EFFECTS OF IRRIGATION RATE AND LEAF HARVEST INTENSITY ON GROWTH, YIELD AND QUALITY COMPONENTS OF MULTI-PURPOSE PUMPKIN (*Cucurbita moschata* Duch.)

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NOVEMBER, 2014

DECLARATION AND APPROVAL

Declaration

This thesis is my original work and has not been presented in this form or any other for the award of a degree or any other award in another university.

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DEDICATION

I dedicate this work to my family John, Faith, Patience and Victor and to my loving parents Joseph and Esther and to all those with a passion and zeal for pumpkin production.

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ABSTRACT

Pumpkin (*Cucurbita moschata* Duch.) is a multi-purpose fruit and leaf vegetable that is rapidly gaining popularity in urban, peri-urban and rural areas in Kenya. The fruits and leaves are rich in vital vitamins and minerals. The seeds are becoming popular as a snack for their nutritional and medicinal properties. However, water stress during dry periods and irregular leaf harvesting are some of the constraints largely affecting optimal fruit and leaf yields. This study was carried out both in Nairobi and Embu Counties from June 2012 to April 2013 to determine the effects of irrigation water rate and leaf harvest intensity in enhancing fruit, seed and leaf yields. A split-plot experiment embedded in a Randomized Complete Block Design with four replications was used. A rain shelter was used to block rain water from the experimental plot. Irrigation was applied to main plots and leaf harvest intensity to split-plots. The treatments included four irrigation rates (1, 2, 3 and 4 litres applied once per week through drip tubes) and four leaf harvest intensities (0, 1, 2 and 3 leaves harvested once per fortnight per branch). One plant spaced at 2 m x 2 m and replicated four times was used per treatment. The parameters studied were: number and fresh biomass of edible leaves; sex ratio; number of male and female flowers; number, size, weight and quality of fruits; number and weight of seeds; germination percentage and seedling vigor. Data obtained were subjected to analysis of variance using JMP IN 5.1 statistical package software. Mean separation for all significant variables was conducted using the Tukey's Studentized Range Test at $P = 0.05$. Results showed that leaf harvest intensity had a significant ($P < 0.05$) decreasing effect on flowers, leaf vegetables, fruit yields and quality. Irrigation rate had a significant ($P < 0.05$) increasing effect on the number of branches. Interaction between irrigation rate and leaf harvest intensity had a significant ($P < 0.05$) increasing effect on number of leaves, seeds and male flowers. Irrigating with three litres of irrigation water once each week recorded the best performance in most treatments and is recommended for pumpkin plant growth and production. The highest yields were 4.7 t/ha edible leaves for 3-LHI and 22.7 t/ha of fruits for no leaf harvest intensity. Harvesting one leaf or none per branch per week recorded the best results in most treatments Harvesting two leaves per branch once per week is recommended for farmers interested in edible leaves and one leaf per branch or none for farmers interested in fruits and seeds.

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LIST OF ABBREVIATIONS AND ACRONYMS

DAE	=	Days after emergence
DI	=	Deficit Irrigation
ETc	=	Evapo-transpiration
FI	=	Full Irrigation,
FAO	=	Food and Agriculture Organization
FAOSTAT	=	Food and Agriculture Organization Statistics
HCDA	=	Horticultural Crops Development Authority
IRR 1	=	Application of one litre of water per plant per week
IRR 2	=	Application of two litres of irrigation water per plant per week
IRR 3	=	Application of three litres of irrigation water per plant per week
IRR 4	=	Application of four litres of irrigation water per plant per week
KALRO	=	Kenya Agricultural and Livestock Research Organization
LHF	=	Leaf harvesting frequency
LHI	=	Leaf harvest intensity
LHI1	=	No leaf harvest
LHI2	=	One leaf harvest per branch per fortnight
LHI3	=	Two leaf harvest per branch per fortnight
LHI4	=	Three leaf harvest per branch per fortnight
L	=	Litre
NARL	=	National Agricultural Research Laboratories
PÂ	=	Probability of A
PRD	=	Partial Root-Zone Drying
RF	=	Rain-Fed
TSS	=	Total Soluble Solutes
WAE	=	Weeks after Emergence
WK	=	Week

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Pumpkins are members of the Cucurbitaceae Family, which includes muskmelon, watermelon, cucumbers and gourds. Pumpkin cultivars may belong to one of several species, namely: *Cucurbita pepo, C. maxima, C. moschata,* and *C. mixta* (Grubben and Chigumira-Ngwerume, 2004). Pumpkin serves as a reliable source of food, providing families with a variety of diets that help ensure stability in household food security. Leaves, flowers and fruits of these cucurbits are used as vegetables, and their seeds are consumed after roasting to make snack (Ndoro *et al*., 2007). Multi-purpose pumpkin is an annual herb that grows laterally using 3–4-branched tendrils. Leaves are harvested during the vegetative growth of the plant, while harvesting of mature fruits occurs during the later growth stages. The emergence of multi-purpose pumpkin as a vegetable has attracted great attention due to its adaptation to a wide range of climates and high-yielding potential (Ondigi *et al*., 2008).

