INFLUENCE OF FERTILIZER APPLICATION, TIME OF PINCHING AND HARVESTING METHOD ON GROWTH, YIELD AND NUTRITIONAL QUALITY OF COWPEA (*Vigna unguilata* L.) AND SPIDER PLANT (*Cleome gynandra* L.)

BY

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DECLARATION

This thesis is my original work and has not been presented for an award of a degree in any other university

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DEDICATION

I dedicate this thesis to my colleagues of goodwill and those who will find benefit from this work.

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ABBREVIATIONS AND ACRONYMS

AILVs	African indigenous leafy vegetables
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ASL	Above sea level
ASAL	Arid and semi-arid land
AVRDC	Asian Vegetable Research and Development Center (World Vegetable Centre)
CAN	Calcium ammonium nitrate
CP	Crude protein
DAP	Diammonium phosphate
DAS	Days after sowing
DAT	Days after transplanting
DMW	Dry matter weight
DW	Dry weight
FAO	Food and Agriculture Organization of the United Nations
FW	Fresh weight
FYM	Farmyard manure
HCDA	Horticultural Crops Development Authority
HPLC	High Performance Liquid Chromatography
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
LAI	Leaf area index

MT	Metric tones
MOA	Ministry of Agriculture
PM	Poultry manure
SPAD	Soil Plant Analysis Development
SSA	Sub-Saharan Africa
WAE	Weeks after emergence
WHO	World Health Organization

GENERAL ABSTRACT

Introduction of exotic vegetables in mainstream agriculture has seen a decline in the utilization of African indigenous leafy vegetables (AILVs) such as cowpea and spider plant. This has caused inadequate, imbalanced nutrients in the human diet, contributing to malnutrition especially in the poor, sick, children and elderly people in Sub-Saharan Africa. These groups have high nutrient requirements but they are unable to access adequate amounts from animal sources due to high cost. African indigenous leafy vegetables contain high levels of minerals such as zinc, calcium, iron, vitamin C and β carotene and proteins. Use of fertilizers and appropriate pinching and harvesting practices could lead to increased leaf yield and nutrition quality of cowpea (*Vigna unguiculata* L.) and spider plant (*Cleome gynandra* L). A study was therefore, conducted at Kabete Field Station, University of Nairobi, during 2014 short rains and 2015 long rains to assess the effect of fertilizers, time of pinching and harvesting method on growth, yield and nutrition quality of cowpea and spider plant. Treatments of each vegetable consisted of four fertilizer levels (no-fertilizer control, 200 kg/ha di-ammonium phosphate, 10 t/ha manure, 100 kg/ha di-amonium phosphate + 5 t/ha manure), two types of pinching (early pinching and late pinching) and two harvesting methods (piecemeal and wholesome) which were evaluated in a randomized complete block design with a factorial arrangement, replicated three times. Data collected included plant height, number of branches, number of edible leaves, canopy span, fresh and dry leaf yields, days to 50% flowering, number of pods per plant, vitamin C, β carotene and mineral elements (zinc, iron, calcium and magnesium). Collected data were subjected to analysis of variance using Genstat software and means separated using the least significant difference test at $P \leq 0.05$.

The results showed significant increase in plant height, number of branches, number of edible leaves and marketable fresh weight of both vegetables due to fertilizer application.

Applications of 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure were superior to other treatments in cowpea and spider plant, respectively. Incorporation of diammonium phosphate and manure either singly or in combination significantly ($P \leq 0.05$) increased β carotene, vitamin C, zinc, calcium and magnesium levels but significantly ($P \leq 0.05$) reduced iron content in both crops. Late pinched cowpea and spider plants had significantly ($p<0.05$) higher plant height, number of edible leaves, fresh and dry leaf yields, vitamin C, calcium, magnesium and iron content than early pinched plants. However, early pinching resulted in significantly ($p<0.05$) higher content of zinc in both crops. Wholesome harvesting led to an increase in number of edible leaves, fresh and dry leaf yields, β carotene, vitamin C, zinc, calcium and magnesium in both crops. Plants subjected to 100 kg/ha DAP + 5 t/ha manure + late pinching + wholesome harvesting recorded the highest leaf yields and accumulation of calcium and magnesium levels. Therefore, to maximize yields and the nutritional composition of cowpea and spider plant, fertilizer application, late pinching and wholesome harvesting should be adopted as a management practice.

Key words: Cowpea, fertilizer, harvesting, nutrition, pinching, spider plant and yield

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Indigenous or native vegetables, referred herein as African indigenous leafy vegetables (AILVs), are simply vegetables whose natural home is known to be in Africa (Van Rensburg et al., 2007). According to Maundu, (1997) indigenous vegetables are described to be vegetables that have been used for a long period of time and they have formed part and parcel of the tradition of a community. According to Lyatuu and Lebotse (2010), the African indigenous leafy vegetables comprise African nightshades *(Solanum* spp*)*, African kales *(Brassica oleracea* L.), cowpea leaves (*Vigna unguilata* L.*)*, spider plant (*Cleome gynandra* L.), leaf amaranth (*Amaranthus* spp), jute mallow (C*orchorus* spp), slenderleaf (*Crotalaria* spp), pumpkin leaves among others. The fleshy leaves and stems together with the young tender flower and fruits form part of the utilized vegetables (Chelang'a et al., 2013).

African indigenous leafy vegetables are regarded as weeds in most parts of the developed world, but in Africa and other developing countries, they form an important source of cheap and indispensable component of balanced food diets, especially among the rural and resource poor communities in Kenya and other African countries (Abukutsa-Onyango, 2010). There are many species of AILVs in Sub-Saharan Africa (SSA) and only a small proportion is utilized as food. For instance, in Kenya there is a big genetic distance in spider plant depending on the geographical region thus affecting the phenotypic expression (Wasonga et al., 2015). The high diversity of these vegetables shows their importance in environment adaptation and consumer preference. Many households in SSA use AILVs as part of their diets. The consumption patterns differ from region to region. For example, in Kenya, it depends on the season of the year and its availability. Ones' ethnic background also influences the consumption pattern (Kimiywe et al., 2007).

For a long period, western Kenya has been the highest producer and consumer of these vegetables (Abukutsa-Onyango, 2007). The acreage and economic contribution of AILVs in Kenya have been reported to increase from 31,864 ha and 4.3%, respectively, in 2011 to 40,000 ha and 5% in 2013. The current average yield of AILVs is 4.5 t/ha (HCDA, 2014) compared to possible yields of 10 to 15 t/ha. According to Abukutsa-Onyango, (2003), this production is still below the optimal yield of 20 to 40 t/ha.

African indigenous leafy vegetables play an important role in combating food insecurity micronutrient deficiency (Faber, 2010). Nutrition analysis has proved that AILVs, contain more micronutrients than commonly consumed cereals like maize. Besides, they are critical in mitigating micronutrient deficiency (Akundabweni et al., 2010). Micronutrient deficiency or 'hidden hunger' has particularly been recognized as a silent catastrophe, but which can be corrected by eating bio-fortified foods. Many foods currently eaten are, however, deficient in macro and micronutrients. To address this problem, among others, there is need to increase the diversity of cropping systems, particularly with respect to production of AILVs.

The production of AILVs is a major source of income to most households (Onyango, 2002a). For example, AILVs fetch premium prices in supermarkets and big food outlets compared to open-air markets (informal markets). This is because, supermarket clients are more nutritionally enlightened with higher incomes hence are more willing to pay premium prices. Besides, the supermarkets have adopted technologies that reduce post harvest losses (Chelang'a et al., (2013).

Most of the AILVs have a high adaptation to the prevailing environmental conditions and can ensure more availability of food at affordable prices to the low-income earners in the rural households (Keantinge et al., 2011; Ojiewo et al., 2013). The vegetables have a short growth period; for instance, cowpea can be harvested within 3-5 weeks after planting. Some AILVs like slender leaf and cowpea can withstand and tolerate some biotic and abiotic stresses. With better agronomic practices like irrigation, fertilization and weeding higher yields can be obtained (Abukutsa-Onyango, 2009).

Studies by Abukutsa-Onyango, (2009) reveal that the production of AILVs could be low due to low sensitization on their value and potential. These findings corroborate with those of Tumwet et al., (2012) in western Kenya. Farmers, on the other hand, lack high quality seeds (certified seeds) for these vegetables thus affecting their competition in the market. Most seeds are farmer owned and are obtained from the informal markets (Onim and Mwaniki, 2008). Problems such as lack of recommendations on the amount of fertilizers to be used for optimal yields and short vegetative phases of the vegetable plants constrain their production (Abukutsa-Onyango, 2010).

Proper utilization of AILVs is constrained by their short shelf lives. The vegetables are highly perishable and cannot withstand shelf lives of more than 24 hrs at room temperature. Initial post-harvest handling techniques like drying and storing in specialized containers are no longer widely used. The current population is lowly enlightened on the preparation and consumption of these vegetables (Mbugua, 2011). Inappropriate harvesting techniques, poor post-harvest handling as as well as poor infrastructure cause massive losses along producer – consumer value chains (Muchoki et al., 2007; HCDA, 2008).

1.2 Problem statement and justification

African indigenous leafy vegetables (AILVs) are among the lowest yielding crops in Africa. For example, in Kenya the average leaf yield of cowpea is 300 kg/ha against its potential leaf yield of 3 t/ha (Karanja et al., 2007) while that of spider plant is in the range of 1-3 tons/ha, against possible leaf yield of 10-15 tons/ha (Abukutsa-Onyango, 2003). The low yields are partly attributed to declining soil fertility due to continuous cultivation with little replenishment with external fertilizers, if any, and poor pinching and harvesting practices.

Cowpea and spider plant production requires supplementation of various nutrients for achieving their yield potentials. The supplementation is generally achieved through application of fertilizers in the soil at various stages of crop life. The use of organic fertilizers, namely farmyard manure (FYM), compost manure, green manure and vermicompost, has been reported to have long-term benefits. Organic manure ensures slow and steady release of nutrients to plants and improves soil physical characteristics (Gulshan et al., 2013). The quantity of organic materials available to African farmers to be used as organic source is generally low (Tittonell and Giller, 2012). Besides, the organic fertilizers are bulky and difficult to transport, they have low nutrient content, which are slowly released and cannot provide adequate nutrients during periods of peak crop nutrient demand (Aderinoye et al., 2017). Inorganic fertilizers on the other hand, readily release nutrients to meet crop demand. However, they have not been supplied in adequate quantities since they are costly. Therefore, they are out of reach to many poor households. The nutrients from inorganic fertilizers are easily leached resulting to low fertilizer use efficiency. Improved yields of AILVs can be obtained with fertilizer application. This is achievable through maintaining a soil nutrient equilibrium via application of mineral fertilizers, manure and mineralization of plant debris.

In other crops like stevia, carnations and marigold, pinching and fertilization have been shown to increase yields through reduced apical dominancy, increased lateral growth and branching and increased vegetative growth (Chauhan et al., 2005; Singh and Kumar, 2003 and Kumar et al., 2014). However, these practices have not been fully applied to most AILVs and where practiced, they have not been well documented.

Smallholders in Kenya cultivate AILVs for their fresh vegetables, though a few farmers cultivate them for seed. Farmers use two main methods in harvesting AILVs; uprooting the entire plant when three to five true leaves have developed before they become too mature and fibrous or continuous picking/plucking of single leaves when the plant starts branching about 3-5 weeks after planting until there is no more leaf production or the plant starts to seed. Hardly any information is available on how these harvesting practices influence growth, yield and nutritional quality of the AILVs and how these practices would interact with the available soil nutrients.

In many instances, AILVs have higher levels of macro and micronutrients than some exotic vegetables like spinach and cabbage (Uusiku et al., 2010). Many of the AILVs are hardy and are well adapted to prevailing environmental conditions and can be produced at low cost with minimum inputs. Considering that, these vegetables are also quite nutritious, their consumption needs to be encouraged. The production and promotion of these vegetables (AILVs) would help overcome the problem of malnutrition, poverty and household food security both in rural and urban areas. With the foregoing in mind, there is need for further studies to evaluate the effect of combined chemical and organic fertilizers, time of pinching and harvesting practices on growth, yield and nutritional quality of cowpea and spider plant to ensure maximum production and exploitation of their high nutritional value.

1.3 Objectives

The main objective of this study was to increase the productivity of cowpea and spider plant through improved fertilization and management practices.

The specific objectives of the study were:

1. To evaluate the influence of fertilizer application, time of pinching and harvesting method on growth and yield of cowpea.

2. To evaluate the influence of fertilizer application, time of pinching and harvesting method on growth and yield of spider plant.
3. To evaluate the influence of fertilizer application, time of pinching and harvesting method on nutritional quality of cowpea.
4. To evaluate the influence of fertilizer application, time of pinching and harvesting method on nutritional quality of spider plant.

1.4 Hypotheses

1. Application of fertilizers enhances growth, yield and nutritional quality of cowpea plant.
2. Application of fertilizers enhances growth, yield and nutritional quality of spider plant.
3. Timing of pinching influences growth, yield and quality of cowpea and spider plant.
4. Method of harvesting influences growth, yield and quality of spider plant.

CHAPTER TWO: LITERATURE REVIEW

2.1 Botany of cowpea and spider plant

Cowpea (*Vigna unguilata* L. (Walp) is a leguminous herbaceous warm season annual crop belonging to the family *fabaceae* and genus *Vigna* (Singh, 1993). The name ‘cowpea’ was first used in America. The earlier English name was cavalance and was first used in West Indies (Rachie and Singh, 1985). It is commonly referred to as southern pea, black eye pea and lubia (Fatahi, 2014). There are more than 7000 cowpea cultivars worldwide, some of them are tall and viny while others are short and bushy and the stem length may reach 4 m (Clark, 2007). Cowpea has a long taproot system, and three parted, egg shaped and hairless leaves. The terminal leaf is symmetrical and the two lateral cowpea leaves are asymmetrical with flower colour either being white or purple (TJAI, 2010). Cowpea flowers are bisexual, and are almost entirely self pollinated in dry climate but may exhibit cross pollination (up to 40%) in humid environments (Madamba et al., 2006). Cowpea seed coat can be smooth or wrinkled; white, green, red, brown, speckled and blotched eye in colour (Aveling, 1999).

Spider plant (*Cleome gynandra* L.) is an erect herbaceous plant belonging to the family *Capparaceae* and genus *Cleome,* (Chweya and Mnzava, 1997; USDA, 2013). Spider plant is a C_4 plant, this photosynthetic pathway enables it to be highly productive in the tropics and subtropics (Brown et al., 2005). In English, *Cleome gynandra* is known as a spider flower or plant and spider wisp. There are more than 50 species of the native African *Cleome* (IItis, 1960). In most parts of Sub-Saharan Africa, spider plant is semi-cultivated while in many tropical countries, it grows as a weed (Van Rensburg et al, 2007). Spider plants are both self and cross pollinated (Mnzava and Chigumira, 2004). The seeds germinate rapidly and flowering may begin three to six weeks after planting while fruit development and maturation may take three to four months (Mnzava, 1997). The plant can grow to a maximum height of 1.5 m, depending on the variety and environment. The plant has alternating compound leaves with three to seven leaflets, but commonly five leaflets. The leaves have various shapes; elliptic, ovate, lanceolate or obovate (Wasonga et al., 2015). The flowers, stems and petiole colours can either be violet, pink or purple (Wasonga et al., 2015). Small white flowers characterize the terminal inflorescence, but pink and lilac flowers may also occur in some species (Iltis, 1967). The spider plant fruit consists of small siluques (Van Wyk and Gericken, 2000).

2.2 Origin, distribution and production of cowpea and spider plant

Cowpea originated in Africa, thereafter it spread to South East Asia, Southern United States and Latin America (Fatokum et al., 2000; FAO, 2010). Sub-Saharan Africa is the largest producer (84%) of cowpea in the world, with Nigeria being the largest producer (2.92 million metric tonnes) and consumer of cowpea in the world followed by Niger at nearly 1.1 million metric tonnes (FAO, 2012). In Kenya, the area under cowpea production in 2014 was estimated to be 24,431 ha (AFFA, 2014). Kitui county, produced the largest quantity of cowpea in 2014, while Siaya, Kilifi, Migori, Bungoma, Kakamega, Siaya, Makueni, Tharaka Nithi and Machakos contributed the remainder (AFFA, 2014). A shift in more drought tolerant vegetable crops in Africa has increased the production of cowpea (Saidi et al., 2007).

Spider plant is thought to have originated in the tropics as a weed and it is native to Africa, South America, Asia and Middle East (Chweya and Mnzava, 1997; Fletcher, 1999). In Kenya spider plant is mainly grown in western, Rift Valley, eastern and coastal regions with key counties being Kisii, Nyamira, Kericho, Migori and Siaya (HCDA, 2014), where it is known by different names. It is known as dek among the Luo, chinsanga (Kisii) and saget among the Kalenjin (Chweya and Mnzava, 1997). Spider plant is also economically important to local traders especially those in the peri-urban areas. The spider leaf yield in Kenya is in the range of 1-3 t/ha, this is still below the potential leaf yield of 10-15 t/ha (Abukutsa-Onyango, 2003).

Production of cowpea and spider plant in Kenya is to a greater extent constrained by lack of adequate scientific knowledge on cultural practices, best varieties to be planted and their optimum handling and nutrition requirements during cultivation till they reach the consumer. Besides, most smallholder farms continue to experience a decline in soil fertility due to continuous cultivation with little or no fertilizer replenishment leading to low AILV yields.

2.3 Ecological requirements for production of cowpea and spider plant

Cowpea requires daytime temperatures of 27^0C (FAO, 2012) and consistent temperatures of at least 18^0C are best (TJAL, 2010). Depending on the variety, cowpea performs well in agro-ecological zones where rainfall ranges between 500 and 1200 mm per year (Madamba et al., 2006). The plant can grow in a wide range of soils (Van Rensburg et al., 2007) though it prefers well-drained soils with a pH of 5-7 (Ecocrop, 2009). The plant can tolerate shade and drought but does not survive flooded conditions (Clark, 2007).

Spider plant thrives best in a temperature of 18-25^0C and high light intensity as it is sensitive to cold. It prefers an altitude of 0-2400 m ASL. The plant has a developed C_4 photosynthetic pathway that enables it to be adapted to areas with short periods of rainfall. The crop can grow on a wide range of soils with a pH of 5.5-7.0 (Chweya and Mnzava, 1997).

2.4 Importance of cowpea and spider plant

The leaves or young shoots of either cowpea or spider plant are used as food. They can either be boiled and eaten as potherbs, stews or side dishes and accompanied with cereal based foods (Onyango et al., 2013). Cowpea is mainly used as an animal feed in form of fodder or vegetable and as a grain crop (Karanja et al., 2013). Cowpea grain contains micronutrients such as zinc and iron which are necessary for healthy living (Boukar et al., 2010) and about 53% carbohydrate, 24% crude protein and about 2% fat (FAO, 2012). Cowpea green leaves and immature pods contain 27-34% and 4-5% protein, respectively (Belane and Dakora, 2009). The leaves are an excellent source of minerals such as calcium, magnesium, iron, zinc, manganese, copper and selenium (Imungi and Potter, 1983; Ahenkora et al., 1998; Van Rensburg et al., 2007). These minerals play a vital role in different body functions (FAO/WHO, 2004).

Cowpea can fix 70 to 80% nitrogen for its own growth requirement demand (Asiwe et al., 2009). Besides, it is capable of fixing about 240 kg/ha of atmospheric nitrogen and avail about 60-70 kg/ha nitrogen for the succeeding crop in a rotation programme (Aikins and Afuakwa, 2008; Maseko, 2014), thereby reducing nitrogen fertilizer demand in the field. Decaying cowpea shoot and root residues improve soil fertility (Karanja et al., 2013). The short and bushy type of cowpea serves as an excellent crop in controlling soil erosion and suppressing weeds (Clark, 2007). It has also shown capability of suppressing nematodes in crop production systems (Roberts et al., 2005).

Spider plant has a high nutritional value. It contains high levels of β-carotene, protein, vitamin C and minerals such as iron, calcium, phosphorus and magnesium (Mbugua et al., 2011). Several authors have reported on its importance for medicinal purposes (e.g; Sankaranarayanan et al., 2010). These authors reported that the compounds from spider leaves are capable of treating diseases such as hypertension, diabetes, rheumatism and cancer; boosting immunity and retarding ageing. The plant has insects and pest repellant characteristics, which enables it to be used as a repellant (Malonza et al., 1992).

The leaves and younger tender shoots of cowpea and spider plant are sold in urban markets mostly by women to earn income. For instance, in Northern Ghana, an average income of $ 3.7 million is generated yearly from cowpea production (ICRISAT, CIAT and IITA, 2012). In Asia, spider plant is produced for seed oil extraction (Chweya and Mnzava, 1997).

2.5 Constraints to cowpea and spider production

Cowpea and spider production in Kenya is faced by a number of constraints. A number of insect pests attack cowpea at different development stages. For example, white flies that suck the phloem sap thereby, reducing vegetative area resulting to reduced photosynthetic capacity and production (Satpathy et al., 2009). Other insect pests of economic importance to cowpea include aphids, foliage beetles, flower thrips, pod borers and cowpea weevils (Satpathy et al., 2009). Severe infestation of weaver birds (*Quelea quelea)* has been reported to cause total seed loss in spider plant production. Other pests of economic importance in spider plant production include green vegetable bugs, aphids, cotton jassids, locusts, flea beetles, pentatomids and their parasitoids (Chweya and Mnzava, 1997).

