1.10	0.323
Error	323.95	0.78	415		

Appendix X: **Dry leaf weight ANOVA 64 days after planting for season 1 and 2**

Source	SS	MS	DF	F ratio	Prob >F
Total	1938.82		503		
Ecotype	389.52	11.13	35	6.09	<.0001*
Rep	528.98	88.16	6	48.26	
Row	11.46	2.29	5	1.25	
Column	12.65	2.11	6	1.15	
Season	83.79	83.79	1	45.87	<.0001*
Ecotype *Season	96.76	2.76	35	1.51	0.033*
Error	758.13	1.83	415		

Appendix XI: Dry leaf weight ANOVA 78 days after planting for season 1 and 2

Source	SS	MS	DF	F Ratio	Prob > F
Total	1812.65		503		
Ecotype	530.51	15.16	35	7.67	<.0001*
Rep	111.79	18.63	6	9.43	
Row	5.12	1.02	5	0.52	
Column	10.94	1.83	6	0.92	
Season	199.38	199.38	1	100.89	<.0001*
Ecotype*Season	44.34	1.27	35	0.64	0.945
Error	820.13	1.98	415		

Appendix XII: **Dry leaf weight ANOVA 92 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	1860.64		503		
Ecotype	378.49	10.81	35	6.08	<.0001*
Rep	77.33	12.89	6	7.25	
Row	19.04	3.81	5	2.14	
Column	7.09	1.18	6	0.66	
Season	494.05	494.05	1	277.86	<.0001*
Ecotype*Season	100.92	2.88	35	1.62	0.0159*
Error	737.90	1.78	415		

Appendix XIII: **Dry leaf weight ANOVA 106 days after planting for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	1697.04		503		
Ecotype	373.81	10.68	35	6.15	<.0001*
Rep	83.72	13.95	6	8.04	
Row	23.42	4.68	5	2.69	
Column	11.94	1.99	6	1.14	
Season	369.60	369.60	1	212.91	<.0001*
Ecotype*Season	66.61	1.90	35	1.09	0.3287
Error	720.42	1.74	415		

Appendix XIV: Total dry leaf weight ANOVA for season 1 and 2

Source	SS	MS	DF	F Ratio	Prob > F
Total	27105.96		503		
Ecotype	8255.90	235.88	35	12.38	<.0001*
Rep	538.77	89.79	6	4.71	
Row	265.04	53.01	5	2.78	
Column	216.77	36.13	6	1.89	
Season	7657.26	7657.26	1	401.76	<.0001*
Ecotype*Season	829.08	23.69	35	1.24	0.1663
Error	7909.70	19.06	415		

Appendix XV: **Number of pods per plant ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	94523.56		503		
Ecotype	6898.83	197.11	35	1.36	0.0866
Rep	10730.80	1788.47	6	12.35	
Row	3011.02	602.20	5	4.16	
Column	2148.69	358.12	6	2.47	
Season	9348.40	9348.40	1	64.57	<.0001*
Ecotype*Season	4468.68	127.68	35	0.88	0.6645
Error	60081.13	144.77	415		

Appendix XVI: **Seed yield ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	442830.72		503		
Ecotype	34655.70	990.16	35	1.67	0.0109*
Rep	65285.60	10880.90	6	18.39	
Row	15541.90	3108.38	5	5.26	
Column	5008.69	834.78	6	1.41	
Season	46097.90	46097.90	1	77.95	<.0001*
Ecotype*Season	21369.20	610.55	35	1.03	0.4212
Error	245415.36	591.36	415		

Appendix XVII: **Number of primary branches ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	1870.16		503		
Ecotype	387.05	11.06	35	4.55	<.0001*
Rep	208.19	34.69	6	14.28	
Row	9.14	1.83	5	0.75	
Column	10.40	1.73	6	0.71	
Season	24.71	24.71	1	10.17	0.0015*
Ecotype*Season	137.30	3.92	35	1.61	0.0168*
Error	1008.59	2.43	415		