World production of pumpkins in 2007 exceeded 20 million tons, especially in China, India, Russia, United States, and Egypt (FAOSTAT, 2008; FAO, 2010). African production was estimated to be 1.8 million tons from 140,000 ha, corresponding with an average yield of 12.8 t/ha (Grubben and Chigumira-Ngwerume, 2004). In Kenya, area under pumpkin production increased from 316 ha in 2006 to 979 ha in 2010 (Horticulture Validated Report, 2010). International trade of pumpkin leaves, fruits and seeds is very small or non-existent, but at national level, leaves, fruits and often seeds are important products in local markets. Pumpkins grow in almost any part of East Africa and store for over 8 months after harvesting as long as the fruit retains its stalk (Grubben and Chigumira-Ngwerume, 2004). Due to these features, pumpkin is a valuable food security crop (Horticulture Validated Report, 2011). Currently there is an increase in production and consumption due to medicinal properties associated with pumpkins (Horticulture Validated Report, 2010).

Pumpkin is a warm-season crop that is relatively easy to grow but that requires a long season to produce a marketable crop. Most varieties require 90 to 180 days from sowing to reach market maturity (Bates *et al*., 1990; Radovich, *et al*., 2011). Most pumpkin production in Kenya is rain-fed. In the dry season, farmers adopt risk-avoidance strategies to meet vegetable needs. These include production along riverbanks and supplementary watering. Cucurbits are drought-tolerant and once established they are harvested all year-round (Radovich *et al*., 2011). Among small-scale farmers, pumpkin crop management entails strategic branch positioning, sequential leaf harvesting and stress control. Vines are coiled around the planting hole to control space occupied and facilitate performance of cultural practices. Tender leaves are sequentially harvested for use as they emerge. The number of leaves harvested varies from one grower to another.

Water plays a major role in uptake of plant nutrients. It acts as a mode of transport of both organic and inorganic solutes in the soil (Suat *et al*., 2006). The main consequence of moisture stress is decreased growth and development caused by reduced photosynthesis. Chemical limitations due to reductions in critical photosynthetic components such as water can negatively impact plant growth (Xu and Zhau, 2006). Low water availability can also cause physical limitations in plants. Stomata are plant cells that control movement of water, carbon dioxide and oxygen into and out of the plant (Katul *et al*., 2010). During moisture stress, stomata close to conserve water. This also closes the pathway for the exchange of water, carbon dioxide, and oxygen resulting in decreases in photosynthesis (Katul *et al*., 2010). Leaf growth will be affected by moisture stress more than root growth because roots are more able to compensate for moisture stress (Pearson, 2005). Water stress management in pumpkin is achieved by intercropping plants or restricting production to rainy periods. Management of various cultural inputs is yet to be systematically studied for standardization so as to facilitate commercial production of multi-purpose pumpkin by small-scale farmers in Kenya to meet the rising demand from consumers particularly in urban centers (Woomer *et al*., 2005).

1.2 Statement of the Research Problem

Water stress and unregulated leaf harvesting intensity have led to low leaf vegetable and fruit yields in multi-purpose pumpkin in various parts of Kenya. Many farmers have been sequentially harvesting the tender leaves for consumption. This has been affecting the fruit yields as a result of reduced photosynthetic area. The farmers lack information on the correct number of leaves to harvest without affecting the yields. Rainfall variability is an important characteristic of climate in Sub Saharan Africa that imposes crop production risks, especially on rain fed subsistence cultivation systems on marginal land. In recent decades, rainfall has become scarce and erratic in most parts of Kenya. As a result, farmers have been experiencing low yields and poor quality produce and seasonal production of Multi-purpose pumpkins. Most small-scale multi-purpose pumpkin farmers do not know the optimal rate of irrigation to use in maximizing leaf vegetable, fruit and seed yields. There is therefore a compelling need to establish the right leaf harvesting intensity and irrigation rate that will not compromise on yield, quality and year round production to ensure steady supply.

1.3 Objectives

1.3.1 General objective

To increase production of multi-purpose pumpkin through provision of optimal quantity of irrigation water and practicing of appropriate leaf harvesting intensity.

1.3.2 Specific objectives

1) To determine the effect of different irrigation rates on growth, yield and quality of multi-purpose pumpkin.
2) To determine the effect of leaf harvesting intensity on growth, yield and quality of multi-purpose pumpkin.
3) To determine the effect of interactions between irrigation rate and leaf harvesting intensity on growth, yield and quality of multi-purpose pumpkin.

1.4 Hypotheses

1) Irrigation rate has no effect on growth, yield and quality of multi-purpose pumpkin.
2) Leaf harvesting intensity has no effect on growth, yield and quality of multi-purpose pumpkin.
3) Interaction between irrigation rate and leaf harvesting intensity has no effect on growth, yield and quality of multi-purpose pumpkin.

1.5 Research Justification

The production of multi-purpose pumpkin as an emerging vegetable has attracted great attention due to its adaptation to a wide range of climates, high-yielding potential and increased consumption due to its nutritional and medicinal properties. Pumpkins are a rich source of vitamins (A, B1, B2, B12, C, E) proteins, carbohydrates, oil, and minerals (zinc, niacin, iron, mg, phosphorous, potassium, folate, calcium) as indicated by Education and Healthy Library Editorial Team, (2004). Their responses also show the diverse medicinal value of the pumpkins. Some of these values have been documented such as its use in the treatment of stomach, eye as well as renal disorders (Isutsa and Mallowa, 2013). Currently, it is a good source of vitamins and minerals in the management of HIV/AIDS (FAO/WHO, 2002). The medicinal potential of the pumpkin cannot be gainsaid, given the diverse value in its fruits, leaves, and seeds. Pumpkin is a source of income to rural farmers, because currently the crop is sold in both rural and urban markets.