Cowpea diseases cause great losses in the yields of the crop. Viral diseases such as cowpea mosaic virus and cowpea chlorotic mottle virus have caused massive cowpea losses in Africa (Ittah et al., 2010). Diseases such as brown blotch, cercospora leaf spot, sclerotium stem blight and web blight are common in cowpea production, especially in the humid agro-ecological areas (Adegbite and Amusa, 2008). Other diseases affecting cowpea include root knot nematodes, damping off disease, powdery mildew, rust and cowpea wilt (Singh et al., 1995; Okechukwu et al., 2008). There are no major diseases that affect spider plant though mildew fungus (*Sphaerotheca fuliginea*) and leaf spots (*Cercospora uramensis)* have been reported to affect this crop (Chweya, 1997; Mbugua *et al.,* 2007).

Yellow witchweed (*Alectra vogeli*) is a great threat in cowpea production in eastern Kenya. Karanja et al., (2013) reported that at least 80% of farmers' fields in eastern Kenya had been infested with yellow witchweed and in some cases, there were total yield loss. Weeds adversely affect spider plant and their control at early growth stages is necessary since it is a poor competitor. Common weeds in spider plant production are thorn apple (*Datura stramonium*), oxalis (*Oxalis sorrel*) and couch grass (*Elymus repens*) (Maundu, 1997).

Most of the AILVs, especially spider plant, when cooked, have a bitter taste. Therefore, to reduce the bitterness, the leaves are boiled and drained with water several times, but there is a tradeoff of loss of nutrients (Chweya and Mnzava, 1997). Other mechanisms developed in reducing bitterness is cooking together with other leafy vegetables or fermenting in milk for several days. Spider plant leaves contain a lot of anti-nutrients, such as phenolic compounds and nitrates, that give them more stringent taste than cowpea leaves (Chigumira and Mnzava, 2004). The big challenge in vegetable food processing is reducing the bitter taste of the vegetables without losing the beneficial nutrients in the vegetable.

The seeds of spider plant are negatively photoblastic, exhibit poor germination possibly because of immature embryos, hard seed coats, and induced secondary dormancy (Borhinger *et al.,* 1999; Chweya and Mnzava, 1997). Besides, spider plant production has also been constrained with a short vegetative phase and premature flowering behavior (bolting) which hinders economic vegetable yield (Abukutsa-Onyango, 2010).

2.6 Effect of organic fertilizers on growth and yields of cowpea and spider plant

In the current agricultural system, more emphasis is placed on improved varieties having better characteristics, soil amendment and improved agricultural technologies for increasing quantity and quality per unit area. However, the full potential of the improved varieties and technologies can only be achieved if essential inputs such as fertilizers are applied in a timely manner and in the right quantities (Ogbodo, 2013). Work done by Chweya (1990) in Kisii, showed that soil amendments with fertilizers significantly improved yields of total tops of spider plant. The AILVs are commonly known to invade areas that were previously cattle 'bomas' (Chweya, 1997; Onyango et al., 2000) and this is because of manure droppings, hence it is likely that these vegetables require such conditions for improved yields and quality. Organic manure provides macro and micronutrients in available forms during mineralization that play a direct role in plant growth, besides they also improve the physical and chemical conditions of the soil (Chaterjee et al., 2005). The use of fertilizers on AILVs is seldom emphasized in Kenya.

Chweya and Mnzava (1997) showed that the plant nutritional value and phenotypic expression varies with soil fertility, plant type (ecotype), plant age, environment, and production techniques used. Mishra et al., (2013) reported that cowpea treated with poultry manure increased pod yields. Working in Pakistan, Badar et al., (2015) reported that cowpea treated with biofertilizers, farmyard manure and diammonium phosphate increased leaf yields by 102%, 44% and 59%, respectively, as compared to no fertilizers. Tagoe et al., (2008), reported that carbonized organic amendment and chemical fertilizer increased phosphorus content of cowpea. According to Mhlonto et al., (2007) higher leaf yields of 487% and 310% were obtained from spider plant plots treated with goat manure and cattle manure, respectively, as compared to those with no fertilizers.

Bisma et al., (2015) reported that coconut coir and farmyard manure increased cowpea plant height by 44% and 52%, respectively, as compared to untreated plots. Lawal and Girei (2013) reported that farmyard manure increased dry matter content by up to 54% in spider plant. They attributed this to increase in nutrient and moisture content of soil together with reduction in soil pH. In another study on spider plant carried out in Kenya, Aguyoh (2012) reported that 15 t/ha FYM produced higher leaf yield than no fertilizer application. This observation is consistent with previous reports on spider plant and black nightshade (Kipkosgei et al., 2004; Ondieki et al., 2011). Materechera (2013) reported the highest fresh leaf yield across three *Cleome gynandra* genotypes treated with goat kraal manure compared to cattle manure and no–fertilizer treatments. In earlier findings by Kipkosgei et al., (2004) higher yields in spider plant were obtained from farmyard manure treated plants than in the controls. Other researchers have also reported low yields in cowpea plants that relied entirely on the natural soil nutrients than those that had their soils amended with organic manure

(Singh et al., 2011 and Nkaa et al., 2014). From the previous studies, it is evident that the use of organic fertilizers improves AILV yields and physical conditions of the soil. This study seeks to fill the information gap on the best rate of organic fertilizer to use in cowpea and spider plant production for better yields and nutrition quality.

2.7 Effect of inorganic fertilizers on growth and yields of cowpea and spider plant

Soils that are poor in nutrients such as nitrogen, sulphur, magnesium, phosphorus and potassium affect plant growth, reduce plant yields and influence nutritional content (Ghaly and Alkoaik, 2010). Van Averbeke et al., 2007 reported that leafy vegetables such as *Solanum villosum* and *Brassica* spp increased in fresh and dry above ground biomass when treated with nitrogen fertilizer. According to Magani and Kuchinda, (2009) increased growth, yield and protein content was observed in two cowpea varieties when phosphorus fertilizer was applied.

Atakora et al., (2014) reported increases in stover yield by 20%, 36% and 28% in cowpea plots treated with 60, 48 and 24 kg/ha of phosphorus, respectively, as compared to the unfertilized plots. Significant increases in green and dry fodder yields as well as leaf yields, of cowpea with increase in phosphorus application have been reported by other researchers (Chavan et al. 2011; Kumar et al., 2012 and Singh et al., 2011). They attributed the increased stover yields to increased intensity of nodulation. According to Patel et al., (2014) application of NPK fertilizer on cowpea accelerated flower initiation and increased plant height.

Studies by Mauyo (2008) revealed that the use of nitrogen fertilizers increased the number of marketable leaves and fresh yield of spider plant. Ng'etich, (2012) reported that calcium ammonium fertilizer applied at different rates significantly increased spider plant fresh leaf yield and crop quality. Similar findings were found by Masinde and Agong (2011) who reported that spider plants treated with nitrogen fertilizers had increased leaf yields and nitrogen content in the harvested leaves. Findings by Ogweno et al., (2015) showed increased vegetative growth and leaf yields in spider plant with increasing NPK applications.

The production of AILVs, especially cowpea and spider plant is still below the potential yields. Besides, there is scanty literature on the effect of fertilizers on nutrition quality of AILVs. Thus, the challenge for researchers in this country is to fill the gap between potential yields and actual yields. Therefore, this study was conducted to determine the influence of fertilizers on growth, yield and nutritional quality of cowpea and spider plant.

2.8 Effect of combined use of organic and inorganic fertilizers on growth and yields of cowpea and spider plant

There is limited information available on the effect of combined use of chemical and organic fertilizers on yields, growth and nutrition quality of cowpea and spider plant. Taura and Fatima (2008) reported that a combination of organic and inorganic fertilizers recorded the greatest number of cowpea leaves and leaf area and the tallest plants as compared to the chemical or organic fertilizers applied singly in a sandy soil. According to Patel et al., (2010) cowpea treated with poultry manure only or in combination with inorganic fertilizers resulted in increased leaf number and plant height but gave lower green pod yields than farmyard manure or neem cake.

Yoganathan, et al., (2013) reported that higher cowpea leaf yield was found in animal manure combined with chemical fertilizers than when applied singly. This finding is in agreement with that of Love (2014) who reported increased number of flowers per plant, plant height, canopy size, stem width, plant dry matter and seed weight in grain amaranth treated with a combination of manure and CAN. Similarly, Ainika et al., (2011) reported that application of inorganic nitrogen combined with farmyard manure significantly increased plant height, plant dry matter and leaf area index in amaranth. This is in agreement with findings of, Rajput et al., (2013) on cowpea where application of phosphatic fertilizer combined with *Azolla* produced significantly higher number of branches, leaves, pods and grain yield. The use of inorganic and organic fertilizers in combination, provide a better synchrony of nutrient availability with crop demand. For instance, there is immediate availability of nutrients from inorganic fertilizers and slow release from manure (Alemu and Bayu, 2005). It is therefore likely that the combination of chemical and organic fertilizers would improve growth and yield in cowpea and spider plant.

2.9 Effect of harvesting method on growth and yields of cowpea and spider plant

Harvesting of consumable products like leaves and grains of AILVs is of great importance to African farmers (Baloyi et al., 2013). The harvesting practices employed have the potential to increase or reduce leaf and grain yields together with the mineral composition of the crop (Rahman et al., 2008). Two main harvesting procedures are commonly used in AILVs; uprooting entire plant at tender stage or having sequential leaf harvesting during the vegetative growth (Onyango and Imungi, 2007). Saidi et al., (2010) and Baloyi et al., (2013) reported that the nutritional quality and biomass yield of leafy vegetable is affected by; intensity and frequency of leaf removal and the stage of the crop.

In a study carried out in Katumani, Kenya by Saidi, (2007), it was found that cowpea leaf harvesting at seven-day intervals had higher leaf yields of 56% and 47% in the short rain and long rain seasons, respectively, than the 14 day-intervals harvesting. Studies by Materechera and Medupe (2006) on leaf amaranth showed that frequent harvesting of leaves resulted to low fresh and dry yields. In another study on *Moringa oleifera*, Amaglo et al., (2006) found that continuous cutting of leaves reduced fresh leaf yields as compared to the less frequently cut ones. Ng'etich (2012) reported that spider plant treated with fertilizers at various rates significantly increased leaf yields at all harvesting intervals with an exception at 70 and 90 days after planting where there was reduced production. In another study on spider plant, continuous harvesting of leaves resulted to higher leaf yield than harvesting once

(Materechera and Seeiso, 2012). Despite the great importance of AIVs, information on how different harvesting methods affect growth, yield and nutrition quality in both smallholder farming and large-scale production is still limited.

2.10 Effect of pinching on growth and yields of cowpea and spider plant

Pinching is a form of pruning that involves removal of terminal buds of herbaceous plants to encourage branching of the plant. Once the terminal bud is removed, several buds on the stem open up to develop into new buds (Walston, 2001). It is a standard practice in cut flower production to produce more flowering stems for increased flower production (Ecke and Matkin, 1976). In herbs it is done to encourage the plant to produce more desirable forage and seeds (Hammo, 2008). In carnations, it is done to delay flowering and hence harvesting (Iftikhar, 2007). In chrysanthemums, it is done to ensure uniform development of basal rosette (MOA et al., 2003).

Studies by Wangolo et al., (2015) revealed that, flower removal in spider plant resulted to an increase in growth parameters and leaf yield as compared shoot tip removal and unpinched plants. Similarly, Ogweno et al., (2015) showed that deflowering increased the number of branches and leaves together with the vegetative yield. Studies by Love (2014) in amaranth showed that pinching at 28 days after sowing had higher dry matter weight of 83% than unpinched plants, while those pinched at 49 days after sowing had a reduction of 8.3% in yield. Similarly, in earlier studies by Mwafusi, (1992) on *Solanum nigrum*, deflowering had 40% more leaf yields than the non-deflowered plants. Zobolo et al., (1999) also reported that flowering in *Bidens pilosa* resulted to reduction in vegetative yield. Pinching in amaranth plant resulted to increased number of leaves (Love, 2014). These observations are in tandem with studies done by Oluoch et al., (2009), on African indigenous leafy vegetables in which flower removal increased leaf yield. Liang et al., (1996) reported that practices such as pruning, pinching and thinning affected vegetative growth and fruit development, which in turn influenced the nutritional composition of crops. According to Kumar et al., (2010), pinching in stevia plants resulted to shorter plants and increased number of branches, plant spread and dry leaf biomass. Results of pinching by Rathore et al., (2011) revealed that pinching on marigold resulted to significant increase in number of branches and flower heads but significantly reduced the plant height.

So far, there is no information on pinching in cowpea but from the previous studies in other crops and spider plant, apical bud removal or deflowering in cowpea would increase the number of leaves and number of branches, which will eventually contribute to increased yields in any other vegetative crops. Timely pinching in cowpea and spider plant should result in increased number of branches, number of leaves and yields. Despite all these benefits, pinching practices have not been fully integrated in the production of AILVs.

2.11 Effect of fertilizers, pinching and harvesting method on nutritional quality of cowpea and spider plant

Most Kenyan farmers have adopted the use of fertilizers to increase crop production. However, fertilizers impact on the nutritional quality of AILVs has received little attention. Other factors such as genotypic differences, soil condition, stage of crop growth, pre-harvest conditions, management practices and post-harvest handling procedures have been reported to affect nutritional quality of certain crops (Kader, 2002). It has been reported that early harvested cabbages resulted to higher ascorbic acid concentration than late harvested cabbages (Beverly et al., 1993). Adeyemi et al., (2012) and Abebe et al., (2005) observed that cowpea plants treated with manure recorded higher crude protein content than those without manure application. Badar et al., (2015) reported that other than biofertilizers, farmyard manure and diammonium phosphate applications increased leaf yields, carbohydrate and phosphorus content of cowpea plants relative to the no-fertilizer applications. Tagoe et al., (2008), reported that cowpea plant treated in a combination of carbonized organic amendment and chemical fertilizer had increased phosphorus content. Mhlonto et al., (2007) reported that manure treated spider plant resulted to higher crude protein contents than untreated plots.

In earlier findings by Kipkosgei et al., (2004) higher yields and vitamin C contents in spider plant were obtained from FYM treated plants than in the controls. Spider plants treated with calcium ammonium nitrate (CAN) significantly increased leaf calcium and magnesium levels, while moderate CAN fertilizer levels significantly increased vitamin C content but higher levels of CAN fertilizer resulted to reduction in vitamin C content (Ong'era, 2012). Onyango et al., (2007) reported higher iron content in CAN fertilizer treated spider plants than the plants that had no fertilizers.

Masinde et al., (2006) showed that time of harvesting significantly affected iron content in spider plant, with mid harvests giving the highest amount of iron content as compared to first and last harvests. Ong'era (2012) reported that calcium content in spider plant increased from the 4^{th} week harvest to the 8^{th} week harvest while highest vitamin C levels were found during the 4^{th} and 6^{th} week harvests. Liang et al., (1996) reported that practices such as pruning, pinching and thinning affected vegetative growth and fruit development, which in turn influenced the nutritional composition of crops. Trimming of outer leaves of Chinese cabbages resulted to reduction in vitamin C content as compared to those that were not trimmed (Klieber and Franklin, 2000). Mondy and Leja (1986) reported lower ascorbic acid content of bruised tissues of potato tuber than the un bruised ones. From the foregoing, the application of fertilizers, pinching and harvesting method could either increase or decrease the nutritional contents of cowpea and spider plant. Hence, it is necessary to determine the best fertilizer, pinching and harvesting practices for both cowpea and spider plant.

CHAPTER THREE: INFLUENCE OF FERTILIZER APPLICATION, TIME OF PINCHING AND HARVESTING METHOD ON GROWTH AND YIELD OF COWPEA

3.1 Abstract

African indigenous leafy vegetables are among the lowest yielding crops in Africa partly due to declining soil fertility and poor management practices. Use of fertilizers and appropriate pinching and harvesting practices could lead to increased cowpea *(Vigna unguiculata* L.*)* leaf and grain yields. A study was conducted at Kabete (Field Station), University of Nairobi, during 2014 short rains and 2015 long rains to evaluate the impact of fertilizer application, pinching time and harvesting method on growth and harvest of cowpea. Fertilization options (no-fertilizer control, 200 kg/ha di-ammonium phosphate, 10 tonnes per hectare (t/ha) chicken manure, 100 kg/ha di-amonium phosphate + 5 t/ha chicken manure), pinching (early pinching and late pinching) and harvesting methods (piecemeal and wholesome harvesting) treatments were evaluated in a RCBD with a factorial arrangement. Data collected included days to 50% flowering, plant height, number of branches and leaves per plant, fresh and dry leaf yields, pod load per plant and grain yield. Using GENSTAT software, the data were subjected to analysis of variance and means separated using the LSD test at $P \leq 0.05$. Fertilizer application, time of pinching and harvesting method significantly ($P<0.05$) influenced plant height, number of branches per plant, fresh and dry leaf yields and number of leaves per plant. Application of 200 kg DAP/ha combined with late pinching and wholesome harvesting gave the highest leaf yields of 15.3 t/ha and 5.4 t/ha in the short and long rains, respectively, compared to the other treatment combinations. This combination also gave the highest records in plant height, number of branches per plant and number of leaves per plant. Application of 200 kg DAP/ha + late pinching, 200 kg DAP/ha + wholesome harvesting and late pinching + wholesome harvesting recorded the highest plant heights, number of branches per plant and fresh and dry leaf yields. Grain yield was not significantly affected by fertilizer application and time of pinching in the short rains, but in the long rains fertilizer application and late pinching significantly ($P<0.05$) increased grain yield. The results of this study

show that growth and leaf yield of cowpea can be substantially increased by application of 200 kg/ha of DAP fertilizer, late pinching and wholesome harvesting.

Keywords: Di-ammonium phosphate, early, late, manure, piecemeal, wholesome.

3.2 Introduction

Cowpea is an important leguminous crop grown in Kenya, covering an estimated area of 24,431 ha (AFFA, 2014). Although, cowpea is produced in most parts of Kenya, Kitui county is the largest producer at 15,470 MT per year, the other producing counties are Migori, Kakamega, Bungoma, Siaya, Makueni, Machakos and Tharaka Nithi (AFFA, 2014). Cowpea is highly valued in low rainfall, drought prone areas because of its ability to withstand drought, multi-purpose use and short growing period (Hallensleben *et al*., 2009). In many areas, cowpea is used as a source of food, animal fodder and income to those who sell leaves and young tender shoots in the market (Karanja et al., 2013). Its grain contains crude protein, carbohydrate and micronutrients, which are necessary for healthy living (Boukar et al., 2010). Its green leaves, on the other hand, contain essential minerals, which play important roles in different body functions (FAO/WHO, 2004). The crop is a good nitrogen fixer (Asiwe et al., 2009), and can also be used as green manure, weed control and as a soil cover (Clark, 2007).

Despite its many uses and contribution to food security, vegetative productivity of cowpea remains below the genetic potential for cultivated varieties (Karanja et al., 2007). Several factors contribute to low productivity, among which are soil problems, especially low fertility, salinity and poor management practices (Waddington et al., 2010; Yoganathan, 2013). Reports by Ayodele and Oso (2014) reveal that application of optimum rates of phosphatic fertilizers leads to higher cowpea yields than no-fertilizer applications. Cowpea plants treated with either inorganic or organic fertilizers improves leaf yields (Singh et al., 2011; Badar et al., 2015). However, there is low adoption of replenishing the soils through fertilizer application, due to several factors ranging from high fertilizer costs to low availability of inorganic fertilizers. Most African farmers, who use chemical fertilizers, rarely apply them at the recommended rates and time because of delays in delivery, high costs and lack of credit for purchase (Heissey and Mwangi, 1996). Besides, the fertilizer recommendations are not site specific as they are formulated on a national basis; hence, one requires soil testing which is costly. Organic manure offers an alternative in soil fertility management to the Kenyan farmers, however, it is not available in adequate quantities to satisfy the nutritional demand of crops. Its transportation as well as management cost is also a major constraint to most farmers (Tittonell and Giller, 2012). Research findings by Vanlauwe et al., (2002b) reported that combining chemical and organic fertilizers improved crop yields and soil fertility. Similarly, (Mucheru-Muna et al., 2014) reported increased maize yields in crops treated with both organic manure and inorganic fertilizers. This was due to improved N synchrony with other nutrients through the interaction of the organic and inorganic sources. Therefore, an integration of inorganic and organic fertilizers could lead to better and sustainable soil fertility management and increased leaf and grain yields of cowpea.

There is limited information on the impact of pinching on the yield and nutrition quality of cowpea plant as well as growth. Generally, removal of an apical bud decreases apical dominance, thus increasing lateral growth and branching (Ferguson et al., 2006; Whiting D et al., 2011). More branches will produce more leaves, leading to an overall increase in leaf yield. In crops such as amaranth and spider plant, pinching has been shown to significantly increase leaf yields (Love, 2014; Mavengahama et al., 2013). There is also limited information on how management practices such as piecemeal leaf harvesting and wholesome harvesting, which involves uprooting the whole plant, would influence total leaf yield.