Appendix XVIII: **1000 seed weight ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	11.49		503		
Ecotype	0.59	0.02	35	0.79	0.7965
Rep	0.39	0.07	6	3.11	
Row	0.14	0.02	5	1.31	
Column	0.08	0.01	6	0.66	
Season	0.77	0.77	1	36.54	<.0001*
Season*Ecotype	0.53	0.02	35	0.71	0.8887
Error	9.27	0.02	415		

Appendix XIX: Days to 1st flowering ANOVA for season 1 and 2

Source	SS	MS	DF	F Ratio	Prob > F
Total	3167.78		503		
Ecotype	75.83	15.17	5	1.34	0.2498
Rep	3.45	0.58	6	0.05	
Row	1.63	0.33	5	0.03	
Column	62.82	10.46	6	0.92	0.4795
Season	0.00	0.00	0	0.00	.
Ecotype*Season	22.85	4.57	5	0.40	0.8467
Error	2599.03	11.35	415		

Appendix XX: **Days to 50% flowering ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	1314.44		503		
Ecotype	16.64	3.33	5	0.68	0.6359
Rep	1.24	0.21	6	0.04	
Row	5.69	1.14	5	0.23	
Column	13.80	2.30	6	0.47	
Season	0.00	0.00	0	0.00	.
Ecotype*Season	3.82	0.76	5	0.15	0.9778
Error	1113.87	4.86	415		

Appendix XXI: **Days to 75% flowering ANOVA for season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	978.44		503		
Ecotype	15.21	3.04	5	0.86	0.5106
Rep	0.85	0.14	6	0.04	
Row	3.16	0.63	5	0.18	
Column	5.32	0.89	6	0.25	
Season	0.00	0.00	0	0.00	.
Ecotype*Season	2.72	0.54	5	0.15	0.9789
Error	812.84	3.54	415		

Appendix XXII: **Dry weight 50 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	386.54	61.84	59		
Fertilizer	151.59	37.89	4	23.29	<.0001*
Deflower	19.27	19.27	1	11.84	0.001*
Season	122.12	122.12	1	75.05	<.0001*
Deflower*Fertilizer	5.38	1.35	4	0.83	0.5164
Season*Fertilizer	13.68	3.42	4	2.10	0.0997
Season*Deflower	1.54	1.54	1	0.94	0.3374
Deflower*Fertilizer*Season	1.83	0.46	4	0.28	0.8881
Block	9.28	4.64	2	2.85	
Error	61.83	1.62	38		

Appendix XXIII: **Dry weight 64 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	570.13	9.66	59		
Fertilizer	204.78	51.19	4	23.73	<.0001*
Deflower	124.42	124.41	1	57.68	<.0001*
Season	69.55	69.55	1	32.24	<.0001*
Deflower*Fertilizer	16.86	4.22	4	1.95	0.0121*
Season*Fertilizer	10.08	2.52	4	1.16	0.3398
Season*Deflower	40.02	40.01	1	18.55	0.0001*
Deflower*Fertilizer*Season	0.15	0.04	4	0.02	0.9994
Block	22.31	11.16	2	5.17	
Error	81.95	2.16			

Appendix XXIV: **Dry weight 78 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	465.06	7.88	59		
Fertilizer	204.82	51.20	4	28.42	<.0001*
Deflower	39.85	39.85	1	22.12	<.0001*
Season	123.55	123.55	1	68.58	<.0001*
Deflower*Fertilizer	20.04	5.01	4	2.78	0.040*
Season*Fertilizer	6.65	1.66	4	0.92	0.4607
Season*Deflower	0.18	0.18	1	0.10	0.7527
Deflower*Fertilizer*Season	0.96	0.24	4	0.13	0.9693
Block	0.53	0.27	2	0.15	
Error	68.46	1.80	38		

Appendix XXV: **Dry weight 92 Days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	263.28	4.46	59		
Fertilizer	147.64	36.91	4	37.17	<.0001*
Deflower	50.05	50.05	1	50.40	<.0001*
Season	9.76	9.76	1	9.83	0.0033*
Deflower*Fertilizer	6.26	1.57	4	1.58	0.0200*
Season*Fertilizer	5.22	1.31	4	1.31	0.28190
Season*Deflower	4.06	4.05	1	4.08	0.05040
Deflower*Fertilizer*Season	0.69	0.17	4	0.18	0.94960
Block	1.82	0.91	2	0.92	
Error	37.73	0.99	38		