Pumpkins have been maintained in East Africa for many generations using indigenous knowledge. The knowledge required to improve the status of this traditional crop is not well documented and research done on the crop is inadequate compared to most mainstream and exotic crops. Although studies on pumpkin have been done, literature on fruit, leaf vegetable and seed yield responses to leaf harvest intensity and irrigation rate together is unavailable. In Kenya particularly, no study has been documented on the effects of different irrigation rates and leaf harvesting intensity on the growth, physiology and productivity of pumpkin. Farmers have been sequentially harvesting tender leaves for use as vegetables (Maereka, 2007). The number of leaves harvested varies from one grower to another and hence is not standardized. Farmers have also been intercropping pumpkin in maize fields as a moisture retention measure or producing pumpkins during the rainy season or along riverbanks to escape drought. Opportunities to enhance and support the production and use of pumpkin are desirable for the purpose of overcoming the problems of undernourishment, contributing to food security and also to farmer’s income (Ondigi *et al.*, 2008). This study was expected to provide reliable information to be used by small-scale farmers and agricultural extension officers in improvement of commercial production of multi-purpose pumpkin.

CHAPTER TWO

LITERATURE REVIEW

2.1 Pumpkin Production in Kenya

The name "pumpkin" is derived from a French word, originally from the Greek, meaning "large melons". The term "squash" comes from a Native American word describing an edible gourd. There are three botanical species in the family of squash and pumpkin produced on trailing vines. According to Marr *et al*. (2004) by common usage, those that are round and orange are called pumpkins, while those of other shapes and colors are called squash. The vine habit for pumpkins and squash is similar, and the production or cultural practices for growing them are almost identical. Fedha *et al*. (2010) reported that varieties of pumpkin grown in Kenya are of the species *C. moschata* (butternut squash) and *C. maxima* (squash pumpkin). They are characterized by sprawling vines and bright yellow flowers.

Pumpkin is one of the leafy vegetables grown in Kenya. The area under production has been increasing since 2006 (Horticultural Validated Report, 2010). However, production of pumpkin is mainly on a subsistence basis. It is often intercropped and rarely occupies a significant proportion of the farm (Ondigi *et al.,* 2008). The production of multi-purpose pumpkin as an emerging vegetable has attracted great attention due to its adaptation to a wide range of climates. It is grown for its leaves and fruits which are a good source of income, nutrition and have medicinal properties (Ndoro *et al*., 2007). Pumpkin is rich in carotenoids that keep the immune system strong and healthy. Its beta-carotene is a powerful antioxidant and anti-inflammatory agent that helps prevent build-up of cholesterol in arteries, thus reducing chances of stroke. Its alpha carotene slows down aging, prevents cataract formation and reduces the risk of muscular degeneration that usually results in blindness. Its high fiber improves bowel health, potassium lowers hypertension risk, and zinc boosts immune system and bone density (Ondigi *et al.,* 2008; Isutsa and Mallowa, 2013). Leaves are harvested during the vegetative growth of the plant, while harvesting of mature fruits occurs later in the season. The high demand for the leaf vegetable has brought about excessive defoliation during harvesting. Harvesting of pumpkin leaves reduces the fruit yield in terms of quantity and quality. Plant leaf harvesting can directly and indirectly affect growth, biomass production and partitioning (Saidi *et al*., 2009; Ibrahim *et al*., 2010).

2.2 Nutrition value of pumpkins

Pumpkins are loaded with the antioxidant beta-carotene, which has been shown to help improve immune function and reduce the risk of cancer and heart disease (Ghanbari *et* *al.*, 2007, Ondigi *et al*., 2008). In addition, the crop also contain many nutrients, including calcium, iron, magnesium, potassium, zinc, selenium, niacin, foliate, and vitamins A, C, and E. One cup of pumpkin contains 50 calories and 3 g of fiber (Murray, 2008; Stevenson *et al*., 2007; Provesi *et al*., 2011; Radovich, 2011). Woomer and Imbuni (2005) reported that pumpkin fruit contains 1% protein and 8% carbohydrate, while the dry seed contains 23% protein, 21% carbohydrate and 50% oil beneficial in human nutrition. The nutritive value of 100 g of the edible portion of the leaf is 57 kcal energy, 82 g water, 5 g protein, 1 g fat, 2 g fibre, 8 g carbohydrates, 392 mg calcium, and 112 mg phosphorus (Gopalan, 2004). In Central and North America, seeds are used as anti-helminths to remove tapeworms, especially in pregnant women and young children who cannot tolerate stronger and toxic remedies (Caili *et al*, 2006).

2.3 Morphological Characteristics of Multi-Purpose Pumpkin

Multi-purpose pumpkin is an annual herb, climbing laterally using 3 to 4-branched tendrils. Stems are obtusely angular, long running, initially pubescent, often rooting at nodes. Leaves are alternate, simple, without stipules. Petioles are 9 to 24 cm long, grooved; blades are broadly ovate, shallowly palmate, 5 to 7-lobed, 10 to 35 cm in diameter, deeply cordate at the base. Margins are toothed, softly hairy, sometimes with white markings disappearing at senescence, 3-veined from the base. Flowers are solitary, unisexual, regular, 5-merous, large, 10–20 cm in diameter, lemon yellow to deep orange. Sepals are free, subulate to linear, 1 to 3 cm long; corolla campanulate, with widely spreading lobes. Male flowers are long-pedicelled, with 3 stamens, while filaments are free, and anthers are usually conniving into long twisted bodies. Female flowers are shortly pedicelled, with inferior, ellipsoid, 1-celled ovary. Styles are thick, while stigmas are 3, bi-lobed as shown in Figure 1.