Previous studies by Nyeko et al., (2004) reported that frequent defoliation on alder crop significantly decreased nitrogen content while Saidi et al., (2010) reported higher cowpea leaf yields in plants harvested at 7-day interval than those harvested at 14-day intervals. There is need to identify the best fertilize regimes, time of pinching and harvesting method in cowpea production, for improving yields and thus contributing to food security and improved nutrition. Therefore, the study was undertaken to evaluate the influence of fertilizer application, time of pinching and harvesting method on growth and yield of cowpea.

3.3 Materials and methods

3.3.1 Site description

The field experiment was conducted at the University of Nairobi's Kabete Field Station, Kenya, in a span of two seasons; namely October 2014-February 2015 and March-July 2015. Kabete Field Station is 1940 m above the sea level and is located on the latitudes 1° 15'S, 36°44' E (Sombroek et al., 1982). The site receives an annual rainfall of 1000 mm per annum with long rains in the months of March to June and short rains from October to December. The area has a mean monthly temperature of 12 ^{0} C - 23 ^{0} C (Anon, 1985). The area has humic nitisols which are very deep and well drained (Michieka, 1978). Soils from the experimental site were sampled at a depth of 0-15 cm together with chicken manure and analyzed for pH, carbon, nitrogen, potassium, sodium, calcium, magnesium and phosphorous in both seasons (Appendix 1). The weather data during the experimental period are shown in (Appendix 2).

3.3.2 Experimental design and treatments

The study was a 4 x 2 x 2 (factorial experiment) laid out in a randomized complete block design with 3 replications. Three factors were studied: (i) fertilizers regimes, (ii) time of pinching and (iii) harvesting method. Fertilizer treatments were four levels: 200 kg/ha of di-ammonium phosphate (DAP), 100 kg/ha DAP + 5 (t/ha) chicken manure, 10 (t/ha) chicken manure and control (no fertilizer). The fertilizer application rates were based on the recommendations of 200 kg DAP/ha (Namakka et al., 2016) and 9 t/ha FYM (Nyankanga et al., 2012). Time of pinching consisted of early pinching and late pinching. Harvesting method treatments comprised piecemeal harvesting and wholesome harvesting. Both the organic and inorganic fertilizers were incorporated into the established drills through sole placement method and mixed thoroughly with the soil before planting. Early pinching involved removal of cowpea apical bud 2 weeks after emergence (2 WAE) while late pinching involved removal of cowpea apical bud at 4 weeks after emergence (4 WAE). The buds were removed using shears. Piecemeal harvesting involved manual plucking of edible cowpea leaves starting at 4 weeks after emergence which continued weekly till the fifth harvest. Wholesome harvesting involved uprooting the entire plant and plucking the leaves. For the early pinched-wholesome harvested cowpea plants, two harvests were made. The first harvests were uprooted 4 weeks after emergence and the leaves harvested. For the second harvest, another planting was done immediately and wholesome-harvested at 4 weeks after emergence. The late pinched-wholesome harvested cowpea plants were harvested once at 8 weeks after emergence.

3.3.3 Crop establishment and maintenance

The field was ploughed two months before sowing with a tractor and then harrowed using a hoe to attain a good tilth. Experimental plot sizes measuring 2 m by 1.5 m were demarcated. An inter-plot spacing of 1 m and 2 m path separating blocks were established. The treatment plots were raised 30 cm high and a guard row separated from the treatment plots by 1 m also established.

Cowpea seeds sourced from World Vegetable Centre, Tanzania, were sown in the seed plots directly at the onset of rains at a spacing of 50 cm x 30 cm, between and within rows respectively. Fertilizers were applied according to the rates of each treatment and mixed with soil before planting. Two seeds were planted in each hill and later thinned to a seedling per hill at 2 weeks after emergence. The plants were sprayed using an insecticide Thunder® 145 OD (Neonicotinoids/pyrethroids) from Bayer East Africa Ltd, Nairobi, Kenya at the rate of 1 ml/ litre water to kill aphids, caterpillars and whiteflies after emergence and before flowering to prevent insect damage. Hand weeding was done to ensure the treatment plots were weed free during the experimental period. Although the experiment was conducted under rain-watered conditions, supplemental overhead irrigation was applied at 4 weeks after emergence at a frequency of three days per week for four weeks.

3.4 Data collection

Data collection for growth and yield began at 28 days after emergence. The parameters measured included: days to 50% flowering, SPAD values, plant height, number of branches and leaves per plant, fresh leaf yield, dry leaf yield, pod load per plant, pod length, 100 seed weight and grain yield.

Six plants from inner rows of each plot were tagged for collection of most data. The growth parameters were measured over time. Plant heights of six tagged plants were measured in centimeters from the bases of the plants to the tips of the outer longest leaves of individual plants using a meter rule. Number of branches was determined by visually counting all the main branches from the tagged plants. Number of leaves per plant was obtained by visual counting of cowpea leaves in each plot.

Leaf chlorophyll content was taken from six tagged plants in each plot. The SPAD values were taken using a non-destructive, hand-held chlorophyll meter Soil Plant Analysis

Development (SPAD-502, Minolta Camera Co., Ltd., Japan). Three recently formed fully expanded leaves in each plant were used to obtain the SPAD readings. Days to 50 % flowering was the number of days taken for 50 % of six tagged plants in each plot to flower.

Fresh leaf yield was obtained from six tagged plants in each plot. The leaves were harvested by plucking leaves at every harvesting interval. The harvested leaves were then weighed immediately using a weighing balance to avoid reduction in mass due to loss of plant water. The piecemeal harvested plants had a total of five harvests. Wholesome harvested plants had three harvests (two harvests from the early pinched-wholesome harvested plants and one harvest from the late pinched wholesome harvested plants). Dry leaf yield was obtained from the harvested fresh leaf yield. Harvested leaves were placed under shade for two hours to remove excess moisture and then dried at 70^0 C to constant weight and weights determined. Mature pods harvested from six tagged plants in each plot were counted. Pod length was obtained through measuring the length of ten pods harvested from the six tagged plants using a string and a ruler. One hundred seeds were sampled and weighed using a weighing balance from the harvested seed lots that had been dried to a moisture content of 13 %. Cowpea grain yield was obtained by taking the weight of dried seeds (13% moisture content) from six tagged plants in each experimental plot and converted into Kg/ha.

3.5 Data analysis

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

3.6 Results

3.6.1 Main effects of fertilizer application, time of pinching and harvesting method on cowpea plant height, branches per plant, number of leaves per plant, fresh leaf yield and dry leaf yield

Fertilizers, time of pinching and harvesting method had significant ($P \leq 0.05$) effects on plant height, number of branches per plant and leaves per plant, fresh leaf yield and dry leaf yield in both seasons (Table 3.1 and 3.2).

In both seasons, cowpea plants treated with fertilizers had significantly ($P \leq 0.05$) taller plants and more number of leaves and branches per plant, fresh and dry leaf yield than plots that were not supplied with fertilizers (Tables 3.1 and 3.2). In the first season, plots treated with 200 kg DAP/ha had significantly ($P \leq 0.05$) higher number of branches per plant than manure treated plants which, in turn, had a higher number of branches per plant than plants treated with 100 kg DAP/ha + 5 t/ha manure. In the second season, fertilized plants were not significantly different in number of branches per plant (Table 3.2). In both seasons, plants treated with 100 kg DAP/ha + 5 t/ha manure out-performed all the other treatments in number of leaves per plant. The number of branches per plant were significantly similar in the second season among all plots supplied with fertilizers. In both seasons, plants treated with 200 kg DAP/ha significantly ($P \leq 0.05$) out-performed plants treated with 100 kg DAP/ha + 5 t/ha manure which, in turn, out-performed manure treated plants in both fresh and dry leaf yield. In the second season, plots supplied with fertilizers were not different in dry leaf yield. In both seasons, late pinching had significantly ($P \leq 0.05$) taller plants and more number of branches per plant and leaves per plant, fresh and dry leaf yields than early pinched plants (Table 3.1 and 3.2). Wholesome harvested plants had significantly ($P \leq 0.05$) taller plants and more number of branches and leaves per plant, fresh leaf yield and dry leaf yield than piecemeal harvested plants in both seasons.

Table 3.1: Main effects of fertilizers, time of pinching and harvesting method on cowpea growth and vegetative yield during 2014 short rains at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
Fertilizers					
Control	20.5	7.1	88.0	2668.4	460.8
200 kg/ha DAP	23.1	10.0	130.9	4925.6	610.4
100 kg/ha DAP + 5 t/ha M	22.4	7.5	133.0	4034.6	610.1
10 t/ha M	22.3	8.5	118.9	3575.9	575.9
P-value	<0.031	<.021	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	1.8	0.8	3.0	176.7	16.2
Pinching					
Early pinching	20.1	6.5	55.1	1300.1	167.8
Late pinching	24.1	10.1	180.3	6337.4	960.8
P-value	<0.001	<0.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.3	0.5	21.2	125.0	11.4
Harvesting					
Piecemeal .H	20.8	8.0	44.0	1101.3	129.5
Wholesome .H	23.3	8.6	191.4	6536.2	999.1
P-value	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.3	0.5	21.2	125.0	11.4

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

Table 3. 2: Main effects of fertilizers, time of pinching and harvesting method on cowpea growth and vegetative yield during 2015 long rains at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
Fertilizers					
Control	13.4	2.5	22.8	534.4	79.5
200 kg/ha DAP	17.3	4.0	46.8	1515.9	203.7
100 kg/ha DAP + 5 t/ha M	18.3	4.3	50.0	1397.8	193.9
10 t/ha Manure	17.5	4.0	48.5	1382.5	192.9
P-value	<0.001	<.015	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	1.3	0.4	2.9	114.6	16.2
Pinching					
Early pinching	14.4	3.0	11.3	212.3	30.6
Late pinching	18.9	4.4	72.2	2203.0	304.3
P-value	<0.001	<0.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.9	0.3	2.1	81.0	11.4
Harvesting					
Piecemeal .H	13.6	2.9	6.3	150.0	19.4
Wholesome .H	19.6	4.5	77.3	2265.3	315.5
P-value	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.9	0.3	2.1	81	11.4

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

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

Interaction of fertilizers and time of pinching had significant ($P \leq 0.05$) effects on plant height, number of branches and leaves per plant, fresh and dry leaf yields in both seasons (Table 3.3). Within each of the fertilizer treatments, late pinching had significantly taller plants and higher number of branches and leaves per plant, fresh and dry leaf yields than early pinching. In early pinched plants, fertilizer application significantly increased the measured plant attributes. There was no significant difference in plant height and number of branches per plant among the early pinched, fertilizer treated plants (Table 3.3).

Table 3.3: Interactive effects of fertilizers and time of pinching on growth and vegetative yield of cowpea during 2014 and 2015 short and long rains, respectively at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
First Season (2014 short rains)					
Control + EP	18.1	5.5	40.2	848.0	128.9
Control + LP	22.9	9.5	135.9	4488.7	792.6
200 kg/ha DAP + EP	20.7	8.5	61.4	1653.1	203.4
200 kg/ha DAP + LP	25.5	11.5	200.3	8339.5	1017.4
100 kg/ha DAP + 5 t/ha M + EP	20.0	5.5	69.7	1630.1	223.7
100 kg/ha DAP + 5 t/ha M + LP	24.7	9.5	196.2	6439.1	996.6
10 t/ha M + EP	21.4	6.5	49.1	1069.2	115.2
10 t/ha M + LP	23.2	10.0	188.7	6082.5	1036.5
P-value (Fertilizer × Pinching)	<0.031	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	1.1	1.0	6.9	249.9	9.8

Second season (2015 long rains)					
Control + EP	11.7	2.0	6.8	91.9	13.0
Control + LP	15.1	3.0	38.9	976.0	146.0
200 kg/ha DAP + EP	14.5	3.0	12.4	238.0	36.4
200 kg/ha DAP + LP	20.1	5.0	81.2	2793.9	371.1
100 kg/ha DAP + 5 t/ha M + EP	15.6	3.5	12.8	261.4	37.3
100 kg/ha DAP + 5 t/ha M + LP	21.0	5.0	85.2	2534.3	350.5
10 t/ha M + EP	15.8	3.5	13.4	258.0	35.9
10 t/ha M + LP	19.2	4.5	83.6	2507.0	349.9
P-value (Fertilizer × Pinching)	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.8	0.5	4.2	162.0	22.8

P.H=plant height, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, EP=early pinching, LP=late pinching, M=manure

In both seasons, application of 200 kg/ha DAP + late pinching significantly outperformed the other treatment combinations in number of branches per plant, fresh and dry leaf yields (Table 3.3). Similarly, unfertilized + late pinched plants significantly ($P \leq 0.05$) out-performed fertilized and unfertilized early pinched plants in number of leaves per plant, fresh and dry leaf yields in both seasons (Table 3.3). There was no significant difference ($P \leq 0.05$) in dry leaf yields of late pinched plants supplied with 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure.

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

The interaction between fertilizers and harvesting method had significant ($P \leq 0.05$) influence on plant height, number of leaves and branches per plant, fresh leaf yield and dry leaf yield in both seasons except for plant height and number of branches in the second season (Table 3.4).

Within each fertilizer treatments, wholesome harvesting had significantly taller plants and higher number of branches and leaves per plant, fresh leaf yield and dry leaf yields (Table 3.4). In piecemeal harvested plants, fertilizer application significantly increased plant height, number of branches per plant, number of leaves per plant, fresh and dry leaf yields. The plant height of piecemeal harvested plants subjected to any fertilizer treatments and wholesome harvested that did receive fertilizers were statistically similar (Table 3.4). Similarly, plants with no-fertilizer application that were wholesome harvested outperformed the piecemeal harvested plants that received fertilizers in number of leaves per plant, fresh leaf yield and dry leaf yield (Table 3.4). In both seasons, 200 kg/ha DAP + wholesome harvested plants generally resulted to significantly ($P \leq 0.05$) more number of branches per plant and fresh leaf yields than the other treatment combinations.

Table 3. 4: Interactive effects of fertilizers and harvesting method on growth and vegetative yield of cowpea during 2014 short and 2015 long rains, respectively, at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
			First Season (2014 short rains)		
Control + P	19.2	7.5	32.7	826.0	125.8
Control + W	21.8	7.5	143.4	4510.8	795.7
200 kg/ha DAP + P	21.9	9.5	48.2	1346.2	141.1
200 kg/ha DAP + W	24.3	10.5	213.5	8646.4	1079.7
100 kg/ha DAP + 5 t/ha M + P	21.2	7.0	50.5	1318.1	148.1
100 kg/ha DAP + 5 t/ha M + W	23.5	8.0	215.4	6751.1	1072.2
10 t/ha M + P	20.8	8.0	44.5	915.0	102.9
10 t/ha M + W	23.8	8.5	193.3	6236.7	1048.8
P-value (Fertilizer × Harvesting)	<.031	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.1	1.0	6.9	249.9	46.0
			Second Season (2015 long rains)		
Control + P	10.2	2.0	4.1	85.2	10.2
Control + W	16.6	3.0	41.6	983.5	148.0
200 kg/ha DAP + P	14.3	3.5	7.9	181.6	24.0
200 kg/ha DAP + W	20.3	4.5	85.7	2850.3	383.5
100 kg/ha DAP + 5 t/ha M + P	15.4	3.0	6.7	177.1	23.0
100 kg/ha DAP + 5 t/ha M + W	21.2	5.5	91.3	2618.6	364.9
10 t/ha M + P	14.6	3.0	6.4	156.2	20.7
10 t/ha M + W	20.4	5.0	90.6	2608.8	365.1
P-value (Fertilizer × Harvesting)	0.195	0.240	<.001	<.001	<.001
$LSD_{(p=0.05)}$	NS	0.5	4.2	162.0	22.8

P.H=plant height, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, P=piecemeal harvesting, W=wholesome harvesting, M=manure

3.6.4 Interactive effects of time of pinching and harvesting method on growth and vegetative yield of cowpea plant

The interactions between time of pinching and harvesting method had significant ($P \leq 0.05$) influence on number of leaves and branches per plant, plant height and fresh and dry leaf yields (Table 3.5). In early pinched plants, harvesting method had no significant effect on plant height. However, wholesome harvested plants had significantly ($P \leq 0.05$) higher fresh and dry leaf yields than piecemeal harvested plants (Table 3.5). In late pinched plants, wholesome harvested plants had significantly taller plants, more number of leaves and branches per plant, fresh leaf yield and dry leaf yield than piecemeal harvested plants. In piecemeal harvested plants, pinching had no effect on all the measured parameters except number of branches per plant in season two (Table 3.5). In both seasons, late pinching + wholesome harvesting resulted to significantly ($P \leq 0.05$) taller plants and higher number of branches and leaves per plant, fresh leaf yield and dry leaf yields than the other treatment combinations (Table 3.5).

Table 3.5: Interactive effects of pinching time and harvesting method on growth and vegetative yield of cowpea during 2014 short and 2015 long rains, respectively at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
First Season (2014 short rains)					
Early pinching + P	20.4	7.8	43.6	1124.8	139.6
Early pinching + W	19.7	5.3	66.6	1475.4	196.0
Late pinching + P	21.1	8.3	44.4	1077.8	119.3
Late pinching + W	27.0	12.0	316.1	11597.0	1802.2
P-value (Pi × Harvesting)	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.8	0.7	6.9	176.7	32.5
Second Season (2015 long rains)					
Early pinching + P	14.1	2.8	8.7	150.9	19.3
Early pinching + W	14.7	3.3	24.3	273.8	42.0
Late pinching + P	13.1	4.0	8.7	149.1	19.6
Late pinching + W	24.6	5.8	173.2	4256.8	589.1
P-value (Pi × Harvesting)	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.3	0.4	4.9	114.6	16.2

P.H=plant height, B/P=number of branches per plant, L.No = number of leaves, FLY=fresh leaf yield, DLY=dry leaf yield, P=piecemeal harvesting, W=wholesome harvesting, Pi=pinching

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

Interactions between fertilizers, time of pinching and harvesting method were significant ($P \leq 0.05$) for number leaves per plant, fresh leaf yield and dry leaf yields in both seasons. However, there was no interaction for plant height and number of branches per plant in the first and second season, respectively (Table 3.6 and 3.7).

Table 3. 6: Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of cowpea plant during 2014 short rains at Kabete Field Station

	P.H (cm)	**B/P**	**L.No.**	**FLY (Kg/ha)**	**DLY (Kg/ha)**
Control + EP + P	18.9	7.0	31.2	822.0	118.3
Control + LP + P	19.6	8.0	34.2	830.0	133.3
Control + EP + W	17.3	4.0	49.1	874.0	139.4
Control + LP + W	26.2	11.0	237.6	8147.5	1452.0
200 kg/ha DAP + EP + P	21.6	10.0	47.2	1331.7	163.2
200 kg/ha DAP + LP + P	22.3	9.0	49.2	1360.6	119.1
200 kg/ha DAP + EP + W	19.7	7.0	75.6	1974.4	243.7
200 kg/ha DAP + LP + W	28.8	14.0	351.4	15318.4	1915.7
100 kg/ha DAP + 5 t/ha M + EP + P	20.4	6.0	52.3	1362.5	170.7
100 kg/ha DAP + 5 t/ha M + LP + P	22.0	8.0	48.7	1273.7	125.4
100 kg/ha DAP + 5 t/ha M + EP + W	19.6	5.0	87.1	1897.7	276.7
100 kg/ha DAP +5 t/ha M + LP + W	27.4	11.0	343.6	11604.4	1867.8
10 t/ha M + EP + P	20.9	8.0	43.7	982.8	106.2
10 t/ha M + LP + P	20.6	8.0	45.4	847.1	99.5
10 t/ha M + EP + W	21.9	5.0	54.6	1155.6	124.3
10 t/ha M + LP + W	25.8	12.0	332.0	11137.8	1973.4
P-value (F × Pinching × Harvesting)	0.460	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	NS	1.4	8.4	353.4	65.0

P.H=plant height, B/P=number of branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, EP=early pinching, LP=late pinching, P=piecemeal harvesting, W=wholesome harvesting, NS=not significant, M=manure, F=fertilizers

Table 3.7: Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of cowpea plant during 2015 long rains at Kabete Field Station

	P.H (cm)	B/P	L.No.	FLY (Kg/ha)	DLY (Kg/ha)
Control + EP + P	10.5	2.0	4.2	79.6	9.4
Control + LP + P	9.8	2.0	4.0	90.8	11.0
Control + EP + W	12.8	2.0	9.4	104.2	16.5
Control + LP + W	20.4	4.0	73.8	1862.8	280.9
200 kg/ha DAP + EP + P	14.9	3.0	8.0	177.1	23.8
200 kg/ha DAP + LP + P	13.7	4.0	7.8	186.0	24.1
200 kg/ha DAP + EP + W	14.2	3.0	16.8	298.9	49.0
200 kg/ha DAP + LP + W	26.5	6.0	154.7	5401.7	718.0
100 kg/ha DAP + 5 t/ha M + EP + P	15.8	3.0	7.0	186.1	23.2
100 kg/ha DAP + 5 t/ha M + LP + P	15.0	3.0	6.3	168.0	22.7
100 kg/ha DAP + 5 t/ha M + EP + W	15.5	4.0	18.6	336.6	51.4
100 kg/ha DAP + 5 t/ha M + LP + W	27.0	7.0	164.0	4900.5	678.3
10 t/ha M + EP + P	15.3	3.0	6.7	160.6	20.7
10 t/ha M + LP + P	13.9	3.0	6.0	151.7	20.6
10 t/ha M + EP + W	16.4	4.0	20.0	355.3	51.1
10 t/ha M + LP + W	24.4	6.0	161.2	4862.3	679.1
P-value (F × Pinching × Harvesting)	<.001	0.285	<.001	<.001	<.001
$LSD_{(p=0.05)}$	2.5	0.7	5.9	229.1	32.2

P.H=plant height, B/P=branches per plant, L.No = number of leaves per plant, FLY=fresh leaf yield, DLY=dry leaf yield, EP=early pinching, LP=late pinching, P=piecemeal harvesting, W=wholesome harvesting, NS=not significant, M=manure, F= fertilizers

Under no fertilizers (control), time of pinching and harvesting method had no significant effect on fresh and dry leaf yields. However, in both seasons, fertilizer treated plants that were late pinched and wholesome harvested resulted to significantly ($P \leq 0.05$) taller plants, increased number of branches and leaves per plant, fresh leaf yield and dry leaf yield than the other treatment combinations (Tables 3.6 and 3.7).