Appendix XXVI: **Dry weight 106 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	214.1240	3.6292	59		
Fertilizer	98.2057	24.5514	4	18.9680	<.0001*
Deflower	54.9127	54.9127	1	42.4246	<.0001*
Season	1.29067	1.29067	1	0.9971	0.3243
Deflower*Fertilizer	1.06233	0.26558	4	0.2052	0.034*
Season*Fertilizer	1.51767	0.37942	4	0.2931	0.8806
Season*Deflower	0.35267	0.35267	1	0.2725	0.6047
Deflower*Fertilizer*Season	1.95567	0.48892	4	0.3777	0.8231
Block	5.641	2.8205	2	2.1791	
Error	49.1857	1.2944	38		

Appendix XXVII: Plant height ANOVA season 1 and 2

Source	SS	MS	DF	F Ratio	Prob > F
Total	36513.44	618.87	59		
Fertilizer	393.08	98.27	4	1.11	0.3649
Deflower	11908.90	11908.90	1	134.82	<.0001*
Season	19235.30	19235.30	1	217.76	<.0001*
Deflower*Fertilizer	257.78	64.45	4	0.73	0.0477*
Season*Fertilizer	247.66	61.91	4	0.70	0.5962
Season*Deflower	1065.97	1065.97	1	12.06	0.0013*
Deflower*Fertilizer*Season	18.98	4.75	4	0.05	0.9944
Block	29.15	14.57	2	0.16	
Error	3356.59	88.33	38		

Appendix XXVIII: **Number of primary branches ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	662.68	11.23	59		
Fertilizer	208.35	52.08	4	23.68	<.0001*
Deflower	217.89	217.89	1	99.07	<.0001*
Season	89.16	89.16	1	40.54	<.0001*
Deflower*Fertilizer	16.56	4.14	4	1.88	0.0133*
Season*Fertilizer	12.35	3.09	4	1.40	0.25120
Season*Deflower	26.88	26.88	1	12.22	0.0012*
Deflower*Fertilizer*Season	6.34	1.58	4	0.72	0.58350
Block	1.58	0.79	2	0.36	
Error	83.57	2.19	38		

Appendix XXIX: Number of days to flowering ANOVA season 1 and 2

Source	SS	MS	DF	F Ratio	Prob > F
Total	945.65	16.03	59		
Fertilizer	105.23	26.31	4	2.94	0.032*
Deflower	6.02	6.02	1	0.67	0.4174
season	109.35	109.35	1	12.22	0.001*
Deflower*Fertilizer	31.90	7.98	4	0.89	0.4787
season*Fertilizer	2.90	0.73	4	0.08	0.9877
season*Deflower	1.35	1.35	1	0.15	0.6999
Deflower*Fertilizer*season	2.90	0.73	4	0.08	0.9877
Block	345.90	172.95	2	19.32	
Error	340.10	8.95	38		

Appendix XXX: **Fresh leaf weight 50 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	18205.01	308.56	59		
Fertilizer	6283.00	1570.75	4	15.32	<.0001*
Deflower	701.10	701.10	1	6.84	0.012*
Season	4312.93	4312.93	1	42.08	<.0001*
Deflower*Fertilizer	109.89	27.47	4	0.27	0.039*
Season*Fertilizer	1033.37	258.34	4	2.52	0.0570
Season*Deflower	4.76	4.76	1	0.04	0.8305
Deflower*Fertilizer*Season	53.79	13.45	4	0.13	0.9700
Block	1811.01	905.50	2	8.83	
Error	3895.15	102.50	38		