Figure 1: Male (left) and female (right) blossoms.
Source: Pumpkin and squash production Fact sheet (2000), Ministry of Agriculture Food and Rural Affairs, Ontario USA

The male flowers occur near the centre of the vine and have long stalks. The female flowers are located on short ridged stems further down the vine. The female flower can be recognized by the oval shape at the base of the flower which develops into a fruit (Grubben and Chigumira, 2004 and Azeez *et al*., 2010; Radovich *et al*., 2011). Pumpkin fruit is a large, globose to ovoid or cylindrical berry, weighing up to 10 kg, with a wide range of colors, often covered with green spots and grey stripes, with small, raised, wart-like spots (Fedha *et al*., 2010). The flesh is yellow to orange and has many-seeds. The fruit stalk is enlarged at the apex. Seeds are obvoid, flattened, 1–2 cm × 0.5–1 cm, usually white or tawny, sometimes dark-colored, with smooth to somewhat rough surface and a prominent margin (Fedha *et al*., 2010). *Cucurbita moschata* has a hard, smoothly angled fruit stalk widened at apex, hard, smoothly grooved stems and soft, moderately lobed leaves. (Grubben and Chigumira-Ngwerume, 2004).

2.4 Climatic Requirements

2.4.1 Temperature

Pumpkins and other members of the Cucurbitaceae family are frost-sensitive and require a relatively long, warm growing season (Walker, 2011). They need a frost-free growing period of 4 to 5 months (Napier, 2009). Soil temperatures above 16^{o}C are required for seeds to germinate; when the soil temperature rises to 20^{o}C, seeds emerge within a week, and at 25^{o}C, within four days of planting (Napier, 2009). Pumpkins and squashes grow best at temperatures of 23°C -29°C day and 15°C - 21°C night. Growth virtually stops at temperatures below 10°C and the plants may be severely injured and maturity delayed by temperatures below 5°C for several days. Plants are usually killed within one hour or more of frost (temperature below 0°C). High temperatures (above 35^{o}C) and low humidity are not conducive to high yields. Plastic mulch and/or row covers can be used to raise soil temperatures and provide some frost protection. Low temperatures also have an adverse effect on flowering and fruit set. During periods of cool temperatures (below 22°C) most pumpkin and squash cultivars respond by producing primarily male flowers (Walker, 2011).

2.4.2 Soil

Pumpkins grow best on fertile, light, well-drained soil supplied with organic matter. They do not tolerate wet or poorly aerated soils. Large amounts of soil organic matter and a soil pH of 6.5 to 7.5 favor maximum production (Napier, 2009; Walker, 2011). Tests should be done to confirm the soil pH, texture and structure. Pumpkins can be grown on a wide range of soil types and their roots can penetrate up to a meter deep.

2.4.3 Water requirements

Pumpkins contain 80-90% water and so they use a lot of water during growth. According to Marr *et al*. (2004) watering should be done in the morning instead of late in the evening to help reduce occurrence of fungal diseases. If overhead sprinklers are used, water should be applied in the morning to give leaves a chance to dry before nightfall. Sprinkling should not be done in the mid-morning during bloom when bees are active for it reduces bee activity, resulting in poor fruit set and small and misshapen fruits. There are, however, three critical growth stages when moisture stress can be a major problem: seedling emergence, early bloom, and 10 days before harvest (Marr *et al*., 2004). Shortages of water at bloom-time can result in poor fruit set and misshapen fruits. When leaves begin to wilt, blossoms drop rather than set fruits. Moisture stress 10 days before harvest can result in a rapid decline of vines with a reduction in fruit size (Walker, 2011). According to Marr *et al*. (2004), it is best to water plants at the roots rather than sprinkling from above. Drip irrigation and soaker hoses are efficient. Pumpkins require uniform irrigation for optimum growth and yield. The quantity of water required varies with the soil type, irrigation method and weather conditions.

Irrigation is crucial during times of flowering, fruit set and fruit fill (Napier, 2009; Walker, 2011). If plants are stressed at these times, flowers and young fruits fall off. Irrigation should be reduced as the fruits reach maturity. Irrigation should be timed with the use of scheduling equipment. Tensiometers are the most common and cost-effective scheduling equipment. If no scheduling tools are used, 25 to 40 mm of water per week should be applied during warm weather and crops should be irrigated at least once a week during critical periods (Napier, 2009). Pumpkin plants tolerate wet conditions fairly well, but foliar diseases and fruit rots increase. Plants also root adventitiously at the nodes, helping with water uptake (Radovich, 2011). If irrigation is available, 2.5-3.75 cm of water per week during flowering and fruit development should be applied. The seasonal crop water requirement for the pumpkin squash was estimated to be 442.12 mm (Fandika *et al*., 2011).

2.4 Flowering and Pollination

Both male and female flowers are produced on the same plant. However environmental factors and various management factors affect the ratio of male to female flowers. Normally, several male flowers form before female flowers develop. During periods of cool temperatures (below 22°C) most pumpkin and squash cultivars respond by producing primarily male flowers (Wien, 2005). Ten weeks after planting, the first flowers suddenly appear between leaves and tendrils. Each female flower blooms for only one day. The flowers start to unfurl just before dawn, and during a four-hour period, they open into luxurious velvet bowls. By mid-day, they are on a slow course of folding-in on themselves and by dusk, they are said to be sealed forever (Bratsch, 2009). The female blossoms usually only last 24 hours and fall off if not pollinated. Bees are the main facilitators of pollination of pumpkins.