In the first season, plants that were subjected to 200 kg/ha DAP + late pinching + wholesome harvesting had significantly ($P \leq 0.05$) higher number of branches and leaves per plant, fresh leaf yield and dry leaf yield than the other treatment combinations. In both seasons, plants subjected to 200 kg/ha DAP + late pinching + wholesome harvesting outperformed the other treatment combinations in fresh leaf yield and dry leaf yield (Tables 3.6 and 3.7). However, in the second season, late pinched plants and wholesome harvested plants that received either 100 kg DAP/ha + 5 t/ha manure or 10 t/ha manure resulted to significantly more leaves per plant than the other treatment combinations.

3.6.6 Main effects of fertilizers and time of pinching on days to 50% flowering, pod load and grain yield

Fertilizers and time of pinching had significant effects on days to 50% flowering, pod load and grain yield in both seasons except that pinching had no significant effect on cowpea grain yield in the first season (Table 3.8). There was no significant effect of the treatments on pod length and 100 seed weight. In the first season, plants in plots treated with 200 kg/ha DAP took significantly ($P \leq 0.05$) the shortest time to flower while the plants in control plots took significantly the longest time to flower (Table 3.8). Similar observations were made in the second season but there was no significant ($P \leq 0.05$) difference between 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure treatments (Table 3.8).

In the first season, significantly ($P \leq 0.05$) higher number of pods was obtained from no-fertilizer plots than in the plots that received fertilizer treatments (Table 3.8). No significant differences were observed among plants that received 200 kg/ha DAP, 100 kg/ha DAP + 5 t/ha manure and 10 t/ha manure in the first season. Plants treated with 100 kg/ha DAP + 5 t/ha manure and 10 t/ha manure significantly ($P \leq 0.05$) out-yielded 200 kg/ha DAP treated plants in number of pods per plant which, in turn, outperformed the control plots, in the second season (Table 3.8).

Fertilizer treatments had significant effects on cowpea grain yield in both seasons. Relative to no-fertilizer applications, the cowpea grain yields in the first season were significantly reduced by all fertilizer applications (Table 3.8). However, in the second season, significantly lowest yields were obtained from no-fertilizer plots. Plants that received 100 kg/ha DAP + 5 t/ha manure resulted to significantly ($P \leq 0.05$) higher grain yields than 10 t/ha manure which, in turn, out-yielded the application of 200 kg/ha DAP (Table 3.8).

Table 3.8: Main effects of fertilizers and time of pinching on days to 50% flowering, pod load and grain yield of cowpea during 2014 short and 2015 long rains, respectively, at Kabete Field Station

	Days to 50% flowering	Pod load/plant	Grain yield (Kg/ha)
First season (2014 short rains)			
Fertilizers			
Control	87.3	29.0	2939.7
200 kg/ha DAP	75.9	22.0	2367.6
100 kg/ha DAP + 5 t/ha M	78.1	22.0	2142.3
10 t/ha M	79.0	23.0	1947.4
P-value	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.4	1.2	125.5
Pinching			
Early Pinching	80.0	23.0	2314.5
Late Pinching	79.3	25.0	2384.0
P-value	0.021	<.001	0.659
$LSD_{(p=0.05)}$	1.0	0.8	NS
Second season (2015 long rains)			
Fertilizers			
Control	90.8	9.0	167.8
200 kg/ha DAP	87.9	18.0	284.4
100 kg/ha DAP + 5 t/ha M	88.5	21.5	315.5
10 tons/ha M	89.8	20.5	297.0
P-value	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.3	1.2	9.5
Pinching			
Early Pinching	90.5	15.3	256.5
Late Pinching	88.0	19.3	275.8
P-value	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.9	0.9	6.7

NS=not significant

Early pinched plants took significantly ($P \leq 0.05$) longer time to reach 50% flowering than late pinched plants in both seasons (Tables 3.8). On the other hand, late pinched plants had significantly ($P \leq 0.05$) more pods per plant than early pinched plants (Tables 3.8). Significant

(P≤0.05) effects of pinching time on yield (grain) were only observed in the second season, where late pinching out-performed early pinching (Table 3.8).

3.6.7 Interactive effects of fertilizers and time of pinching on days to 50% flowering, pod load and grain yield

The interaction between fertilizer application and time of pinching had a significant (P≤0.05) effect on pod load and grain yield in both seasons and days to 50% flowering in the second season (Table 3.9).

Table 3.9: Interactive effects of fertilizers and time of pinching on days to 50% flowering, pod load and grain yield of cowpea during 2014 short and 2015 long rains, respectively, at Kabete Field Station

	Days to 50% flowering	Pod load/plant	Grain yield (Kg/ha)
First season (2014 short rains)			
Control + EP	88.2	32.0	2911.9
Control + LP	86.5	26.0	2967.6
200 kg/ha DAP + EP	76.2	22.0	2295.2
200 kg/ha DAP + LP	75.7	22.0	2440.1
100 kg/ha DAP + 5 t/ha M + EP	79.2	22.0	1834.6
100 kg/ha DAP + 5 t/ha M + LP	77.0	22.0	2060.2
10 tons/ha M + EP	79.8	24.0	2216.4
10 tons/ha M + LP	78.2	22.0	2068.3
P-value (Fertilizers × Pinching)	0.56	<.001	0.023
$LSD_{(p=0.05)}$	NS	1.7	177.5
Second season (2015 long rains)			
Control + EP	92.2	7.0	121.7
Control + LP	89.5	11.0	213.8
200 kg/ha DAP + EP	89.7	21.0	287.4
200 kg/ha DAP + LP	86.2	25.0	281.3
100 kg/ha DAP + 5 t/ha M + EP	90.2	22.0	309.4
100 kg/ha DAP + 5 t/ha M + LP	86.8	21.0	321.5
10 t/ha M + EP	89.8	21.0	307.5
10 t/ha M + LP	89.7	20.0	286.5
P-value (Fertilizers × Pinching)	0.002	<.001	<.001
$LSD_{(p=0.05)}$	1.8	1.7	13.4

NS = not significant, EP=early pinching, LP=late pinching, M=manure

In the second season, 200 kg/ha DAP + late pinching and 100 kg/ha DAP + 5 t/ha manure + late pinching resulted to significantly ($P \leq 0.05$) shorter time to 50% flowering than late pinched plants supplied with 10 t/ha manure. No significant differences were observed in days 50% flowering in the early pinched plants supplied with fertilizers (Table 3.9).

Early pinched plants not supplied with fertilizers took significantly ($P \leq 0.05$) the longest time to flower compared to all other treatment combinations (Table 3.9).

In the first season, early pinched plants that did not receive fertilizers had significantly ($P \leq 0.05$) higher number of pods in each plant than late pinched plants that did not receive fertilizers, which, in turn, had significantly higher number of pods in each plant than early pinched and late pinched plants that were supplied with fertilizer (Table 3.9). In the second season, plants subjected to fertilizer application + early pinching or late pinching had significantly ($P \leq 0.05$) higher number of pods than the no fertilizer control + early or late pinched plants. Application of 200 kg/ha DAP + late pinching had significantly ($P \leq 0.05$) the highest number of pods per plant (Table 3.9).

During the first season, no-fertilizer content + early or late pinched plants significantly ($P \leq 0.05$) outperformed the other treatment combinations in grain yield. Application of 100 kg/ha DAP + 5 t/ha manure + early pinching resulted to significantly ($P \leq 0.05$) the lowest grain yield among the treatment combinations (Table 3.9). In the second season, plants supplied with fertilizers + early pinching or late pinching had significantly ($P \leq 0.05$) higher grain yields than no fertilizer content + early or late pinched plants (Table 3.9). Early pinched plants that did not receive fertilizers had significantly ($P \leq 0.05$) the lowest grain yield. Application of 100 kg/ha DAP + 5 t/ha manure + late pinching resulted to significantly ($P \leq 0.05$) the highest grain yield. No significant differences were observed between 100 kg/ha

DAP + 5 t/ha manure + early pinching and 100 kg/ha DAP + 5 t/ha manure + late pinching (Table 3.9).

3.7 Discussion

3.7.1 Impact of fertilizers application, pinching time and harvesting method on cowpea growth and vegetative yield

The fertilizer treated plants had taller plants and higher number of branches and leaves per plant, fresh leaf yield and dry leaf yields than the no-fertilizer control plants. These findings are in line with those Yoganathan, et al., (2013) and Singh et al., (2011) who showed an increase in growth attributes and leaf yields in cowpea plants amended with either organic or inorganic fertilizers. Other researchers have reported the effect of nutrient deficiency especially nitrogen or phosphorous in terms of stunted growth and low yields in cowpea (Aboyami et al., 2008). Similarly, Badar et al., (2015) and Patel et al., (2010) observed taller plants and increased number of leaves in cowpea plants treated with chicken manure. The increase in growth parameters and yields could be attributed to availability of phosphates and ammonium forms and their interaction with the available soil nutrients for plant use. This enhanced plant physiological functions such as photosynthesis, nitrogen fixation, cell division and enlargement, leading to increased number of branches and leaves per plant that translated to eventual increase in leaf yield (Ayodele and Oso, 2014).

The superior performance of 200 kg/ha DAP fertilizer in fresh and dry leaf yields compared to manure application could be attributed to immediate availability of nutrients in the latter. The findings are in agreement with the reports of (Singh et al., 2011), who obtained higher fresh yields in cowpea plants treated with DAP fertilizer. Besides, nitrogen and phosphorous from DAP is readily released for plant uptake compared to that supplied by manure which has to be decomposed and organic nutrients mineralized.

Delaying pinching from 2 WAE to 4 WAE resulted to taller plants and increased number of branches and leaves per plant, fresh and dry leaf yields. These results concur with those of

Ogweno et al., (2015) who showed an increase in number of leaves, branches, leaf yields and dry shoot biomass of spider plant in response to late pinching as compared to early pinching and no pinching. An increase in leaf yield and growth parameters as a result of pinching has been reported in other crops such as *Solanum nigrum, Bidens pilosa* and amaranthus (Love, 2014; Mwafusi, 1992; Zobolo et al., 1999). Pinching temporarily reduces auxin concentration at the tip of the plant and this takes away apical dominance, leading to stimulation of production of more side buds which grow into branches (Habiba et al., 2012). Research findings by Wangolo et al., (2015) in Kenya on spider plant, showed that late pinching/deflowering resulted to significantly higher leaf yields of 12.3 t/ha and 9 t/ha in both short and long rainy seasons compared to early pinching/shoot removal of 9 t/ha and 5.7 t/ha. They attributed this trend to re-allocation of more resources to the tips of more mature buds ready for flowering, which promoted more vegetative growth.

Wholesome harvesting resulted to taller plants and increased number of branches and leaves per plant, fresh and dry leaf yield as compared to piecemeal harvesting. These results tally with those of Amaglo et al., (2006) on *Moringa oleifera* in which frequent leaf harvesting reduced the number of leaves and fresh leaf yield. Similarly, Materechera and Medupe (2006) and Materechera et al., (2013) found that frequent leaf harvesting reduced fresh leaf yields but increased number of leaves in amaranthus. In contrast to these observations, Barimavanndi et al., (2010) found that cowpea plants that had frequent defoliation resulted to higher number of leaves and fresh leaf yield. Piecemeal harvesting had lower number of leaves per plant (6 and 77) than wholesome harvesting (44 and 191) in the short and long rains, respectively. This in turn, reduced the photosynthetic leaf area in piecemeal harvested plants, resulting in reduction in light interception by the foliage. It could be possible, piecemeal harvesting caused a diversion of assimilates towards healing wounds of the defoliated leaves at the expense of proliferating more leaves or perhaps, it did not give the leaves sufficient time to grow, hence the low yields.

The treatment combinations that had fertilizers and late pinching produced the tallest plants and highest total number of branches and leaves in each plant, fresh and dry leaf yields. Among the different fertilizers used, 200 kg/ha DAP together with late pinching recorded the highest yield. These observations are supported with the reports of Mavengahama, (2013) on spider plant who observed that late pinching in combination with fertilizer application resulted to increased number of leaves, branches, plant heights and leaf yields. Irrespective of the fertilizer used, early pinching did not influence the measured plant attributes.

Plants that received 200 kg/ha DAP + wholesome harvesting resulted to the tallest plants and highest number of branches and leaves per plant, fresh and dry leaf yields. This might be due to the immediate release and uptake of N and P from 200 kg/ha DAP and optimum light interception. Nitrogen may have helped in cell division and cell elongation that facilitated development of more shoots (Miller, 2010) while availability of phosphorous in early plant life laid down the primordial for cowpea growth. Wholesome harvesting favored light interception since the photosynthetic leaf area was not affected by defoliation, thus enhancing photosynthesis and consequently leading to increased number of leaves and yield. The impact of piecemeal harvesting on yield was not affected by the fertilizer treatments.

Late pinching and wholesome harvesting resulted to taller plants, increased number of leaves and branches per plant, fresh leaf yield and dry leaf yield. This could be due to re-allocation of more resources in the tips of late pinched plant that stimulated more vegetative growth (Kriedemann et al., 2010). Besides, wholesome harvesting increased light interception and allowed the plant to develop good vegetative growth that promoted adequate photosynthesis (Saidi et al., 2010). Irrespective of the time of pinching, there were no benefits of piecemeal harvesting. This study has demonstrated that the benefits of wholesome harvesting are enhanced when late pinching is carried out as a management practice.

Treatment combinations that had fertilizers, late pinching and wholesome harvesting produced taller plants, more number of leaves and branches per plant, fresh and dry leaf yields than all other treatment combinations. The combination that had 200 kg/ha DAP + late pinching + wholesome harvesting outperformed the other treatment combinations possibly due to immediate availability of plant available phosphate and ammonium that favoured vegetative growth and leaf yield. In addition, late pinching encouraged more vegetative growth as wholesome harvesting increased light interception, thereby enhancing photosynthesis and consequently vegetative growth. The findings of this study suggest that growers of cowpea are likely to benefit more from applying fertilizers, especially DAP at the rate of 200 kg/ha, late pinching and wholesome harvesting.

3.7.2 Effects of fertilizers and time of pinching on days to 50% flowering, pod load and grain yield

In both seasons, application of fertilizers accelerated time to 50% flowering in cowpea. Similar results were observed in cowpea (Uarrota, 2010) and soybean (Osman et al., 2011) in soybean. The results may be linked with the presence of nutrients (N and P) from both the fertilizer regimes, 200 kg/ha DAP readily released larger amounts of N and P nutrient levels than the other fertilizer regimes. Availability of phosphorous stimulated and enhanced bud development and set, seed formation and blooming as well as quickening plant maturity (Bender et al., 2015). In the first season, higher number of pods per plant and grain yield were recorded in no-fertilizer treatments. The highest number of pods per plant and grain yield were obtained in plants treated with 100 kg/ha DAP + 5 tons/ha manure in the second season. These results concur with results obtained by (Farhad et al., 2009; Kyei-Boahen et al., 2017) in soybean and cowpea, respectively, whereby grain yield in fertilizer and no-fertilizer treatments varied in two seasons of production. Chowdhury et al., (2000) showed that grain and pod yield in cowpea increased when nitrogen levels were increased up to a particular level beyond which, it resulted to reduced yields with increased vegetative growth. It could be possible, in the first season cowpea was able to obtain most of its nitrogen requirement through symbiotic fixation. Besides, the soils had high phosphorous contents (944.25 ppm). Addition of any external fertilizers provided luxurious growth at the expense of grain filling. Weather patterns particularly high precipitation in the second season may have provided conditions which encouraged leaching of N. Several researchers have reported that low soil P availability constrains nitrogen fixation and cowpea productivity (Singh et al., 2011; Patel et al., 2010). This is attributed to the crucial role that phosphorous plays in nodulation, nitrogen fixation and nutrient absorption through enhanced root development (Nziguheba et al., 2016).

Late pinched cowpea plants took significantly shorter time to flower. Previous research by Iftikhar et al., (2007) also reported that pinching resulted to delay in flowering. Late pinching may have allowed other side buds to develop into flowers unlike early pinching that had only one bud. The higher number of pods per plant from late pinched plants than early pinched plants could be due to the increased lateral branches and leaves from late pinched plants. This further translated to increased photosynthetic area that was essential for photosynthesis, pod development and grain filling. It could be possible, late pinching resulted to more branches that produced more flowers and pods thus, contributing to increased grain yield. Rathore et al, (2011) reported that pinching marigold reduced flower height, and increased number of flowering stems.

Irrespective of the time of pinching, plants that did not receive fertilizers in the first season had higher number of pods per plant and grain yield than those supplied with fertilizers. This is in line with (Chowdhury et al., 2000) finding on cowpea. It could be possible, in the first season, fertilizer application released more nutrients that encouraged luxurious growth and photosynthates portioning to more growing points at the expense of grain filling. Heavy precipitation experienced in the second season, may have caused leaching of soluble nutrients such as nitrogen in the control treatments. Thereby, allowing supplementation with fertilizers to increase cowpea yield. Singh et al., (2011) reported that addition of phosphatic fertilizers increased cowpea yield. In both seasons, time of pinching did not influence fertilizer application in pod load/plant and grain yield. Therefore, whether late pinched or early pinched cowpea pod load and grain yield was not affected.

3.8 Conclusion

From the results, applications of fertilizers increased vegetative growth and leaf yield and accelerated time to 50 % flowering in cowpea. Plants subjected to 200 kg/ha DAP significantly increased fresh and dry leaf yield relative to those treated with 100 kg/ha DAP + 5 t/ha manure and 10 t/ha manure treatments. Combinations of fertilizers with late pinching and wholesome harvesting was the best combination for increasing cowpea yields. Therefore, it is recommended that farmers supply their cowpea crops with 200 kg/ha DAP since it results to higher yields than 10 t/ha manure and 100 kg/ha DAP +5 t/ha manure and also adopt late pinching and wholesome harvesting practices.

CHAPTER FOUR: EFFECT OF FERTILIZER APPLICATION, TIME OF PINCHING AND HARVESTING METHOD ON GROWTH AND YIELD OF SPIDER PLANT

4.1 Abstract

Consumption of spider plant in Kenya (*Cleome gynandra* L.) is on the increase. Production of the vegetable is constrained by low leaf yields resulting from declining soil fertility, short vegetative phase and poor management practices among other factors. A study was conducted at Kabete Field Station, University of Nairobi, during 2015 short rains and 2016 long rains to assess the effect of fertilizers, time of pinching and harvesting method on growth and yield of spider plant. Fertilization options (no-fertilizer control, 200 kg/ha di-ammonium phosphate, 10 t/ha chicken manure and 100 kg/ha di-amonium phosphate + 5 t/ha chicken manure), pinching (early pinching and late pinching) and harvesting method (piecemeal and wholesome harvesting) treatments were evaluated in a randomized complete block design with a factorial arrangement. Data collected were plant height, canopy span, number of branches per, number of leaves per plant, fresh and dry leaf yields, days to 50% flowering, pod length and 1000 grain weight. Data were subjected to analysis of variance using Genstat software and means separated using the least significant difference test at $P \leq 0.05$. Fertilizer application, late pinching and wholesome harvesting significantly ($p<0.05$) increased plant height, canopy span, number of branches per plant, number of leaves per plant, marketable fresh leaf weight, leaf dry weight and number of days to 50% flowering. Application of a combination of 100 kg DAP/ha and 5 t/ha manure produced 1803.3 and 1740.9 kg/ha of fresh leaf yield in the first season and second season, respectively, which were significantly greater than leaf yields of treatments with 200 kg DAP/ha (1717.6, 1543.9 kg/ha), manure (1487.8, 1555.7 kg/ha) and control (281.5, 563.4 kg/ha). Late pinched plants resulted to leaf yields of 2032.5 and 2043.6 kg/ha in the first season and second season, respectively, while early pinching gave significantly lower leaf yields of 612.7 and 658.4 kg/ha, respectively. Wholesome harvested plants had significantly higher leaf yields of 2028.1 and 2006.5 kg/ha than piecemeal harvested plants which had 617.0 and 695.5 kg/ha in the first season and second season, respectively. In both seasons, 100 kg/ha DAP + 5 t/ha manure + late pinching, 100 kg/ha DAP + 5 t/ha manure + wholesome harvesting and late pinching + wholesome harvesting resulted to significantly ($p<0.05$) higher number of leaves per plant, fresh and dry leaf yields than other treatment combinations. Fertilizer application increased 1000 seed weight in the first season but had no significant effect in the second season. The results of this study show that growth and leaf yield of spider plant can be substantially increased by practicing fertilizer application, late pinching and wholesome harvesting.