Appendix XXXI: **Fresh leaf weight 64 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	27567.33	467.24	59		
Fertilizer	7683.09	1920.77	4	27.12	<.0001*
Deflower	7598.25	7598.25	1	107.23	<.0001*
Season	4355.42	4355.42	1	61.46	<.0001*
Deflower*Fertilizer	572.98	143.25	4	2.02	0.011*
Season*Fertilizer	441.25	110.31	4	1.56	0.2056
Season*Deflower	2990.62	2990.62	1	42.20	<.0001*
Deflower*Fertilizer*Season	34.68	8.67	4	0.12	0.9736
Block	1198.29	599.14	2	8.46	
Error	2692.75	70.86	38		

Appendix XXXII: **Fresh leaf weight 78 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	20405.43	34.67	59		
Fertilizer	8768.35	2192.09	4	43.90	<.0001*
Deflower	7115.53	7115.53	1	142.51	<.0001*
Season	183.05	183.05	1	3.66	0.0631
Deflower*Fertilizer	443.39	110.85	4	2.22	0.045*
Season*Fertilizer	704.18	176.04	4	3.53	0.015*
Season*Deflower	666.67	666.67	1	13.35	0.008*
Deflower*Fertilizer*Season	421.39	105.35	4	2.11	0.0985
Block	205.56	102.78	2	2.06	
Error	1897.32	49.93	38		

Appendix XXXIII: **Fresh leaf weight 92 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	12860.36	217.97	59		
Fertilizer	5700.47	1425.12	4	46.95	<.0001*
Deflower	4576.27	4576.27	1	150.78	<.0001*
Season	245.63	245.63	1	8.09	0.007*
Deflower*Fertilizer	364.45	91.11	4	3.00	0.030*
Season*Fertilizer	298.02	74.51	4	2.45	0.0622
Season*Deflower	279.07	279.07	1	9.19	0.004*
Deflower*Fertilizer*Season	13.17	3.29	4	0.11	0.9789
Block	229.92	114.96	2	3.79	
Error	1153.35	30.35	38		

Appendix XXXIV: **Fresh leaf yield 102 days after planting ANOVA season 1 and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	11784.06	199.73	59		
Fertilizer	4968.77	1242.19	4	51.29	<.0001*
Deflower	3013.25	3013.25	1	124.42	<.0001*
Season	1524.10	1524.10	1	62.93	<.0001*
Deflower*Fertilizer	518.39	129.59	4	5.35	0.001*
Season*Fertilizer	282.04	70.50	4	2.91	0.034*
Season*Deflower	153.60	153.60	1	6.34	0.016*
Deflower*Fertilizer*Season	137.56	34.39	4	1.42	0.246
Block	266.05	133.02	2	5.49	
Error	920.29	24.29	38		

Appendix XXXV: Total dry leaf weight ANOVA season 1 and 2

Source	SS	MS	DF	F Ratio	Prob >F
Total	7665.72	129.93	59		
Fertilizer	3917.54	979.39	4	46.22	<0.001*
Deflower	1320.70	1320.70	1	62.33	<0.001*
Season	1208.71	1208.71	1	57.04	<0.001*
Deflower *Fertilizer	150.19	37.55	4	1.77	0.01547*
Season*Fertilizer	124.88	31.22	4	1.47	0.22950
Season * Deflowering	112.34	112.34	1	5.30	0.0269*
Deflower *Fertilizer*Season	8.85	2.21	4	0.10	0.98030
Block	17.26	8.63	2	0.41	
Error	805.24	21.19	38		

Appendix XXXVI: **Total fresh leaf yield ANOVA season 1and 2**

Source	SS	MS	DF	F Ratio	Prob > F
Total	324111.10		59		
Fertilizer	163578.00	40894.60	4	69.71	<.0001*
Deflower	102747.00	102747.00	1	175.13	<.0001*
Season	1669.50	1669.54	1	2.85	0.0998
Deflower*Fertilizer	8450.20	2112.55	4	3.60	0.014*
Season*Fertilizer	10721.40	2680.35	4	4.57	0.004*
Season*Deflower	6828.80	6828.80	1	11.64	0.002*
Deflower*Fertilizer*Season	545.60	136.40	4	0.23	0.9180
Block	7276.90	3638.48	2	6.20	
Error	22293.70	586.70	38		