Pumpkin is a cross pollinated plant and depends on insects to effect pollination. For complete pollination, each female blossom should be visited by bees about 15 times; otherwise, small malformed fruits develop (Marr *et al*., 2004; Vidal, 2010). Pollination is vital for good fruit set and the use of bees in pumpkin production is required for high yields. Two to three hives per hectare is recommended (Schulthesis, 2005; Strang, 2010). Good fruit set and development needs 500 to 1,000 live pollen grains on the stigma of the female flower. The more the pollination takes place, the more the seeds that develop. Production of seeds allows growth regulating compounds to be formed to enhance fruit size. The flowers of pumpkins, in general, are not overly attractive to pollinating bees but the bees must be in close proximity to the crop (Schultheis, 2005; Strang, 2010). Pollination occurs during a two- to three-week period of intense blooming (Bratsch, 2009). Temperature is important with pollination, as high and low temperatures can cause death or low production of pollen (Wien, 2005; Surcică, 2010). This can result in fruits not setting, or the fruits abort when they reach golf ball size. Cross-pollination can take place between different species of Cucurbitaceae, but this will not affect yield or the shape of crop set on the vine. However, seed from the resulting cross produces genetically different plants to the parents and should not be saved (Bratsch, 2009).

2.5 Sex Expression

The sex expression of summer squash and pumpkin is determined by hormones produced within the plant as well as environmental conditions (Yongan *et al*., 2002; Wien *et al*., 2004). Temperature, light, humidity and soil moisture are all involved in determining the ratio of female to male flowers. Both day length and temperature can determine the flower type. High temperatures and long days tend to keep the plants in the male phase, whereas low temperatures and short days speed up the development of female flowers (Hassell, 1999; Johnson, 2011).

2.6 Yields and Fruit Size

Fruit size is generally controlled by genetics but any factor that limits plant growth will adversely affect fruit size (Searle, 2003). This includes water, temperature, insects, diseases, pollination, fertility, soil type, plant population, and weeds, among others. While irrigation is needed in more valuable crops, when plants are under moisture stress, extra water can help maintain or improve good fruit size (Yi-jie *et al*., 2011). Pumpkin should be harvested when mature with a deep orange color and hard enough rind to resist bruising. Harvesting can be delayed until plants begin to shrivel and dry. Yields vary between pumpkin types and varieties. The average yield for all pumpkins across Australia is about 18 t/ha but Yields can be much higher than this under intensive irrigated cropping systems (Nappier, 2009).

Grey pumpkins are a higher yielding type of pumpkin than Japanese or butternut pumpkins. Under irrigation, experience has shown that a good yield for grey pumpkins is between 30 and 40 t/ha. Higher yields can often be achieved with hybrid types. Information from Michigan indicates that in general, good to excellent yields of Halloween pumpkins are generally 37.5 to 50 tons per hectare. Horticultural Validated Report (2010) report indicates that 979ha of pumpkins were cultivated in Kenya in the year 2010. These produced 20,769 metric tons of leaves and fruits lamped together and was worth Ksh 529,519.00

2.7 Effects of Water on Various Growth Processes, Physiological Responses and Yields

Low leaf water potentials influence leaf production through their effects on leaf initiation in meristems and there is evidence that vegetative growth is reduced as moisture stress is increased (Hussain, 1994). Prolonged exposure to low soil moisture, due to lack of rainfall or irrigation, has been shown to significantly reduce fruit yield and quality (Yi-jie *et al*., 2011). Transient water deficits are also observed in cucumber plants when transpiration rates exceed the rate of water uptake by the root system, such as at midday. Plant water deficits are evidenced by leaf wilting, closure of stomata, and ultimately, a reduction in photosynthetic rate (Ackerson *et al*., 1981; Genty *et al*., 1987; Ramalho *et al*., 2014). Amer (2011) working on tomato reported that the total plant biomass decreased with stress level, while the fruit dry matter increased. He also found that the harvest index (fruit dry matter weight/plant dry matter weight) was increased with stress level while both the number and size of tomato fruits decreased with moisture stress. The total soluble solute content was increased with stress level, while the fruit water content was decreased. In another experiment by Amer (2011) on field grown melon where 6 and 12 day intervals were used, the highest yield was obtained from the treatment employing the greatest frequency and quantity of irrigation. Most fruit traits were also significantly affected by differences in irrigation treatments.

Asoegwu (1988), working on fluted pumpkin (*Telfairia occidentalis* Hook.) using irrigation frequencies of 3, 6, and 9 days intervals compared to no irrigation, reported that irrigation prolonged the productive life of the crop and enhanced leaf and pod yields. Irrigation at 3 days interval gave the best leaf and pod yield and the highest percentage of plant survival. Yi-jie *et al*.(2011) in an experiment to test the response of muskmelon to drip irrigation water inside a plastic greenhouse ,reported that plant development and fruit production were significantly affected under different irrigation amounts with higher soil water content enhancing vegetative growth, increasing the plant height and stem diameter. It was further reported that variation on soil water content not only had effects on fruit size but also on fruit yield. The highest fruit yield and irrigation water use efficiency was obtained from the treatment employing the greatest irrigation thresholds and quantity of irrigation. In another study by Sezen *et al*. (2011) comparing drip and sprinkler irrigation strategies on sunflower seed oil yield and quality, it was concluded that irrigation treatments influenced significantly sunflower seed and oil yields, and oil quantity. Seed yields decreased with increased water stress levels under both irrigation methods. Amer (2011) found that squash fruit yield, seed yield and their quality were significantly affected by irrigation method and quantity. Adequate irrigation quantity under trickle irrigation enhanced squash yield and improved its quality.