Keywords: Di-ammonium phosphate, early, late, manure, piecemeal, wholesome.

4.2 Introduction

Interest in African indigenous leafy vegetables has recently increased due to the much sensitization of their health benefits (HCDA, 2012). The vegetables can withstand harsh climatic conditions and are highly tolerant to pest and diseases as compared to the exotic vegetables. Besides, AILVs have high nutritional components that are associated with health benefits (Prasad *et al.*, 2008). In Kenya, some of the African indigenous vegetables commonly utilized are; cowpea (*Vigna unguiculata* L.), spider plant (*Cleome gynandra* L.), African nightshade *(Solanum* spp), slenderleaf (*Crotalaria brevidens*), jute mallow (*Corchorus* spp), leaf amaranth (*Amaranthus* spp), (Chweya and Mnzava, 1997). *Cleome gynandra,* commonly known as spider plant, has a great potential for development as cultivated crops in rural areas in Kenya. For many years, spider plant grew as a volunteer crop in gardens. The leaves were domesticated and utilized as food. The great increase in demand of spider plant has led to increased leaf yield production in Kenya from 19,428 MT in 2012 to 21,507 MT in 2013 (HCDA, 2014). This trend was associated with increases in acreage under spider plant from 5,634 acres to 8,249 acres in 2013 (HCDA, 2014). The major producing counties are Kisii, Nyamira and Kisumu (HCDA, 2012).

Spider plant is an annual herb belonging to *Capparaceae* family (Chweya and Mnzava, 1997; USDA, 2013). The plant grows in a wide range of environmental conditions and has a high level of diversity with various phenotypic expressions (Wasonga et al., 2015). It does well at an altitude of 0-2400 meters above the sea level and requires temperatures of 18°C to 25°C. It grows well in a wide range of soils with a pH range of 5.5-7.0. The tender shoots and leaves of spider plant are consumed (Chweya and Mnzava, 1997). They contain antioxidants that are anti-cancer and anti-diabetes (Mibei et al., 2012). They contain nutrients like vitamin C, β-carotene, protein and minerals like; iron, calcium, phosphorus and magnesium (Mbugua *et al.*, 2011). Eating the vegetable has been reported to reduce dizzy spells in pregnant women and the length of time taken in labour and to regain normal health after childbirth (Kamatenesi et al., 2007). The plant has insects and pest repellant characteristics, which enables it to be used as an insecticide, anti-feedant and pest repellant (Malonza et al., 1992).

In spite of the very many benefits associated with spider plant, the leaf yield in Kenya is still in the range of 1-3 t/ha compared to the optimal range of 20-40 t/ha (Abukutsa-Onyango, 2003). This can be attributed to lack of adequate information regarding spider plant best production and management practices. For example, problems such as a short vegetative phase, early flowering behavior and lack of information on the recommended amounts and types of fertilizers to be used have not been adequately addressed. Continuous cultivation on arable land with low or no adoption of fertilizer use has often resulted to reduction in soil fertility thereby reducing crop yields (Ayoola and Makinde, 2007). Organic manure obtained from animals, can supply large quantities of major plant nutrients hence promote growth and leaf yields of spider plant (Materechera and Seeiso, 2012). Besides, animal manure provides organic acids that facilitate dissolution of soil nutrients and make them available for the plants (Husson, 2013). Animal manure is, however, not available in adequate quantities

(Tittonell and Giller, 2012). Chemical fertilizers have also been reported to increase leaf yields in spider plant (Mauyo et al., 2008; Ogweno et al., 2015) but they are costly and easily leached. Adoption of nutrient supplementation to spider plant production whereby chemical and organic fertilizers are combined can lead to increased spider plant yields and improved soil fertility.

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

4.3 Materials and methods

4.3.1 Site description

The field experiment was conducted at the University of Nairobi's Kabete Field station, Kenya for two seasons namely: March-July 2015 and October 2015-February 2016. The study site is situated on latitude 1° 15'S, longitude 36°44'E, and at an altitude of 1940 m above sea level (Somroek et al., 1982). The agro-ecological zone of the area is Upper Midland Zone three (Jaetzold and Schmidt, 1983). The area receives mean annual rainfall of 1006 mm with the long rains from early March to late May and short rains from October to December. The site has a mean annual temperature of 18^{o} C (Onyango et al., 2012). The soils are well-drained, dark red to darkish brown humic nitisols (Michieka, 1978). Soils were sampled before planting at 30 cm depth and chicken manure used in the study were analyzed for pH, carbon, nitrogen, potassium, sodium, calcium, magnesium and phosphorous in both seasons (Appendix 1). The rainfall and temperature data during the experimental period are shown in (Appendix 3).

4.3.2 Experimental design and treatments

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

4.4 Crop establishment and maintenance

Land preparation included deep ploughing using a tractor followed by harrowing. Treatment plots measuring 2 m by 1.5 m were established. The beds were then raised to 30 cm high with an inter plot spacing of 1 m and a 2 m path separating blocks. A guard row of 1 m from the treatment plots was also established.

Spider plant seeds sourced from Kenya Seed Company, Nairobi, were drilled along furrows separated at a spacing of 50 cm apart. A seed rate of approximately 54 seeds per m^2 was used to ensure maximum growth. The emerged spider plant seedlings were thinned 3 weeks after emergence to remain with 18 vigorously growing plants per plot at an intra-row spacing of 30 cm. Three hand weedings were applied at 3, 5 and 8 weeks after emergence to keep the plants relatively weed free. Scouting for pests such as aphids, white flies and spider mites was done. Since there were no incidence of pests, no pest management practices were carried out.

4.5 Data collection

Data collected included: plant height, number of branches per plant, days to 50% flowering, leaf chlorophyll content, number of edible leaves, canopy span, fresh leaf yield, dry leaf yield, pod load per plant, pod length and 1000 seed weight.

Six plants in each plot from the inner rows were tagged for data collection. The outer rows were excluded in data collection to avoid border effects. From these plants, plant height, number of edible leaves per plant, number of branches per plant, canopy span and leaf chlorophyll content were measured from five weeks after emergence and weekly thereafter till the ninth week.

Plant height was determined using a meter rule by measuring the distance between soil surface and the tip of the central shoot in centimeters. Canopy span was determined using a meter rule by measuring the widest span of plant canopy. The number of branches was obtained through physical counting. Number of edible leaves was determined by counting the fresh leaves harvested that were consumable as a vegetable. The fourth youngest leaf from each of the six plants was used to determine chlorophyll content. The reading were obtained using Minolta SPAD-502 chlorophyll meter. The data obtained from the sampled plants were averaged and recorded as representative of plot population. Days to 50% flowering were the number of days taken for half of the six tagged plants to flower in each plot.

Fresh leaf yield in this research included all the weight of edible leaves harvested and measured immediately using a weighing balance. The harvesting was done at weekly intervals starting at 5 weeks after emergence from a set of six plants per treatment for piecemeal harvested plants till the fifth harvest was obtained. For wholesome harvesting it was done thrice. Dry leaf yield was obtained from the six plants that were harvested for fresh leaf yield by oven drying the leaves at 70^0 C for 72 hours to a constant weight. Pod load was determined by averaging the number of pods from the six tagged plants. It was obtained through physical counting of the number of mature dry harvested pods. The lengths of ten harvested pods were measured using a string and a ruler. Seeds from the six sampled plants were sun dried, threshed and winnowed, 1000 seeds in each plot selected and weighed using a weighing balance.

4.6 Data analysis

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

4.7 Results

4.7.1 Main effects of fertilizers, time of pinching and harvesting method on spider plant height, canopy span, branches per plant, leaf number, fresh leaf yield and dry leaf yield

Fertilizers, time of pinching and harvesting method had significant effects ($P \leq 0.05$) on plant height, canopy span, branches per plant, leaf number, fresh leaf yield and dry leaf yield in both seasons (Tables 4.1 and 4.2).

In both seasons, spider plant treated with fertilizers had significantly ($P \leq 0.05$) taller plants, wider canopy spans and higher number of branches per plant, number of leaves per plant, fresh leaf yield and dry leaf yield than plants that did not receive any fertilizer (Tables 4.1 and 4.2). In both seasons, plants treated with 100 kg/ha DAP + 5 t/ha chicken manure significantly ($P \leq 0.05$) outperformed those treated with 10 t/ha manure and 200 kg/ha DAP in all the measured attributes. In the first season, plants treated with 200 kg/ha DAP out-performed those treated with 10 t/ha manure in plant height, canopy span, fresh leaf yield and dry leaf yield while in the second season, no significant ($P \leq 0.05$) differences were noted between 200 kg/ha DAP and 10 t/ha manure in all the measured plant attributes except number of branches.

In both seasons, late pinched plants were significantly ($P \leq 0.05$) taller with wider canopy spans and higher number of branches per plant, number of leaves per plant, fresh and dry leaf yields than early pinched plants. For example, late pinched plants had at least three times more fresh leaf yield than early pinched plants in both seasons (Tables 4.1 and 4.2). In both seasons, piecemeal harvested plants had significantly ($P \leq 0.05$) taller plants and wider canopy spans than wholesome harvested plants. In contrast, the latter had significantly higher number of leaves and branches per plant, fresh and dry leaf yields (Tables 4.1 and 4.2).

Table 4. 1: Main effects of fertilizers, time of pinching and harvesting method on spider plant growth and vegetative yield during 2015 short rains at Kabete Field Station

	PH (cm)	CS (cm)	B/P	L.No	FLY(Kg/ha)	DLY (Kg/ha)
Fertilizers						
Control	6.3	9.0	1.0	3.7	281.5	41.4
200 kg/ha DAP	49.0	36.5	8.0	26.5	1717.6	252.3
100 kg/ha DAP + 5 t/ha M	57.0	41.3	9.0	32.0	1803.3	264.5
10 t/ha Manure	43.3	34.1	8.0	25.3	1487.8	218.4
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	5.3	1.9	0.8	1.9	48.2	6.9
Pinching						
Early pinching	32.2	28.1	5.0	14.2	612.7	86.1
Late pinching	45.7	32.4	8.0	29.7	2032.5	302.0
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	3.7	1.3	0.5	1.3	34.1	4.9
Harvesting						
Piecemeal H	44.1	31.3	7.0	15.0	617.0	87.9
Wholesome H	33.8	29.2	8.0	28.7	2028.1	300.4
P-value	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	3.7	1.3	0.5	1.3	34.1	4.9

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

Table 4. 2: Main effects of fertilizers, time of pinching and harvesting method on spider plant growth and vegetative yield during 2015 short rains at Kabete Field Station

	P.H (cm)	C.S (cm)	B/P	L.No.	FLY(Kg/ha)	DLY (Kg/ha)
Fertilizers						
Control	16.4	20.1	1.9	13.5	563.4	80.7
200 kg/ha DAP	43.2	35.3	5.6	32.5	1543.9	219.1
100 kg/ha DAP + 5 tons/ha M	53.4	40.8	6.6	39.6	1740.9	246.1
10 tons/ha Manure	43.3	36.6	6.2	35.5	1555.7	220.6
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	6.7	2.5	0.5	3.6	71.2	9.8
Pinching						
Early pinching	30.9	30.6	3.9	18.4	658.4	88.2
Late pinching	47.3	35.8	6.3	42.2	2043.6	295.0
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	4.7	1.8	0.4	2.6	50.4	6.9
Harvesting						
Piecemeal H	46.7	35.6	5.7	20.2	695.5	92.5
Wholesome H	31.5	31.8	4.5	40.3	2006.5	290.7
P-value	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
$LSD_{(p=0.05)}$	4.7	1.8	0.4	2.6	50.4	6.9

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

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

In both seasons, the interaction between fertilizers and time of pinching had significant ($P \leq 0.05$) effects on plant height, canopy span, number of leaves and branches per plant, fresh leaf yield and dry leaf yield (Table 4.3).

All plants supplied with fertilizer had significantly ($P \leq 0.05$) taller plants, wider canopy spans and higher number of leaves and branches per plant, fresh and dry leaf yields than plants that did not receive fertilizer, irrespective of whether they were early pinched or late pinched (Table 4.3).

Table 4. 3: Interactive effects of fertilizers and time of pinching on growth and vegetative yield of spider plant during 2014 short rains and 2015 long rains at Kabete Field station

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

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

In both seasons, late pinched plants treated with fertilizers significantly increased all the measured plant attributes. For instance, in both seasons, plants that received 100 kg/ha DAP + 5 t/ha manure + late pinching had significantly higher records of plant height, canopy span, number of branches per plant, number of leaves per plant, fresh and dry leaf yields than the other treatment combinations (Tables 4.3).

In the first season, 100 kg/ha DAP + 5 t/ha manure + late pinching and 200 kg/ha DAP + late pinching were not significantly different in fresh and dry leaf yields. Besides, in the first season, 200 kg/ha DAP + late pinching had significantly ($P \leq 0.05$) higher number of leaves per plant than 10 t/ha manure + late pinching, while in the second season, 10 t/ha manure treated + late pinched plants significantly (P≤0.05) out-performed late pinched plants treated with 200 kg/ha DAP in number of leaves and canopy span (Table 4.3). No-fertilizers + late pinched spider plants and 100 kg/ha DAP + 5 t/ha manure treated + early pinched plants significantly (P≤0.05) out-yielded early pinched plants supplied with 10 t/ha manure, 200 kg/ha DAP and no fertilizers (control) in fresh leaf yield, respectively (Table 4.3). Similar patterns were observed in dry leaf yields.

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

Interaction of fertilizers and harvesting methods had significant effects (P≤0.05) on number of edible leaves, fresh and dry leaf yields in both seasons, plant height and number of branches per plant in the first season. In both seasons, no significant interaction was observed on canopy span (Table 4.4).

In the first season, fertilizer treated + piecemeal harvested plants were significantly (P≤0.05) taller and had more number of branches per plant than wholesome harvested plants treated with fertilizers (Table 4.4). Plants subjected to 100 kg/ha DAP + 5t/ha manure + piecemeal harvesting resulted to significantly (P≤0.05) taller plants than plants supplied with 200 kg/ha DAP + piecemeal harvesting which, in turn, had taller plants than plants supplied with 10 t/ha manure + piecemeal harvesting (Table 4.4).

Under the control treatments, no significant differences were noted in plant height and number of branches per plant for the piecemeal and wholesome harvested plants. In wholesome harvested plants, fertilizer application significantly (P≤0.05) increased the number of leaves, fresh and dry leaf yields in both seasons (Table 4.4).

Table 4. 4: Interactive effects of fertilizers and harvesting method on growth and vegetative yield of spider plant during 2015 short and long rains at Kabete Field Station

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

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

In both seasons, wholesome harvested plants that received 100 kg/ha DAP + 5 t/ha manure had significantly higher number of leaves, fresh and dry leaf yields than wholesome harvested plants treated with 200 kg/ha DAP which, in turn, outperformed wholesome harvested plants that received 10 t/ha manure.

In the first season, there was no significant difference in fresh and dry leaf yields between wholesome harvested plants that were subjected to 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha. However, in the second season, no significant difference was observed in fresh and dry leaf yields between wholesome harvested plants subjected to either 200 kg/ha DAP and 10 t/ha manure treatments (Table 4.4).

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

The interaction between time of pinching and harvesting method had significant ($P<0.05$) effects in plant height, canopy span, number of leaves and branches per plant, fresh and dry leaf yields (Table 4.5).

In early pinched plants, piecemeal harvesting significantly ($P<0.05$) increased plant heights, canopy spans, number of leaves and branches per plant and fresh and dry leaf yields relative to wholesome harvesting. In the first season, there was no significant difference in fresh leaf yield between early pinched plants, which were either piecemeal harvested or wholesome harvested (Table 4.5). In late pinched plants, piecemeal harvesting significantly ($P<0.05$) reduced canopy span, number of leaves per plant, fresh and dry leaf yields. In wholesome harvested plants, late pinching significantly increased canopy span, number of leaves per plant, fresh and dry leaf yields. In both seasons, late pinching + wholesome harvesting resulted to significantly the highest number of leaves per plant, fresh and dry leaf yields as compared to the other treatment combinations (Table 4.5).

Table 4. 5: Interactive effects of time of pinching and harvesting method on growth and vegetative yield of spider plant during 2015 short and long rains at Kabete Field Station

	PH (cm)	CS (cm)	B/P	LNo	FLY(kg/ha)	DLY (kg/ha)
First season (2015 short rains)						
Early pinching + P	42.1	32.9	6.0	15.0	633.1	90.1
Early pinching + W	22.2	23.6	3.0	13.2	592.2	82.1
Late pinching + P	46.1	30.1	8.0	15.0	601.0	85.7
Late pinching + W	45.4	34.7	8.0	44.2	3464.0	518.7
P-value (P × H)	<.001	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	7.5	1.9	0.8	1.9	48.2	6.9
Second season (2015 long rains)						
Early pinching + P	45.3	36.9	5.0	20.2	697.8	92.9
Early pinching + W	16.4	24.3	2.7	16.6	619.0	83.5
Late pinching + P	48.1	32.2	6.3	20.3	693.1	92.2
Late pinching + W	46.5	39.4	6.2	64.1	3394.0	497.9
P-value (P × H)	<.001	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	6.7	2.5	0.5	3.6	71.2	9.8

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

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

The interactions among fertilizers, time of pinching and harvesting method were significant ($P \leq 0.05$) with respect to plant height, canopy span, branches per plant, number of edible leaves per plant, fresh and dry leaf yields for all seasons except plant height and number of branches in the second season (Tables 4.6 and 4.7).

Table 4. 6: Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of spider plant during 2015 short and long rains at Kabete Field Station

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

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

Table 4. 7: Interactive effects of fertilizers, time of pinching and harvesting method on growth and vegetative yield of spider plant during 2015 short and long rains at Kabete Field Station

	C.S (cm)	L.No.	FLY(Kg/ha)	DLY (Kg/ha)
Second season (2015 long rains)				
Control + EP + P	27.2	7.9	277.0	36.8
Control + LP + P	17.4	8.0	224.5	29.9
Control + EP + W	10.5	5.9	97.9	13.4
Control + LP + W	25.4	32.2	1654.0	242.6
200 kg/ha DAP + EP + P	43.3	24.9	829.0	110.2
200 kg/ha DAP + LP + P	29.6	20.0	704.0	93.7
200 kg/ha DAP + EP + W	27.5	19.0	711.3	95.9
200 kg/ha DAP + LP + W	40.9	66.3	3931.4	576.7
100 kg/ha DAP + 5 t/ha M + EP + P	42.9	26.5	960.2	127.8
100 kg/ha DAP + 5 t/ha M + LP + P	42.2	29.1	994.0	132.1
100 kg/ha DAP + 5 t/ha M + EP + W	32.5	20.6	876.4	118.1
100 kg/ha DAP + 5 t/ha M + LP + W	45.6	82.3	4133.0	606.3
10 t/ha manure + EP + P	34.4	21.6	725.0	96.6
10 t/ha manure + LP + P	39.6	24.0	849.9	113.1
10 t/ha manure + EP + W	26.7	20.7	790.3	106.7
10 t/ha manure + LP + W	45.7	75.7	3857.8	565.9
P-value (F×P×H)	0.011	<.001	<.001	<.001
$LSD_{(p=0.05)}$	5.0	7.3	142.5	19.6

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

In the first season, no significant difference was observed in plant height, canopy span and number of branches per plant among the plants grown in no fertilizer plots irrespective of time of pinching and harvesting method. However, in both seasons, plants that received no-fertilizers + late pinching + wholesome harvesting had significantly the highest number of leaves per plant, fresh and dry leaf yields (Tables 4.6 and 4.7). Plants that received a combination of fertilizer treatments, late pinching and wholesome harvesting had significantly (P≤0.05) taller plants, wider canopy spans, number of leaves and branches per plant, fresh and dry leaf yields than the other treatment combinations. In both seasons, plants subjected to 100 kg/ha DAP + 5t/ha manure + late pinching + wholesome harvesting significantly ($P \leq 0.05$) out-yielded the other treatments combinations in canopy span, number of leaves per plant, fresh and dry leaf yields (Tables 4.6 and 4.7).

In the second season, plants subjected to 100 kg/ha DAP + 5 t/ha manure + late pinching + wholesome harvesting and 10 t/ha manure + late pinching + wholesome harvesting had significantly ($P \leq 0.05$) similar number of leaves per plant but significantly out-performed plants subjected to 200 kg/ha DAP + late pinching + wholesome harvesting (Table 4.7).

4.7.6 Main effects of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain yield

Significant ($P \leq 0.05$) effects of fertilizers and time of pinching on days to 50% flowering were observed in both seasons except pod length and 1000 seed weight which were only observed in the second season (Table 4.8).

Fertilizer applications significantly accelerated time to 50% flowering in both seasons. Plants that received 200 kg/ha DAP took significantly fewer days to flower than plants that were treated with 10 t/ha manure. In the first season, there was no significant difference in pod length and 1000 seed weight between plots that received 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure (Table 4.8). Similar observations were made in the second season (Table 4.8). Late pinched plants took significantly ($P \leq 0.05$) longer time to reach 50% flowering than early pinched plants in both seasons (Tables 4.8). In the first season, there was no significant effect of pinching on pod length and 1000 grain weight, while in the second season, early pinching resulted to significantly longer pods than late pinching (Table 4.8).

Table 4. 8: Main effects of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain yield of spider plant during 2015 short and long rains at Kabete Field Station

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

NS=not significant

4.7.7 Interactive effects of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain yield

The interaction of fertilizers and time of pinching had significant ($P \leq 0.05$) effect on only days to 50% flowering in season one (Table 4.9). Under no fertilizer plots, no differences were noted between early and late pinching in days to 50% flowering. Under all fertilizer treated plots, late pinching significantly delayed time to 50% flowering.

Table 4. 9: Interactive effect of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain yield of spider plant during 2015 short and long rains at Kabete Field Station

Second season (2015 long rains)

	Days to 50% Flowering	Pod length (cm)	1000 grain weight(g)
Control + EP	64.0	11.8	1.4
Control + LP	64.3	12.1	1.4
200 kg/ha DAP + EP	48.5	16.4	1.9
200 kg/ha DAP + LP	51.2	16.1	2.0
100 kg/ha DAP + 5 t/ha M + EP	48.8	16.3	2.1
100 kg/ha DAP-5 t/ha M + LP	53.2	16.0	1.9
10 t/ha M + EP	49.0	15.8	1.9
10 t/ha M + LP	53.7	15.0	1.3
P-value	<.001	0.727	0.195
$LSD_{(p=0.05)}$	0.5	NS	NS

EP=early pinching, LP=late pinching, M=manure, NS=not significant

In early pinched plants, fertilizer application significantly reduced number of days to 50% flowering. All fertilizer treated plants that were early pinched were statistically similar in days to 50% flowering. Plants that were late pinched and subjected to 10t/ha manure took significantly longer time to flower than late pinched plants, subjected to 100 kg/ha DAP + 5 t/ha manure which, in turn, took a longer time than late pinched plants subjected to 200 kg/ha DAP (Table 4.9).

4.8 Discussion

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

Plants that were supplied with inorganic fertilizers showed evidence of increased growth and leaf yields. These findings are in agreement with those of Azeez et al., (2010) who found higher yields in spider plant that received inorganic fertilizer supplementation. Research findings by Mavengahama, (2013), Ogweno, (2015) and Mauyo et al., (2008) also reported an increase in growth parameters and yields of spider plant with applications of inorganic fertilizers. It is apparent that DAP encouraged growth of spider plant through provision of readily available inorganic N and P, which stimulated root elongation and proliferation together with uptake of other plant nutrients (Ndor et al., 2012). Availability of N also encouraged stem elongation which correlated to more vegetative growth, thereby leading to increased yields (Kujeke et al., 2017). According to Chweya and Mnzava (1997); Aguyoh et al., (2012) and Ondieki et al., (2011) manure application increased growth parameters and yield of spider plant. The increase in yields may be due to the effect of chicken manure in improving soil aggregation, soil aeration, water holding capacity and good soil conditions for the spider plant root growth. Furthermore, chicken manure may have ensured slow and steady supply of nutrients throughout the growing period.

Application of 100 kg/ha DAP + 5 t/ha chicken manure outperformed all the other fertilizer treatments in plant height, canopy span, number of branches per plant and leaf yields. These results are consistent with those reported by Akanbi and Tugon, (2002) and Alemu and Bayu, (2005) who found an increase in growth parameters and yields of amaranth plant treated with combinations of manure and inorganic fertilizer as compared to those with sole applications. Similar observations were made by Fusire, (2008) on spider plant. Love, (2014) reported higher number of flowers per plant, individual plant canopy size, plant height and 1000 seed weight in grain amaranth supplied with both cow dung manure and calcium ammonium nitrate. The increase in growth attributes and yields may be attributed to the greater benefits of manure such as slow and steady supply of nutrients, improvement of soil structure and water holding capacity, coupled to high and fast nutrient release to the crop by DAP.

Plants that were early pinched had shorter plants, lower canopy span, number leaves and branches per plant and fresh and dry leaf yields than late pinched plants. These observations are in agreement with the findings of Wangolo et al., (2015) and Ogweno et al., (2015) who stated that late pinching increased the number of branches, number of leaves and, consequently, fresh and dry leaf yields in spider plant. Similar observations were reported earlier in black night shade and *Solanum nigrum* (Mwafusi, 1992; Maumba, 1993). When plants begin to bolt, resources are re-allocated to the flowers and fruiting bodies, drawing energy away from vegetative growth (Kriedemann et al., 2010). By removing this resource sink through late pinching, energy and resources continue to supply leaves and shoots. This extended vegetative stage, resulting in increased plant growth parameters and vegetative yields. Late pinched plants outperformed early pinched plants in the growth attributes probably because of higher sinks in the late pinched plants than the early pinched ones, that encouraged higher vegetative growth leading to higher yields.

Piecemeal harvested plants were taller and had higher canopy span and branches per plant than wholesome harvested plants. These observations are in line with those of Saidi et al., (2007) and Barimavandi et al., (2010) who found that frequent leaf cutting resulted to more vegetative growth in cowpea. This could have resulted from redistribution of auxins at the point where leaves were plucked, stimulating the growth of more buds that later developed to branches and leaves resulting to increased plant height, canopy span and branches per plant. Contrary to the earlier findings (Saidi et al., 2007; Barimavandi et al., 2010), this study showed significantly higher number of leaves and fresh and dry leaf yields from wholesome harvested plants than piecemeal harvested plants. Similar observations had been made in other crops whereby frequent leaf harvesting resulted to lower fresh leaf yields than those harvested once (Baufeld and Freir, 1991 and Salisbury and Ross, 1991). Materechera and Seeiso, (2014) reported low yields in amaranth leaves that were frequently harvested as compared to those that were less frequently harvested. The results of this study could be probably due to reduction in photosynthetic capacity caused by heavy defoliation in piecemeal harvested plants that contributed to low light interception due to reduced photosynthetic area. It could also be due to the diversion of assimilates in healing wounds and developing buds for the frequently harvested plants at the expense of proliferating more leaves (Alleman, 1996).

Fertilizers treatments and time of pinching interaction effects were significant for plant height, number of leaves and branches per plant and fresh and dry leaf yields. A combination of 100 kg/ha DAP + 5t/ha manure and late pinching gave the highest values of these measured plant attributes as compared to the other treatments. Ogweno et al., (2015) reported that a combination of fertilizers and deflowering significantly enhanced spider plant growth and yield attributes. Benefits of fertilizer application in spider plant production are more pronounced when late pinching is carried out because of efficient utilization of the sinks that results to improved yields.

The interaction of fertilizers and methods of harvesting significantly affected the number of leaves per plant, fresh leaf yield and dry leaf yield. A combination of 100 kg/ha DAP + 5 t/ha manure + wholesome harvesting had higher values of the measured plant attributes than the other treatment combinations. This is possibly due to synergistic effects of inorganic fertilizers and organic fertilizers which increased soil available macro- and micro- nutrients that are readily available for plant uptake thus promoting vegetative growth and yields (Singh et al., 2006). To increase spider plant production, farmers should practice wholesome harvesting and use combinations of inorganic and organic fertilizers.

A combination of late pinching and wholesome harvesting significantly increased plant height, canopy span, number of branches and leaves per plant and leaf yields. This could be probably due to re-allocation of more resources in the tips of late pinched plants than early pinched plants that stimulated more vegetative growth (Kriedemann et al., 2010). Wholesome harvesting on the other hand, increased light interception and allowed the plant to develop good vegetative growth that promoted adequate photosynthetic cells (Saidi et al., 2010). Irrespective of the time of pinching, piecemeal harvesting did not influence spider plant growth and yield. Similarly, wholesome harvesting and early pinching reduced number of leaves per plant and leaf yields of spider plant. Spider plant producers should therefore adopt late pinching and wholesome harvesting as a management practice to increase leaf yields.

Combination of 100 kg/ha DAP + 5 t/ha manure + late pinching and wholesome harvesting resulted to higher number of leaves per plant, fresh leaf yield and dry leaf yield than all the other treatment combinations. This could be possibly due to the synergistic effects of combined organic and inorganic fertilizers (Alemu and Bayu, 2005), and increased photosynthetic area due to wholesome harvesting and late pinching which may have led to increased photosynthesis and, consequently, plant growth and final leaf yield (Materechera et al., 2013). Farmers may need to adopt the use of combined organic and inorganic fertilizers, late pinching and wholesome harvesting in production of spider plant to increase harvestable vegetable yield.

4.8.2 Effects of fertilizers and time of pinching on days to 50% flowering, pod length and 1000 grain weight

Fertilizer application reduced the number of days to 50% flowering and increased pod length and 1000-grain weight. Reduction of number of days to 50% flowering were observed by Uarrota (2010) in cowpea, Thriveni et al., (2015) in bitter gourd and Anjanappa et al., (2012) in cucumber. Increases in pod length and grain weight have been reported by Singh et al., (2011) in french beans and Love, (2014) in grain amaranth. These observations could be attributed to the availability of nutrients from both organic and inorganic fertilizers which stimulated both vegetative and reproductive growth. Incorporation of manure ensured slow and steady release of nutrients while the inorganic fertilizers readily availed the nutrients. Phosphorous is a key nutrient in plants involved in stimulating and enhancing bud development and set, seed formation and blooming as well as quickening plant maturity (Bender et al., 2015). Nitrogen increases shoot dry matter, pod load and elongation. In addition, phosphorous release from the fertilizers encouraged extensive and deep root system that may have played a significant role in nutrient absorption, photosynthesis, pod development and elongation (Rathi and Singh, 1976).

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

4.9 Conclusion

Spider plant supplied with 10 t/ha chicken manure or 200 kg/ha DAP had a more vigorous growth, higher leaf yields, enhanced flowering, longer pods and higher 1000 grain weight than most of the other fertilizer treatments. Generally, combined application of 100 kg/ha DAP + 5 t/ha manure was the best combination that promoted growth and vegetative yield. Late pinching and wholesome harvesting contributed to significant increase in the growth parameters and vegetative yield relative to early pinching and piecemeal harvesting respectively. Early pinching accelerated time taken to reach 50 % flowering in spider plant. The study revealed that combinations of fertilizers with late pinching and wholesome harvesting was the best combinations for increasing yields in spider plant. Specifically, applications of combined inorganic fertilizer (100 kg/ha DAP) and organic fertilizer (5 t/ha chicken manure) resulted in the highest spider plant yields.

CHAPTER FIVE: EFFECT OF FERTILIZERS, TIME OF PINCHING AND HARVESTING METHOD ON NUTRITIONAL QUALITY OF COWPEA (*Vigna unguiculata* L.) AND SPIDER PLANT (*Cleome gynandra* L.)

5.1 Abstract

African indigenous leafy vegetables have the potential to contribute to human diets and alleviate malnutrition but their nutritional value is influenced by agronomic management practices. Adequate fertilization, timely pinching and appropriate harvesting methods can enhance high nutritional quality. A study was conducted to determine the effect of fertilizers, time of pinching and harvesting method on nutritional quality of cowpea (*Vigna unguiculata* L.) and spider plant (*Cleome gynandra* L.). Field trials were set up at Kabete Field Station, University of Nairobi during 2014 short rains and 2015 long rains. The treatments comprised: fertilizer levels (no-fertilizer control, 200 kg/ha di-ammonium phosphate, 10 t/ha chicken manure and 100 kg/ha di-amonium phosphate + 5 t/ha chicken manure), time of pinching (early and late pinching) and harvesting method (piecemeal and wholesome harvesting). Evaluations of the treatments were done using a randomized complete block design with a factorial arrangement. Data collected included β carotene, vitamin C, zinc, iron, calcium and magnesium content. The collected data were subjected to analysis of variance using Genstat software and means separated using least significant difference at $P \leq 0.05$. Incorporation of diammonium phosphate and manure either singly or in combination significantly ($P \leq 0.05$) increased the content of β carotene, vitamin C, zinc, calcium and magnesium but significantly ($P \leq 0.05$) reduced iron content in both crops. Late pinching produced significantly higher vitamin C, calcium, magnesium and iron content than early pinching but significantly reduced zinc content in both cowpea and spider plant. Wholesome harvested cowpea and spider plants had significantly higher β carotene, vitamin C, zinc, calcium and magnesium than piecemeal harvested plants. Manure application and late pinching significantly increased vitamin C levels, while a combination of 100 kg/ha DAP + 5 t/ha manure + late pinching resulted to the highest Ca and Mg contents. A combination of 10 t/ha manure + wholesome harvesting resulted to the highest vitamin C levels while a combination of 100 kg/ha DAP + 5 t/ha manure + wholesome harvesting significantly increased Ca and Mg contents. A combination of early pinching + wholesome harvesting resulted to the highest amounts of zinc levels in both crops, while a combination of late pinching + wholesome harvesting significantly increased vitamin C, Ca and Mg contents. Therefore, use of combined organic and inorganic fertilizers, late pinching and wholesome harvesting practices improve the nutritional quality of cowpea and spider plant.

Keywords: Di ammonium phosphate, early, late, manure, piecemeal, wholesome

5.2 Introduction

Food insecurity and malnutrition are issues of concern in Kenya and other countries in Nilo-Saharan Africa (Kumar et al., 2014). Close to one billion people in the world are food insecure (Burchi et al., 2011). This is based on caloric deficits, however, these people are also deficient in some of the micronutrients. Micronutrient deficiency also referred to as 'hidden hunger' affects close 2 billion people worldwide (WHO, 2013). Majority of these people exist in African continent and Indian sub-continent (Muthayya et al., 2013). Over one third of all children's deaths in the world is estimated to be contributed by malnutrition (Bain et al., 2013). In 2013, approximately 3 million children below the age of five years died in the WHO African region due to malnutrition (WHO, 2013). In Kenya, low nutrition uptake contributes to an estimated one third of all deaths of children under five years (Maternal and Child Health Kenya, 2016).

In Kenya over 60% of the rural population lives below the poverty line, resulting in, low access to basic necessities (World Bank Kenya Overview, 2014). Inadequate food and low intake of nutrients are major causes of human malnutrition (WHO, 2010) for the poor, pregnant women, lactating mothers, children, elderly people, people living with HIV/AIDS and the sick (MDG, 2005). These groups are not able to access adequate amounts of nutrients from animal sources due to their scarcity and high cost (Ghaly and Alkoaik, 2010). The spread of drought and hunger across Africa, has led to a huge focus being turned on increasing yields of cereal crops like rice, wheat and maize. The importance of these crops in reducing food security cannot be overlooked, though they cannot be entirely relied upon to solve the malnutrition problem. In Kenya, areas characterized with frequent droughts, high level of poverty and food insecurity, also experience high levels of malnutrition (KDHS, 2009).

Most Kenyan rural population is not able to access adequate nutritious foods. This is because, the rise in prices of foods, which causes consumers to continue feeding on staple foods while reducing their intake on non-staple foods despite the latter being more nutritious (Bouis et al., 2011). Minerals (calcium, iron, cupper, iodine, magnesium, selenium and zinc) and vitamin absorption and intake can be too low to sustain a healthy life and promote development, hence causes “hidden hunger”, (FAO, 2014). The factors that contribute to micronutrient deficiency include poor diets, diseases, infections or parasites and increased demand for micronutrient needs during certain life stages such as pregnancy and lactation (FAO, 2014).

Several strategies can be used to combat hidden hunger. First, supplementation with vitamins and minerals is a key strategy, though its implementation varies from year to year in the priority countries depending on donor funding (Tan-Torres et al., 2005). Another strategy is food fortification. However, this strategy is only limited to urban dwellers and those with high purchasing power who can buy commercial processed and fortified foods (Anderson et al., 2012). Third, food bio-fortification which involves breeding food crops conventionally and through genetic modification with high micronutrient density. Examples include, orange flesh sweet potato with high β-carotene (Saltzman et al. 2013), and also through agronomic management practices like application of organic fertilizers (Adeyemi et al., 2012). Fourth, dietary diversification which ensures a healthy diet that contains a combination of macronutrients and essential micronutrients together with dietary fibre. These strategies should be considered complementary with the aim of increasing micronutrient uptake (Thompson and Amaroso, 2011). Micronutrient deficiencies can be alleviated through dietary diversification such as production and consumption of vegetables among the poor. This has been indicated as a sustainable and affordable method of increasing intake of micronutrients, (Thompson and Amaroso, 2011).

African indigenous leafy vegetables (AILVs) are well documented for their great importance. They provide millions of Kenyans with essential nutrition components such as vitamins, minerals, crude protein, anti-oxidants and anti-cancer factors needed to maintain good health and fight off infections (Abukutsa-Onyango, 2003), besides, they are easily accessible and inexpensive (ICRAF, 2004). African indigenous leafy vegetables have a shorter growing period than staple crops, they have less risk to drought, maximize scarce water and soil nutrients supplies (Vans Rensburg et al., 2007; Modi et al., 2013; Chivenge et al., 2015). They can withstand pest and diseases infestation as compared to exotic vegetables (DAFF, 2008). They can also be used to earn income when sold to consumers (Smith and Eyzaguire, 2007). This necessitates the need to explore AILVs to overcome the nutritional disorders. Nutritional studies on spider plant have shown that it contains higher levels of β- carotene, vitamin C, protein, Fe, Ca and Mg than exotic vegetables like cabbages (Abukutsa-Onyango, 2003). The compounds from spider plant leaves are also capable of alleviating a number of non-communicable diseases (e.g hypertension, diabetes, cancer and rheumatism), boosting immunity and retarding ageing (Sankaranarayanan et al., 2010). Cowpea, on the other hand, is also very nutritious. The grain contains about 24% crude protein and 53% carbohydrate (FAO, 2012). The green leaves and green pods contain proteins and essential minerals such as Ca, Mg, Zn, Mn, Cu and Se (FAO/WHO, 2004). The rest of the cowpea plant, after harvesting, can be used as a livestock fodder (Abebe et al., 2005). Cowpea is also able to fix up to 80% nitrogen for its own growth demand (Asiwe et al., 2009) and make available about 60-70 kg ha^{-1} nitrogen for subsequent crops in a rotation or intercropped system (Aikins and Afuakwa, 2008).

The use of fertilizers to increase production of field crops such as maize and rice has been widely adopted by most farmers in Kenya. The AILV farmers still continue to achieve low yields of 1-3 tons per hectare, which is still below the optimal levels of 20-40 t/ha (Abukusta-Onyango, 2003). This can be attributed to problems such as short vegetative phase and lack of recommendations on the amounts and types of fertilizers to be used for optimal yields (Abukutsa-Onyango, 2010). Besides, the impact of fertilizers on nutritional quality of AILVs has received little attention. Many other factors like genotypic differences, soil condition, crop handling procedures and stage of crop growth have been reported to affect nutritional quality of crops (Kader, 2002). Beverly et al., (1993) reported that early harvested cabbages had higher ascorbic acid concentration than late harvested cabbages. In crops like strawberries, harvest methods and handling operations have been shown to influence vitamin C content (Ezell et al., 1947). Increased nitrogen application in kales have resulted in reduced ascorbic acid (Hornick and Parr, 1989). However, there is limited information available on how fertilizers and pre-harvest practices like pinching, different harvesting methods affect the nutritional composition of AILVs which have the potential to combat 'hidden hunger' and increase biodiversity in Kenya. An study was conducted to evaluate the influence of fertilizers, time of pinching and harvesting method on nutritional quality of cowpea and spider plant.

5.3 Materials and methods

5.3.1 Site description

A field experiment was carried out at Kabete Field Station, University of Nairobi. The study was conducted in a span of two seasons; October 2014-February 2015 and October 2015-February 2016. The study site is situated on a latitude of 1° 15’S, 36°44’ E, and at an altitude of 1940 m above sea level (Sombroek et al., 1982). The agro-ecological zone of the area is Upper Midland Zone three (Jaetzold and Schmidt, 1983). The rainfall distribution is bimodal with long rains from early March to late May and short rains from October to December. Mean annual maximum and minimum temperatures are 23^0 C and 13^0 C, respectively (Siderus, 1976). The mean annual rainfall is about 1000 mm with a range of 700-1500 mm per annum (Mburu, 1996). Kabete soils are humic nitisols according to the FAO-UNESCO system (FAO, 1990). The soils are deep and are well drained. Soil samples were obtained from the experimental plots before planting to determine the soil nutrient status at the time the experiment commenced. The soil samples together with chicken manure were analyzed for total nitrogen, available phosphorous, pH, organic carbon, and exchangeable cations (Appendix 1). The weather data during the experimental period are shown in (Appendix 4).