2.8 Effects of Leaf Harvesting

Plant leaves play a very important role in plant growth, development and production in that they function as centers of photosynthesis and thus a source of assimilates required for the above-mentioned metabolic processes, among others (Ibrahim *et al.,* 2010). The leaves form the photosynthetic machinery of the plant and their removal therefore constitutes a reduction in photosynthetic tissue and photo-assimilates needed in crop growth. Ibrahim *et al.* (2010) reported that defoliation alters hormone balance, starch, sugar, and protein and chlorophyll concentrations of source leaves as well as stomatal resistance and senescence rate. Madakadze *et al*. (2007) working on defoliation on jute mallow reported that defoliation made the plant concentrate on recovering the lost leaf area that is essential for photosynthesis rather than on reproduction, resulting in a reduced seed yield. The older leaves left on the plant were less efficient in photosynthesis and this also reduced seed yield. Saidi *et al*. (2009) concluded that cowpea leaf vegetable yield was significantly affected by leaf harvesting intensity with lower seed weight recorded in more frequent harvesting at 7-day interval than for 14-day interval. The number of pods per plant was also significantly affected with the highest number of pods produced in the control (where no leaf harvesting was done). The number of seeds per pod increased with decrease in leaf harvest frequency from 7-day to 14-days.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Experimental site

The research was conducted on station in two different sites of the Kenya Agricultural and Livestock Research Organization (KALRO) Centres at Kabete and Embu. KALRO Kabete, also referred to as the National Agricultural Research Laboratories (NARL) station, is located 8 km northwest of Nairobi at longitude 36°41'E and 01°15'S and an altitude1737 m above sea level in upper mid-land agro-ecological zone (Jaetzold *et al*., 2005). The area is sub-humid with average annual maximum and minimum temperatures of 23.8^{o}C and 12.6^{o}C, respectively. It has a bimodal rainfall pattern and an average annual rainfall of 980 mm, ranging from 600 mm to 1800 mm, in two distinct rainy seasons (Jaetzold *et al*., 2005). The long rains fall between mid–March and June, and the short rains between mid-October and December (Jaetzold *et al*., 2005). The soil is well drained, very deep dark-reddish brown to dark-red, friable clay classified as a Humic Nitisols, according to the Soil Map of the World, and known locally as the Kikuyu red clay loam (Jaetzold *et al*., 2005).

KALRO Embu is located in Embu County and lies 00^{0} 33.18'South; 037^{0} 53.27'East and 1420 m above sea level in upper midlands agro-ecological zone. The area is sub-humid with average annual maximum and minimum temperatures of 27^{o}C and 12^{o}C respectively (Nicholson, 2000; Jaetzold *et al*., 2005). The soils are deep Nitisols of moderate to high fertility. It has a bimodal rainfall pattern and an average annual rainfall of 1250 mm per year, which is divided into two distinct rainy seasons .The long rains fall between mid–March and June, and the short rains between mid-October and December (Ouma *et al*., 2002).

3.2 Experimental Design and Treatment Application

A two factor split-plot design embedded in a Randomized Complete Block Design with four replications in each site was used. Individual plots in a block measured 2 m x 2 m separated from each other by 1 m buffer. The two factors were irrigation rate and leaf harvest intensity each at four levels. Irrigation was applied to main plots and leaf harvest intensity to sub-plots. Specially designed drippers from Amiran Kenya were used to apply equal discharge to plants. To achieve the different irrigation rates, drippers were opened for half an hour, one hour, one and a half hours, and two hours per plant once a week. The leaf harvest entailed manual picking of mature well developed edible leaves from every branch according to the treatments which were none, one, two and three leaves harvested per branch per fortnight for 10 weeks starting from 8 weeks after emergence. Fruits were harvested when physiologically mature