5.3.2 Experimental design and treatments

The study was a 4 x 2 x 2 factorial experiment laid out in a randomized complete block design with three replications. Cowpea and spider plant experiments were carried out independently. Three factors were studied in each of the crops: (i) fertilizers regimes, (ii) time of pinching and (iii) harvesting method. Fertilizer regimes were: 200 kg/ha of di-ammonuim phosphate (DAP), 100 kg/ha DAP + 5 tons per ha chicken manure, 10 t/ha chicken manure and control (no fertilizer). Time of pinching had two treatments: early pinching and late pinching. Harvesting treatments comprised piecemeal and wholesome harvesting. The fertilizers were incorporated in the established drills and mixed thoroughly with the soil before planting. Early pinching involved removal of apical buds at 2 weeks after emergence (WAE) and at 3 WAE for cowpea and spider plant, respectively. Late pinching involved removal of apical buds or flower buds, using pruning shears, at 4 and 5 WAE for cowpea and spider plant, respectively. Piecemeal harvesting involved manual plucking of all edible leaves weekly, starting at 4 and 5 WAE for cowpea and spider plant, respectively, till the fifth harvest. Wholesome harvesting involved uprooting the entire plant and plucking the edible leaves. The early pinched-wholesome harvested cowpea and spider plant were uprooted and leaves harvested at 4 and 5 WAE, respectively. Another planting was done immediately and harvested at 4 and 5 WAE for cowpea and spider plant, respectively. For the late pinched wholesome harvested plants, leaf harvesting was done once at 8 and 10 WAE for cowpea and spider plants, respectively.

5.4 Crop establishment and maintenance

Land preparation was done two months before planting using a tractor and then harrowed to a fine tilth. The experimental plot sizes measured 2 m by 1.5 m with up to 30 cm high raised plots. An inter-plot spacing of 1 m and a 2 m path separating blocks was also maintained together with a guard row separated from the treatment plots by 1 m. Fertilizers were incorporated into the respective plots according to the recommended rates before planting. They were thoroughly combined with the soil to reduce direct contact with seeds. Cowpea seeds sourced from world vegetable centre in Tanzania and spider plant seeds sourced from Kenya Seed Company, Nairobi were sown directly along the established hills and drills. Cowpea and spider plant seedlings were later thinned after 2 weeks and 3 weeks, respectively, to attain a spacing of 50 cm × 30 cm between plants. Each subplot remained with 24 and 18 healthy vigorous growing plants for cowpea and spider plant, respectively. Fields were kept relatively weed free by manual weeding.

5.5 Data collection

Nutritional data collected included: vitamin A (beta-carotene), vitamin C (ascorbic acid), Ca, Mg, Fe and Zn. Six inner plants were used for data collection in both crops. Samples for nutritional analysis were taken after every harvesting interval. The vegetables were harvested according to the treatments and stored immediately in a freezer at a temperature of 0^0 C until the harvesting of leafy vegetables was terminated. The harvested vegetables were transported in a cool box to the laboratory. A total of 48 samples for each vegetable were used for nutritional analysis.

The ascorbic acid content in the sample was determined by the HPLC method (Vikram *et al*., 2005). Five grams of the sample was weighed and extracted with 0.8% metaphosphoric acid. This was made to 20 ml of juice extract. The juice extract was centrifuged at 100 revolutions per minute for 10 minutes. The supernatant was filtered and diluted with 10 ml of 0.8% metaphosphoric acid. This was then filtered using cotton wool and micro-filtered through 0.45 μ filter and 20 μL injected into the HPLC machine. Various concentrations of ascorbic acid standards were also made to make a calibration curve. The mobile phase in the HPLC machine was 0.8% metaphosphoric acid, at 1.1mL/min flow rate and wavelength of 266.0 nm. HPLC analysis was done using Shimadzu UV-VIZ detector.

To determine β-carotene, approximately 2 g of spider plant and cowpea samples were weighed accurately. They were then placed in a motor with about 10 ml of acetone and ground thoroughly. The acetone extract was then transferred to a 100 ml volumetric flask and the residue extracted again with 10 ml of acetone and transferred to the volumetric flask. The extraction with acetone was repeated until acetone was colorless. The combined extract was then made to the 100 ml mark. Twenty five millimeters of the extract was evaporated to dryness on a rotary vacuum evaporator and the residue dissolved in about 1 ml petroleum ether. The solution was introduced into chromatographic column and eluted with petroleum ether. Beta-carotene went through the column very quickly as a yellow pigment and was then collected in a 25 ml volume in the volumetric flask with petroleum ether. Five solutions of standard pure β-carotene with concentrations between 0.5 µg/ml and 2.5 µg/ml were prepared from a stock solution containing 2.5 µg/ml. The absorbance values of the solution were determined at 440 nm using UV-vis spectrophotometer and plotted against their corresponding concentrations to give a standard curve (AOAC, 1999).

Minerals were determined after dry ashing according to the method described by the AOAC (2000). The total ash obtained after ashing was boiled with 20 ml of 1N HCL. This was then transferred to 100 ml volumetric flask and filled to the mark using 1 N HCL. Insoluble matter was filtered and the filtrate kept in labeled plastic bottle. The levels of Ca, Fe, Zn and Mg were determined by atomic absorption spectrophotometer (AAS, Model A 6200, Shimadzu, Corp, Kyoto, Japan) using standard methods. Working standards of 0, 0.5, 1.0, 2.0 and 2.5 ppm were prepared from the standard solutions by serial dilution. Each standard was aspirated into AAS and its emission and absorption recorded to prepare a standard curve. The same procedure was applied for the prepared sample solutions for each extract and results recorded. The samples were prepared and read in triplicates. The mineral concentration was calculated from the standard curve.

5.6 Data analysis

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

5.7 Results

5.7.1 Effect of fertilizers, time of pinching and harvesting method on β carotene, vitamin C and mineral composition in cowpea and spider plant

Plants treated with fertilizer significantly ($P \leq 0.05$) increased β-carotene, vitamin C, zinc, calcium, and magnesium in cowpea plant relative to no fertilizers (control), but significantly reduced iron content (Table 5.1). Similar observations were made for spider plant except that there was no significance difference between control (no fertilizers) and application of 200 kg DAP/ha in vitamin C accumulation (Table 5.1).

Plants subjected to 10 t/ha chicken manure had significantly higher vitamin C content than application of 200 kg DAP/ha and 100 kg DAP/ha + 5 t/ha manure in both crops. In cowpea, plants subjected to 100 kg/ha DAP + 5 t/ha manure resulted to significantly higher β-carotene than 200 kg/ha DAP treated plants which, in turn, out-yielded 10 t/ha manure treated plants (Table 5.1). Application of 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure resulted in higher β-carotene content in spider plant than 10 t/ha manure. In both crops, application of 100 kg/ha DAP + 5 t/ha manure resulted to significantly higher zinc, calcium and magnesium content than the other treatments (Table 5.1). In cowpea, plants treated with 200 kg/ha DAP had higher calcium than plants treated with 10 t/ha manure. There was no significant difference in magnesium and zinc levels between 200 kg/ha DAP and 10 t/ha manure treated plants. In spider plant, application of 200 kg/ha DAP resulted to significantly higher zinc and calcium content than 10 t/ha manure treated plants (Table 5.1).

Table 5.1: Main effects of fertilizers on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

	β-Carotene	Vitamin C	Zinc	Calcium	Magnesium	Iron
Fertilizers		**Cowpea**				
Control	1.88	12.65	1.11	18.45	1.28	30.47
200 kg/ha DAP	4.96	17.66	1.29	31.31	1.60	25.64
100 kg/ha DAP + 5 t/ha Manure	5.18	19.30	1.57	34.84	1.69	24.81
10 t/ha Manure	4.60	25.61	1.34	29.91	1.59	26.67
P-value	<.001	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.24	0.89	0.06	1.15	0.07	1.62
		Spider plant				
Control	2.80	77.28	0.99	10.34	1.54	36.19
200 kg/ha DAP	6.87	78.74	1.28	29.88	2.15	29.64
100 kg/ha DAP + 5 t/ha Manure	6.70	94.95	1.35	30.07	2.45	25.98
10 t/ha Manure	6.31	115.12	1.18	27.27	2.16	31.99
P-value	<.001	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.39	1.66	0.06	1.11	0.07	1.23

Iron accumulation in cowpea and spider plant significantly ($P \leq 0.05$) reduced with fertilizer application. For both vegetables, 100 kg/ha DAP + 5 t/ha manure treated plants resulted to significantly ($P \leq 0.05$) lower accumulation of iron content than 200 kg/ha DAP treated plants which, in turn, had lower iron content than 10 t/ha manure treated plants (Table 5.1).

Time of pinching had no significant effect on β-carotene content for both vegetables (Table 5.2). Late pinching had significantly higher vitamin C, calcium, magnesium and iron content than early pinching. Conversely, late pinched plants had significantly lower zinc content than early pinched plants (Table 5.2). For both crops, wholesome harvesting significantly ($P \leq 0.05$) out-performed piecemeal harvesting in vitamin C, zinc, calcium and magnesium content (Table 5.2). Harvesting method and time of pinching had no significant effect on iron content.

Table 5. 2: Effects of time of pinching and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in spider plant

	β Carotene	Vitamin C	Zinc	Calcium	Magnesium	Iron
Pinching						
			Cowpea			
Early pinching	4.35	16.66	1.49	25.01	1.26	25.06
Late pinching	4.31	20.95	1.16	32.25	1.81	28.74
P-value	0.285	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	NS	0.63	0.05	0.81	0.047	1.15
			Spider plant			
Early pinching	6.02	89.94	1.30	20.39	1.63	29.11
Late pinching	5.89	98.10	1.11	28.39	2.51	32.79
P-value	0.21	<.001	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	NS	1.17	0.04	0.79	0.05	0.87
Harvesting						
			Cowpea			
Piecemeal .H	4.00	18.32	1.16	27.62	1.51	27.42
Wholesome .H	4.31	19.30	1.49	29.63	1.57	26.37
P-value	<.001	<.001	<.001	<.001	<.001	0.36
$LSD_{(p=0.05)}$	0.17	0.63	0.05	0.81	0.05	NS
			Spider plant			
Piecemeal .H	5.50	91.82	1.00	23.85	1.72	30.82
Wholesome .H	5.84	96.23	1.40	24.93	2.42	30.08
P-value	0.03	<.001	<.001	<.001	<.001	0.51
$LSD_{(p=0.05)}$	0.28	1.17	0.04	0.98	0.05	NS

Values presented are means, H=harvesting

5.8.2 Interactive effects of fertilizers and time of pinching on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

Interaction of fertilizers and time of pinching had significant ($P \leq 0.05$) effects on vitamin C, zinc, calcium and magnesium contents in both cowpea and spider plant (Table 5.3). The interaction of fertilizers and time of pinching did not have a significant effect on β-carotene and iron accumulation of cowpea and spider plant.

Table 5.3: Interactive effect of fertilizers and time of pinching on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

	Vitamin C	Zinc	Calcium	Magnesium
Cowpea				
Control + EP	9.77	1.15	16.67	1.11
Control + LP	15.54	1.06	20.23	1.44
200 kg/ha DAP + EP	16.73	1.5	27.66	1.24
200 kg/ha DAP + LP	18.59	1.07	34.97	1.96
100 kg/ha DAP + 5 t/ha Manure + EP	17.38	1.85	29.21	1.36
100 kg/ha DAP + 5 t/ha Manure + LP	21.22	1.28	36.47	2.01
10 t/ha Manure + EP	22.77	1.44	26.49	1.34
10 t/ha Manure + LP	24.46	1.23	33.32	1.83
P-value (F×P)	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.26	0.09	1.63	0.10
Spider plant				
Control + EP	74.7	0.94	8.12	1.09
Control + LP	79.86	1.04	12.57	1.98
200 kg/ha DAP + EP	78.16	1.5	25.48	1.62
200 kg/ha DAP + LP	79.32	1.07	34.27	2.68
100 kg/ha DAP + 5 t/ha Manure + EP	92.63	1.45	25.55	1.99
100 kg/ha DAP + 5 t/ha Manure + LP	97.27	1.25	34.59	2.91
10 t/ha Manure + EP	114.27	1.29	22.39	1.82
10 t/ha Manure + LP	118.97	1.07	32.14	2.49
P-value (F×P)	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	2.34	0.08	1.58	0.10

EP=early pinching, LP=late pinching

Within each of the fertilizer treatments, early pinching significantly reduced vitamin C, calcium and magnesium contents in both vegetables (Table 5.3). However, it increased zinc contents in both cowpea and spider plant. In late pinched plants, fertilizer application significantly increased vitamin C, calcium and magnesium contents in both vegetables. Application of 10 t/ha manure + late pinching resulted to significantly ($P \leq 0.05$) more vitamin C than plants that received 100 kg/ha DAP + 5 t/ha manure + late pinching which, in turn, outperformed 200 kg/ha DAP + late pinched treated plants (Table 5.3). In both vegetables, plants subjected to 100 kg/ha DAP + 5 t/ha manure + late pinching gave significantly higher calcium and magnesium contents than the other treatment combinations.

In cowpea, plants that were subjected to 100 kg/ha DAP + 5 t/ha manure + early pinching resulted to significantly higher zinc contents than the other treatment combinations. In spider plant, application of 200 kg/ha DAP + early pinching gave significantly higher zinc contents than the other treatment combinations; however, there were no significant difference in zinc accumulation between early pinched plants subjected to 200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure (Table 5.3).

5.8.3 Interactive effects of fertilizers and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

The interaction between fertilizers and harvesting method had a significant ($P \leq 0.05$) effect on vitamin C and magnesium content of both cowpea and spider plant. Significant ($P \leq 0.05$) effects on calcium were only observed in spider plant (Table 5.4). Interaction of fertilizers and harvesting method had no effect on β-carotene, iron and zinc accumulation in cowpea and spider plant.

In both vegetables, application of fertilizer treatments and wholesome harvesting had significantly ($P \leq 0.05$) higher vitamin C and magnesium content. Similar observations were made on calcium accumulation in spider plant (Table 5.4). In both cowpea and spider plant, the top three treatment combinations in vitamin C levels were 10 t/ha manure + wholesome harvesting, 10 t/ha manure + piecemeal harvesting and 100 kg/ha DAP + 5 t/ha manure + wholesome harvesting, respectively. In piecemeal harvested plants, fertilizer application significantly reduced vitamin C and magnesium contents, in both cowpea and spider plants (Table 5.4). Similarly, it also reduced calcium content in spider plant.

Table 5.4: Interactive effect of fertilizers and harvesting method on β carotene, vitamin C and mineral composition in cowpea and spider plant (mg/100g)

	Vitamin C	Calcium	Magnesium
Cowpea			
Control + P	11.60	19.11	1.41
Control + W	13.71	18.79	1.14
200 kg/ha DAP + P	16.45	32.20	1.51
200 kg/ha DAP + W	18.87	31.43	1.68
100 kg/ha DAP + 5 t/ha Manure + P	18.46	34.17	1.60
100 kg/ha DAP + 5 t/ha Manure + W	20.14	33.51	1.77
10 t/ha Manure + P	24.64	28.77	1.50
10 t/ha Manure + W	26.58	30.05	1.68
P-value (F×H)	<.001	0.61	<.001
$LSD_{(p=0.05)}$	1.26	1.63	0.10
Spider plant			
Control + P	75.23	10.12	1.36
Control + W	76.33	12.57	1.72
200 kg/ha DAP + P	78.99	28.73	1.62
200 kg/ha DAP + W	78.48	31.02	2.67
100 kg/ha DAP + 5 t/ha Manure + P	93.25	29.26	2.19
100 kg/ha DAP + 5 t/ha Manure + W	96.64	30.89	2.71
10 t/ha Manure + P	109.43	26.00	1.72
10 t/ha Manure + W	118.81	27.53	2.59
P-value (F×H)	<.001	<.001	<.001
$LSD_{(p=0.05)}$	2.34	1.58	0.10

P=piecemeal harvesting, W=wholesome harvesting, H=harvesting, F=Fertilizers

In cowpea, plants subjected to wholesome harvesting and fertilizer application, irrespective of the regime, resulted to higher magnesium content than the other treatment combinations. Wholesome harvested spider plants that received 100 kg/ha DAP + 5 t/ha manure and 200 kg/ha DAP gave significantly higher magnesium and calcium content than the other treatment combinations (Table 5.4).

5.7.4 Interactive effects of time of pinching and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

Interaction of time of pinching and harvesting method had significant ($P<0.05$) effects on vitamin C, calcium, zinc and magnesium content, but not on β-carotene and iron accumulation in both crops (Table 5.5).

In early pinched cowpea and spider plant, piecemeal harvesting had significantly higher vitamin C, calcium and magnesium content than the wholesome harvested ones (Table 5.5). However, plants subjected to early pinching + piecemeal harvesting had significantly ($P<0.05$) lower zinc contents than wholesome harvested ones. In late pinched plants, wholesome harvesting significantly increased vitamin C, calcium and magnesium contents but significantly reduced zinc contents in both crops (Table 5.5). In wholesome harvested crops, early pinching significantly ($P<0.05$) increased zinc contents and reduced vitamin C, calcium and magnesium contents relative to late pinching (Table 5.5). In both crops, late pinching + wholesome harvesting outperformed all the other treatment combinations in vitamin C, calcium and magnesium contents. Similarly, early pinching + wholesome harvesting outperformed the other treatments in zinc accumulation (Table 5.5).

Table 5. 5: Interactive effect of time of pinching and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in cowpea and spider plant

	Vitamin C	Zinc	Calcium	Magnesium
Cowpea				
Early pinching + P.Harvesting	18.09	1.23	29.75	1.49
Early pinching + W.Harvesting	15.23	1.74	20.26	1.04
Late pinching + P.Harvesting	20.51	1.09	29.51	1.52
Late pinching + W.Harvesting	21.40	1.23	34.99	2.10
P-value (P×H)	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	0.89	0.06	1.15	0.07
Spider plant				
Early pinching + P.Harvesting	95.40	0.96	23.84	1.67
Early pinching + W.Harvesting	84.48	1.63	16.93	1.59
Late pinching + P.Harvesting	97.05	1.05	23.86	1.78
Late pinching + W.Harvesting	99.15	1.16	32.93	3.25
P-value (P×H)	<.001	<.001	<.001	<.001
$LSD_{(p=0.05)}$	1.66	0.06	1.11	0.07

P-Piecemeal Harvesting, W-Wholesome Harvesting, P=pinching, H=harvesting

5.7.5 Interactive effects of fertilizers, time of pinching and harvesting method on β carotene, vitamin C and mineral composition in cowpea and spider plant

The interaction of fertilizers, time of pinching and harvesting method had significant (P≤0.05) effects on vitamin C, calcium and magnesium contents, but not β-carotene, zinc and iron content, in both cowpea and spider plant (Tables 5.6 and 5.7).

Cowpea and spider plant that did not receive any fertilizer regime in the three way interaction of fertilizers, time of pinching and harvesting method, recorded the lowest vitamin C, calcium and magnesium contents relative to the other treatment combinations (Tables 5.6 and 5.7). In fertilizer treated plants, late pinching and wholesome harvesting significantly increased vitamin C, calcium and magnesium contents. Cowpea and spider plant that were subjected to 10 t/ha manure + late pinching + wholesome resulted to significantly (P≤0.05) the highest amount of vitamin C accumulation. On the other hand, plants subjected to 100 kg/ha DAP + 5 t/ha manure + late pinching + wholesome harvesting significantly

($P \leq 0.05$) out-performed the other treatment combinations in calcium and magnesium content in both crops (Tables 5.6 and 5.7).

Table 5.6: Interactive effect of fertilizers, time of pinching and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in cowpea

	Vitamin C	Calcium	Magnesium
Control + EP + P	12.59	19.21	1.10
Control + LP + P	12.96	18.93	1.13
Control + EP + W	13.61	18.81	1.08
Control + LP + W	17.46	21.66	1.25
200 kg/ha DAP + EP + P	18.24	30.46	1.42
200 kg/ha DAP + LP + P	15.21	30.86	1.46
200 kg/ha DAP + EP + W	19.49	28.93	1.60
200 kg/ha DAP + LP + W	20.69	34.00	1.91
100 kg/ha DAP + 5 t/ha manure + EP + P	19.04	30.75	1.60
100 kg/ha DAP + 5 t/ha manure + LP + P	15.71	32.67	1.12
100 kg/ha DAP + 5 t/ha manure + EP + W	20.25	26.59	1.61
100 kg/ha DAP + 5 t/ha manure + LP + W	21.20	34.34	2.12
10 t/ha manure + EP + P	21.49	28.40	1.55
10 t/ha manure + LP + P	20.67	28.69	1.45
10 t/ha manure + EP + W	21.65	21.59	1.23
10 t/ha manure + LP + W	27.24	30.95	2.06
P-value (F×Pi×H)	0.02	<.001	<.001
$LSD_{(p=0.05)}$	1.78	2.30	0.13

EP-Early pinching, LP- Late pinching, P-Piecemeal Harvesting, W-Wholesome Harvesting, F=fertilizers, Pi=pinching, H=harvesting

Table 5.7: Interactive effect of fertilizers, time of pinching and harvesting method on β carotene, vitamin C and mineral composition (mg/100g) in spider plant

	Vitamin C	Calcium	Magnesium
Control + EP + P	70.43	9.99	1.18
Control + LP + P	73.03	10.25	1.00
Control + EP + W	73.97	9.25	1.53
Control + LP + W	78.68	12.89	1.89
200 kg/ha DAP + EP + P	76.11	28.32	2.31
200 kg/ha DAP + LP + P	76.21	30.64	1.73
200 kg/ha DAP + EP + W	77.88	28.72	1.73
200 kg/ha DAP + LP + W	80.75	32.82	2.42
100 kg/ha DAP + 5 t/ha manure + EP + P	90.26	29.07	2.19
100 kg/ha DAP + 5 t/ha manure + LP + P	88.99	31.04	1.89
100 kg/ha DAP + 5 t/ha manure + EP + W	95.25	28.45	2.19
100 kg/ha DAP + 5 t/ha manure + LP + W	98.29	33.74	2.62
10 t/ha manure + EP + P	98.80	26.99	1.78
10 t/ha manure + LP + P	103.86	27.01	1.65
10 t/ha manure + EP + W	101.74	24.79	1.86
10 t/ha manure + LP + W	118.89	29.26	2.33
P-value (F×Pi×H)	<.001	<.001	<.001
$LSD_{(p=0.05)}$	3.31	2.23	0.14

EP-Early pinching, LP- Late pinching, P-Piecemeal harvesting, W=wholesome harvesting, F=fertilizers, Pi=pinching, H=harvesting

5.8 Discussion

Effects of fertilizers, time of pinching and harvesting method on β carotene, vitamin C and mineral composition in cowpea and spider plant

Application of manure and DAP either singly or in combination significantly increased β-carotene, vitamin C, zinc, calcium, magnesium uptake in cowpea and spider plant but significantly reduced iron content. This finding agrees with observations of Singh et al., (1986), Chweya, (1993) and Kipkosgei, (2004) who noted that both manure and inorganic fertilizers (CAN) increased β-carotene in spider plants. Similar observations have been made in other crops such as *Solanum nigrum* (Murage, 1990) and carrots (Kansal, 2005). Cowpea and spider plant grown in fertilizer treated plots had significantly higher β-carotene probably due to the presence of nitrogen, which facilitated formation of more leaves. This increased activity of chlorophyll and associated light absorbing equipment in carotenoids. Formation of more leaves resulted to more chloroplasts, which are rich in β carotene (Salisbury and Ross, 1991).

It is worth noting that among the fertilizer treated plants, manure applications significantly increased vitamin C content while inorganic fertilizers (200 kg/ha DAP and 100 kg/ha DAP + 5 t/ha manure) had lower vitamin C content. Kipkosgei, (2004) made similar observations on spider plant indicating that vitamin C contents increased with organic manure application. Earlier observations by Chweya, (1993) and Kebwaro, (2013) on spider plant and Rados et al., (2012) on carrots indicated a decrease in vitamin C content with inorganic fertilizer treatment. It could be possible the greater amounts potassium present in manure (1.6 cmol/kg) as compared to the soils (1.1 cmol/kg) favored greater synthesis of vitamin C. Appropriate K nutrition improved photosynthates assimilation and enzyme activation which favored vitamin C synthesis (Kanai et al., 2007). The inorganic fertilizers may have increased nutrients availability especially nitrogen, which translated to increased vegetative growth that lowered light intensity, hence the lower vitamin C content in the plant tissues. Low light intensity reduces accumulation ascorbic acid in plant tissues (Harris, 1975). It may also be possible, the great vegetative growth in inorganic fertilizer treated plants had a dilution effect on vitamin C accumulation.

The incorporation of manure or DAP fertilizers singly or in combination resulted to lower iron accumulation in both crops as compared to the control treatments. Application of nitrogen fertilizers has been reported to depress iron content of other vegetables like *Amaranthus caudatus*, *Curcubita pepo, Solanum macrocarpon* and *Telfaira occidentalis* (Taylor et al., 1983). Earlier findings by Kipkosgei (2004) reported that iron content of spider plant and *Solanum nigrum* decreased with application of manure and CAN. This could be due to the presence of nitrates from the fertilizers that suppressed iron accumulation. Nitrate uptake enhances the release of hydroxide ions that increases the pH in the root zone and this counteracts efficient uptake of iron (Sela, 2016).

Application of fertilizers significantly increased magnesium, calcium and zinc contents in both cowpea and spider plant as compared to the control treatments. Earlier studies by Aguyoh et al., (2012) indicated that high levels of nitrogen and phosphorous access to the plant increased number of chloroplasts and consequently chlorophyll content in leafy vegetables such as spider plant. Magnesium being a major component in chloroplasts was also increased (Stocking and Ongun, 1962). These results are in line the findings of Kebwaro (2013) who reported increase in magnesium content in spider plant with increase in nitrogen level application. It could be possible, the phosphorous content from DAP and manure improved rooting, which in turn, increased absorption of micronutrients such as magnesium from the soil and manure. Higher uptake by the fertilized plants may have facilitated formation of more chloroplasts, magnesium being a major constituent of chloroplasts was also increased.

Application of fertilizers increased zinc content in both crops. According to Peck et al., (1980) and Welch et al., (2016) increasing supply of zinc content increased the concentration of zinc in pea plants and wheat, respectively. Another study by Kebwaro, (2013) to determine the effect of nitrogen level on zinc accumulation in spider plant showed that uptake of zinc increased with increasing levels of nitrogen. Nitrogen is a constituent of all proteins, chlorophyll, co-enzymes and nucleic acids and zinc is a key constituent of many enzymes and proteins which play important roles such as growth hormone production (Sela, 2016). Sela, (2016) showed further that zinc availability varied in plants, depending on its availability in the soil or growing media. It could be possible, zinc increased with the availability of more nutrients from a combination of organic and chemical fertilizers.

In this study, incorporation of fertilizers significantly increased calcium content in both crops. Kipkosgei, (2004) had similar findings in *Cleome gynandra* where calcium levels increased in plants treated with 5-15 t/ha farmyard manure or 400 kg/ha calcium ammonium nitrate. Application of 100 kg/ha DAP + 5 t/ha manure consistently increased β-carotene, zinc, calcium and magnesium contents of both cowpea and spider plant more than application of 200 kg/ha DAP and manure singly. This might have resulted from synergetic influence of combining chemical and organic fertilizers (Alemu and Bayu, 2005). The DAP fertilizer may have ensured quick release of nitrogen and phosphorous which enhanced root development which aided in absorption of other nutrients from the soil. Manure on the other hand, may have ensured slow and steady supply of nutrients. Higher nutrient availability, (N and P) ensured increase in photosynthetic efficiency that translated to increase in β-carotene and improvement in absorption of minerals such as zinc, magnesium and calcium from the soil. High levels of nitrogen in fertilizers have been reported to increase β-carotene content and increase uptake of zinc, magnesium and calcium by spider plant (Kipkosgei, 2004; and Kebwaro, 2013), *Solanum nigrum* (Murage, 1990) and jute mallow (Aluko et al., 2014). The higher vitamin C content in 10 t/ha manure treated plants than other plants may be as a result of the high potassium content from chicken manure (1.6 cmol/kg). Previous reports have demonstrated that fertilizers with high potassium content increase vitamin C synthesis in plants through improved photosynthates assimilation and enzyme activation (Kipkosgei, 2004; Lee et al., 2000 and Kanai et al., 2007).

Late pinching significantly increased vitamin C, calcium and magnesium in both cowpea and spider plant, but increased iron only in cowpea plants. Mozafar (1993) reported that ascorbic acid accumulation in plants increased with increased light intensity. The increased vitamin C content could be due to increased canopy span caused by late pinching that resulted to increased light interception thus facilitating synthesis of more ascorbic acid, iron and magnesium. Briat et al., (2009) reported that over 80% of iron is found in photosynthetic cells where it is essential for biosynthesis of molecules such as cytochromes and chlorophyll. Magnesium is critical in photosynthesis process as it is a building block of chlorophyll which makes leaves appear green (Sela, 2016). Salisbury and Ross (1991) reported that calcium is almost immobile in phloem tissues and as a result its accumulation in young tissues is low. The higher calcium content in late pinched plants than early pinched plants could be due to provision of adequate time to translocate the calcium ions to the leaf tissues. Early pinched plants had significantly higher zinc content than late pinched plants. Sela, (2016) and Salisbury and Ross (1991) observed a greater accumulation of zinc contents in younger leaves. Increased zinc accumulation in early pinched plants could be due to the increased mobility of the ions to the younger tissues. Under low-adequate supply of zinc, its accumulation is always higher in growing tissues than in mature tissues (Lindsay, 1972).

Wholesome harvested plants produced significantly higher β carotene, calcium and magnesium content in both cowpea and spider plant than piecemeal harvested plants. Salisbury and Ross (1991) reported that chloroplasts are rich in β carotene and they exist in larger amounts in older tissues. Similarly, Howard et al., (2000), reported that β carotene of pepper cultivars increased as the fruit became more mature. Higher β carotene in cowpea and spider plants that were wholesome harvested may be attributed to high number of chloroplasts in the older and more mature tissues of wholesome harvested plants than in the piecemeal harvested plants that had immature leaves at the growing tips of the defoliated leaves.

Piece-meal harvesting decreased vitamin C content. Other researchers have reported similar findings on cantaloupe (Gil et al., 2006; Beaulieu and Lea, 2007), potato (Mundy and Maria, 2006) and asparagus (Saito et al., 2000). The researchers observed that vitamin C decreased with bruising of the plants. Barrett et al., (2010) reported that vitamin C is very unstable and degrades more rapidly when exposed to light, heat and oxygen. The frequent cuts from piecemeal harvested plants could have accelerated loss of vitamin C.

Late pinched plants supplied with 10 t/ha manure, had the highest content of vitamin C, while those supplied with 100 kg/ha DAP + 5 t/ha manure had highest contents of Ca and Mg. According to Kipkosgei (2004) use of organic manure increased vitamin C while late pinching increased canopy span, which allowed for more light interception. Lee and Kader, (2000) reported that greater light intensity encouraged vitamin C concentration. Increased Ca and Mg content in both crops treated with combinations of inorganic and organic fertilizers could be due to synergistic effects, which may have increased the absorption of soil available macro and micronutrients by the plants. Early pinched plants supplied with 100 kg/ha DAP + 5 t/ha manure resulted to higher content of Zn than the other treatment combinations. According to Welch, (2016) increasing supply of Zn to wheat increased Zn contents. It could be possible, the fertilizer combination improved Zn availability in the soil and early pinching encouraged production of new younger plants. Younger plants have greater accumulation of Zn contents (Salisburry and Ross, 1991). Fertilizer application in combination with late pinching increased vitamin C, Ca and Mg while early pinching in combination with fertilizer application favored production of Zn.

Plants that were supplied with fertilizers and wholesome harvested had increased vitamin C, Ca and Mg content compared to other treatments. Piecemeal harvesting may have accelerated loss of vitamin C (Barrett et al., 2010) while wholesome harvesting also favored production of Ca and Mg ions relative to piecemeal harvesting Salisburry and Ross, (1992). On the other hand, fertilizers enhance vitamin C, Ca and Mg accumulation. This shows that fertilizers and wholesome harvesting had synergistic effects in these nutrients in spider plant and cowpea.

A combination of 10 t/ha manure, late pinching and wholesome harvesting gave the highest values of ascorbic acid relative to all other treatment combinations. This could be attributed to synergistic effects of these treatments because they all associated with increase in ascorbic acid (Harris, 1975; Kipkosgei, 2004 and Saito et al., 2000).Kebwaro, 2013). Similarly, (Saito et al., 2000) reported a reduction in vitamin C content of asparagus plant that were cut. When vitamin C is of interest, one should use manure with high K content, practice late pinching and wholesome harvesting.

The combination of 100 kg/ha DAP + 5 t/ha manure + late pinching + wholesome harvesting resulted to significantly the highest magnesium and calcium content in cowpea and spider plant leaves. This can be attributed to the positive effects of each of these treatments on Mg and Ca uptake (Kipkosgei 2004, Morteza et al., 2011, Salisburry and Ross, 1991 and Sela, 2016). To promote higher production of magnesium and calcium in cowpea and spider plant, producers should apply fertilizers, practice late pinching and wholesome harvesting.

5.9 Conclusion

Fertilizer application increased Ca, vitamin C, β carotene, zinc and magnesium but reduced iron content in cowpea and spider plant. Plants subjected to 100 kg/ha DAP + 5 t/ha manure proved to be the best fertilizer combination for promoting the contents of β carotene, zinc, calcium and magnesium while application of 10 t/ha manure to the plants resulted to the highest amount of vitamin C accumulation.

Late pinching of cowpea and spider plant increased vitamin C, calcium, magnesium and iron content while early pinching increased zinc content.

A combination of 100 kg/ha DAP + 5 t/ha manure + late pinching and 100 kg/ha DAP + 5t/ha manure + wholesome harvesting increased Ca and Mg contents in both crops. A combination of late pinching and wholesome harvesting increased vitamin C, Ca and Mg content while a combination of early pinching and wholesome harvesting had the highest Zn content. Minerals such Ca and Mg were significantly increased when plants were supplied with 100 kg/ha DAP + 5 t/ha manure + late pinching + wholesome harvesting. A combination of 10 t/ha manure + late pinching + wholesome harvesting led to the highest levels of vitamin C.

CHAPTER SIX: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 Discussion

Application of fertilizers (organic and inorganic) increased vegetative growth and consequently the fresh and dry leaf yields. The increase in the growth parameters and yield obtained could be due to the presence of readily available nutrients (e.g. nitrogen and phosphorous) from the inorganic and organic fertilizers. Phosphorous and nitrogen may have enhanced plant physiological functions such as photosynthesis, respiration, energy storage, cell division, enlargement and chlorophyll synthesis that contributed to increase in the growth parameters and yields. Combined application of 100 kg/ha DAP and 5 t/ha manure out-performed sole applications of higher levels of the same fertilizers (200 kg/ha DAP and 10 t/ha manure) in growth and leaf yields. This could be attributed to additive nutrient supply and better synchrony of nutrient availability with crop demand. Organic manure may have ensured slow and steady release of plant nutrients while mineral fertilizers could have readily availed the nutrients.

Late pinching increased the growth parameters and consequently leaf yields relative to the early pinched plants. This could be attributed to the removal of the terminal apical bud. This, in turn, may have reduced auxin concentration and removed apical dominance, resulting to production of more buds, thus, increased vegetative growth and leaf yield. The higher yields of late pinched than early pinched plants could be due to the existence of more resource sinks at the growing tips of late pinched plants.

The results of this study have revealed that significantly higher number of leaves and leaf yields were obtained from wholesome harvested plants than piecemeal harvested plants. This could be probably due to reduction in photosynthetic leaf area caused by heavy defoliation in piecemeal harvested plants. It could also be due to the diversion of assimilates in healing wounds and developing buds for the frequently harvested plants (piecemeal harvested plants) at the expense of proliferating more leaves.

Application of fertilizers increased β-carotene, vitamin C, zinc, calcium, magnesium contents in both cowpea and spider plant but significantly reduced iron content. The better performance under fertilizer treated plants may be attributed to the addition of nutrients (nitrogen and phosphorous), which enhanced root development and plant growth that enhanced uptake of Ca, Mg and Zn and facilitated formation of more chloroplast which are rich in β carotene. Application of fertilizers suppressed iron accumulation possibly due to the presence of nitrates which enhanced release of hydroxide ions that counteracted efficient uptake of iron. Application of fertilizer either singly or in combination released nutrients such as nitrogen that may have encouraged more vegetative growth, especially plots with DAP and DAP-Manure, that had a dilution effect in vitamin C. Manure treated plots had greater vitamin C content probably, due to presence of more potassium that favoured synthesis of more vitamin C.

Late pinching significantly increased vitamin C, calcium and magnesium in both cowpea and spider plant. The high calcium content in late pinched plants may be due to the provision of adequate time for calcium ions to be translocated to the leaf tissues, since pinching was carried out when the plants were older. Calcium is immobile within plants and is easily translocated in older tissues than younger tissues. The increased contents of vitamin C and magnesium contents in late pinched plants could be due to increased canopy span that resulted to increased photosynthetic area, thus facilitating increased synthesis of more ascorbic acid and magnesium ion uptake. Increased zinc accumulation in early pinched plants could be due to the increased mobility of the zinc ions to the younger tissues than the older tissues of late pinched plants especially under low-adequate iron accumulation in the soil.

Wholesome harvesting produced significantly higher content of β carotene, vitamin C, calcium and magnesium in both cowpea and spider plant than piecemeal harvesting. This may be attributed to increased photosynthetic area and chloroplasts that contain carotene and magnesium. Piecemeal harvesting may have caused bruises to the plant whose exposure to light may have encouraged loss of vitamin C which degrades rapidly when exposed to light.

The combinations of fertilizers + late pinching, fertilizers + wholesome harvesting, late pinching + wholesome harvesting and fertilizers + late pinching + wholesome harvesting increased the leaf yield, vitamin C, Ca and Mg content in both cowpea and spider plant relative to other respective treatment combinations. Combinations with 10 t/ha chicken manure had higher vitamin C content than the combinations with other fertilizer treatments, probably due to the presence of K which is associated with enhanced vitamin C synthesis. Pinching and wholesome harvesting combinations with 100 kg/ha DAP + 5 t/ha manure had higher contents of Ca, Mg and Zn. This could be possibly due to the complementary role played by combining organic and inorganic fertilizers which availed more soluble nutrients for plant absorption. Early pinched plants supplied with 100 kg/ha DAP + 5 t/ha manure resulted to higher content of Zn than the other treatment combinations, possibly due to the fact that, early pinching encouraged production of new younger plants, which have greater accumulation of Zn content, while combined organic and inorganic fertilizers enhanced Zn availability and uptake.

6.2 Conclusion

In this study, plants treated with DAP or manure singly or in combination and subjected to late pinching and wholesome harvesting resulted to significantly higher yields. Treatment combinations with 200 kg/ha DAP had better growth parameters and yield than the other treatment combinations in cowpea production, while combinations with 100 kg/ha DAP + 5 t/ha manure outperformed the other treatments in spider plant.

Similarly, combinations of fertilizers, late pinching and wholesome harvesting increased β-carotene, Mg, Ca and Zn uptake in both cowpea and spider plant. However, fertilizer treated plants significantly reduced iron content. Among the various fertilizer combinations, application of 100 kg/ha DAP + 5 t/ha manure resulted to higher β-carotene, Mg, Ca and Zn while treatments with 10 t/ha manure accumulated the highest content of vitamin C. Most micronutrients were tapped when plants were subjected to 100 kg/ha DAP + late pinching + wholesome harvesting. It's worth noting that higher zinc content were tapped when both cowpea and spider plant were early pinched than when late pinched.

6.3 Recommendations

From the study, the following are recommended:

1. It is advisable that cowpea and spider plant farmers apply 100 kg/ha DAP plus 5 t/ha manure in their fields and also practice late pinching and wholesome harvesting to improve yield and nutritional quality (Ca and Mg).When β-carotene and Zn content is of main interest, a combination of 100 kg/ha + 5 t/ha manure plus early pinching (for Zn) should be adopted. In addition, to tap more vitamin C, 10 t/ha manure should be applied together with late pinching and wholesome harvesting.
2. Further research on the response of cowpea and spider plant to varying rates of both organic and inorganic fertilizers in order to identify the best rate that will optimize both leaf yield and nutritional quality of the plants.

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APPENDICES

Appendix 1: Chemical composition of soil and chicken manure used in the experiment

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

Appendix 2: Monthly rainfall and temperature received in Kabete Field Station during the experimental period between September 2014 to July 2015

Months	**Temperature (^{0}C)**	**Rainfall (mm)**
September	17.50	22.90
October	20.10	136.20
November	19.80	91.00
December	19.80	88.60
March	22.60	66.04
April	21.00	270.5
May	18.50	87.10
June	16.90	50.50
July	16.60	3.60

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

Appendix 3: Monthly rainfalls and temperatures received in Kabete Field Station during the experimental period in 2015

Months	Temperature (^{0}C)	Rainfall (mm)
March	22.60	66.04
April	21.00	270.5
May	18.50	87.10
June	16.90	50.50
July	16.60	3.60
September	18.23	29.50
October	20.23	41.70
November	20.16	160.30
December	19.37	69.6

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

Appendix 4: Monthly rainfalls and temperatures received in Kabete Field Station during the experimental period between September 2014 and December 2015

Months	Temperature (^{0}C)	Rainfall (mm)
September	17.50	22.90
October	20.10	136.20
November	19.80	91.00
December	19.80	88.60
March	22.60	66.04
April	21.00	270.5
May	18.50	87.10
June	16.90	50.50
July	16.60	3.60
September	18.23	29.50
October	20.23	41.70
November	20.16	160.30
December	19.37	69.6

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