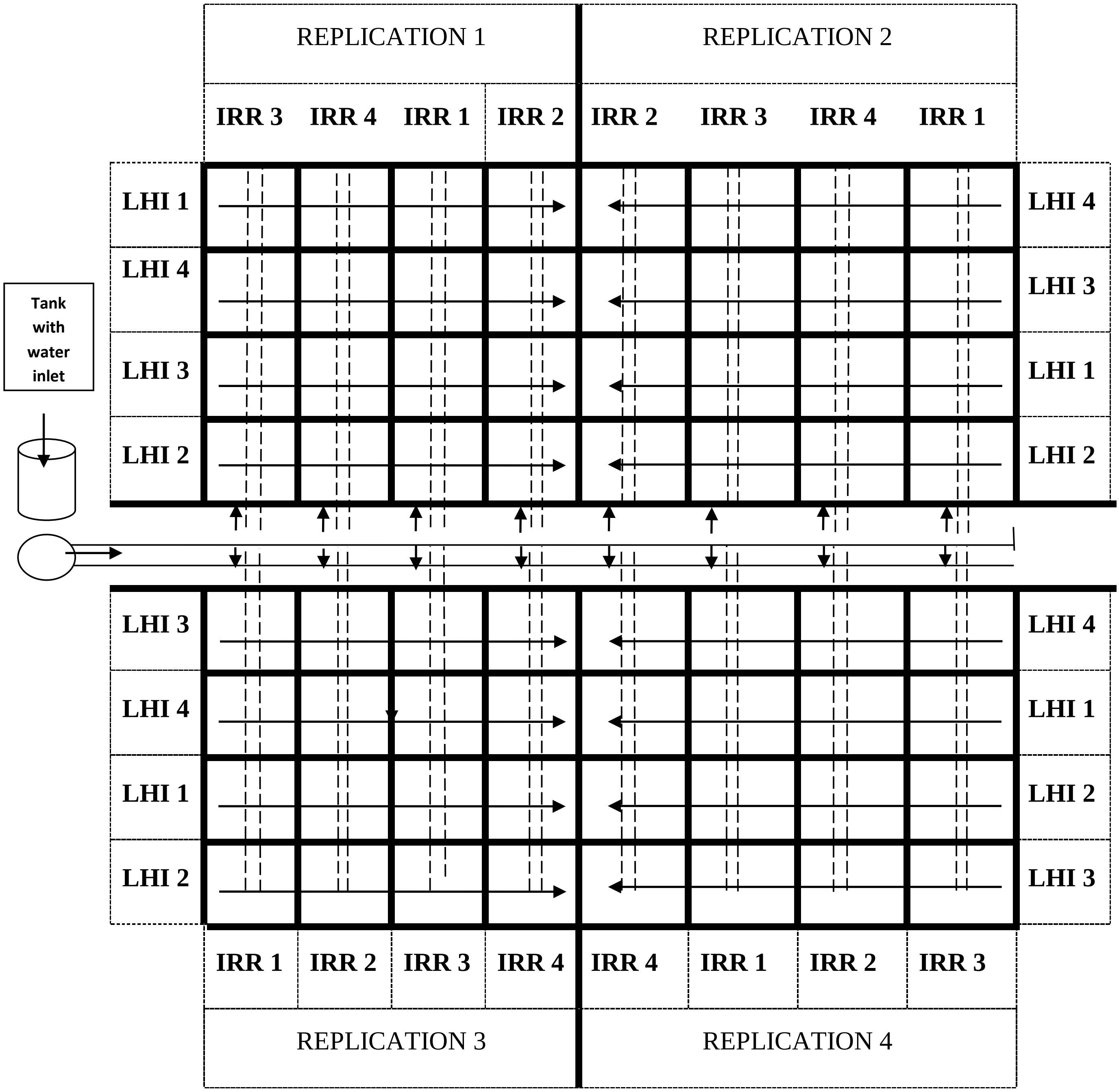

Figure 2: Experimental layout, where IRR = Irrigation rate; LHI = Leaf harvest intensity; Thick lines mark replicates and sub-plots.; Dotted lines show the laterals.

3.2.1 Treatment combinations

The sixteen treatments were replicated four times. Randomization was done for each replicate separately. Each treatment was assigned a unique number which was written on a paper, folded and placed in a bowl and all of them mixed thoroughly. A blind folded assistant picked the numbers and allocated them to the sub- plots. The treatment combinations were as shown in table 1 below.

Table 1: Treatment combinations

	Litres of irrigation water per plant per week	Leaf harvest intensity per branch per fortnight
IRRILHI1	1	0
IRRILHI2	1	1
IRRILHI3	1	2
IRRILHI4	1	3
IRR2LHI1	2	0
IRR2LHI2	2	1
IRR2LHI3	2	2
IRR2LHI4	2	3
IRR3LHI1	3	0
IRR3LHI2	3	1
IRR3LHI3	3	2
IRR3LHI4	3	3
IRR4LHI1	4	0
IRR4LHI2	4	1
IRR4LHI3	4	2
IRR4LHI4	4	3

3.3 Crop Establishment and Horticultural Practices

Soil testing was done at KALRO NARL to determine its fertility and suitability for pumpkin production and give recommendations on fertilizer and manure quantities to be used (Appendix I). The field was thoroughly ploughed to a fine tilth and leveled. The main plots and sub-plots were laid out and drip irrigation system installed. Overhead rain shelter was constructed to keep out rain water. Three multi-purpose pumpkins were bought in the market and seeds extracted. The seeds were treated and three seeds were sowed in each planting hole. All treatment plots received the same amount of basic fertilizer and well rotten farmyard manure according to the soil test recommendations. In Kabete site, 2 tons/acre of well decomposed manure were mixed well with the soil during the last stage of land preparation. At planting time, 120kg/acre calcium ammonium nitrate (CAN) was mixed with 80kg/acre of single superphosphate and applied. After thinning the crop was top dressed with 60kg/acre of (CAN) followed by 120kg/acre of CAN prior to flowering. At Embu site, 2 tons/acre of well decomposed manure were mixed well with the soil during the last stage of land preparation. During planting, 120kg/acre of single superphosphate was applied. After thinning the crop was top dressed with 60kg/acre of (CAN) followed by 120kg/acre of CAN prior to flowering.

After germination, seedlings were thinned to leave one per hole. All plots were irrigated to 100% field capacity immediately after sowing, but subsequent irrigations were carried out according to the treatments (Figure 2). Weeding with a hoe was done as and when required. Vines were coiled when required but leaving them in contact with the soil so as to freely develop roots into the soil at nodes. Crop protection was done when required using recommended pesticides. Irrigation water was applied using drip lines which discharged two litres of irrigation water per hour. To achieve the different treatments, the irrigation time was varied from half an hour to 2 hours.

3.4 Plant Materials

Cucurbita moschata Duch., landrace was used. This species is commonly cultivated in most parts of Kenya. It is predominantly multi-purpose, as it is cherished for its edible leaves, fruits and seeds. Uniformly appearing pumpkin fruits were purchased from the local market, seeds extracted, air-dried and stored in a cool dry place to await planting.

3.5 Routine Management Practices

Shallow weeding was done three times during the crop period especially in the first two months. Weeds were uprooted manually from the second month until harvesting to avoid crop disturbance and injury. The crops faced a challenge of Aphids and Powderly mildew which were addressed using Cotaf 5% EC (Hexalonazole) for Powderly mildew and Confidor 70 WG (imidacloprid 700g/kg) for Aphids. Plants were trained to avoid tangling.

3.6 Data Collection

To determine the effects of the treatments, various variables were assessed. These variables are described below.

3.6.1 Branches and Leaves

The number of branches was counted and recorded on fortnight basis for ten weeks starting from eight weeks after emergence. Each plant was an experimental unit and data was therefore collected on all the plants.

3.6.2 Leaf area

Four leaves per plant each from a different branch at the thirteenth node were used to determine the leaf area. The leaf area was measured using linear measurements. This method is non-destructive and was done one week after the onset of flowering. The leaf length x width x a constant was used to estimate the leaf area using a formulae given by Gao (1999) that stated that: $y = 0.838x - 0.558$, where y = area, and x = length × width.

3.6.3 Sex expression

Counting of male and female flowers weekly for three weeks from the onset of flowering season was done. Each plant was an experimental unit and data was therefore collected on all the plants.

3.6.4 Leaves

One, two and three leaves were harvested per branch according to the treatments. The harvested leaves were counted and weighed starting from eighth week after seed emergence for a continuous period of 10 weeks at fortnightly interval. The leaf vegetable weight for each treatment was obtained at the different leaf harvesting dates and expressed in grams.

3.6.5 Fruits

Fruit harvesting was done on piece meal as they matured that is fruits that had a dry stalk and its skin was hard and dull. Harvesting was carefully done to leave a stalk of 3cm on the fruit. Fruits were counted and weighed and the weight expressed in kilograms.

3.6.6 A thousand seed weight

Three fruits were randomly selected from each treatment, the seeds were removed, air-dried and 1000 seeds counted and weighed to get the 1000 dry seed weight in grams per fruit.

3.6.7 Fruit quality

The size of the fruits was determined using the average length × width of three randomly selected fruits per treatment. Edible flesh thickness was used to estimate fruit quality. Three mature fruits randomly selected to represent a treatment were cut into two halves and the edible flesh thickness measured using a Vernier-caliper (Khattab *et al*., 2009). The average flesh thickness was used as the thickness for each treatment.

3.6.8 Seed viability and growth rate

Four replicates of 10 seeds from each sample were subjected to germination test. Germination percentage was calculated by counting the number of emerged seedlings and expressing it as percentage. Seedling growth rate was determined through measuring the rate of growth (stem length, stem thickness/girth, root length and leaf number at 2 weeks from emergence) (AOSA, 1993).

3.7 Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) at $\alpha = 0.05$ using JMP IN 5.1 (Sall *et al*., 2003). Mean separation for all significant treatments were carried out using Tukey's Studentized Range Test at $P \leq 0.05$. Correlation analysis was carried out on the interactions to find out their relationship to the independent factor.

The model fitted for the experiment was:

$Y_{ijk} = \mu + \beta_i + W_j + W_{ij} + L_k + WL_{jk} + \varepsilon_{ijk}$

Where:

Y_{ijk} = pumpkin response

i = Blocks 1, 2, 3, 4.

j = Irrigation levels 1, 2, 3 and 4

k = Leaf harvesting intensities 1, 2, 3 and 4

μ = Overall mean

β_i = Effect of the i^{th} block

W_j = Effect of the j^{th} irrigation

W_{ij} = Main plot error (a)

L_k = Effect of the k^{th} leaf harvesting intensity

WL_{jk} = Effect of the interaction between j^{th} irrigation and k^{th} leaf harvesting intensity

ε_{ijk} = Random error component(b) which is normally and independently distributed about zero means with a common variance σ^2.

CHAPTER FOUR

RESULTS

4.1 Effects of Irrigation Rate and Leaf Harvest Intensity on Growth Parameters

4.1.1 Effects on number of branches

4.1.1.1 Effects on number of branches at Embu

Irrigation rate had a significant effect (P<0.05) on the number of branches during the 14th week after emergence (WAE) at Embu (Table 2). Application of three litres of irrigation water per week produced the highest number of branches (214). In both sites, the number of branches increased with the increase in the irrigation rate up to three litres of irrigation water after which the number of branches started to decrease. Application of one litre of irrigation water per week produced less number of branches (189) compared with the others, although not significantly different. Leaf harvest intensity had no significant effect (P< 0.05) on the number of branches in Embu (Table 2). Harvesting of one leaf per branch gave the highest total number of branches (212). Plants where leaves were not harvested produced the lowest number of branches (189) as compared to other treatments.

Table 2: Mean number of pumpkin branches at Embu as influenced by irrigation rate and leaf harvest intensity from 8th to14th week after emergence (WAE)

Irrigation rate in litre (s)/plant/week	8 WAE	10 WAE	12 WAE	14 WAE
1	28.3	41.6	50.3	57.0b
2	29.7	43.5	51.0	64.0ab
3	30.3	46.8	54.3	71.4a
4	32.0	45.4	56.3	65.6ab
LHI/branch/fortnight				
None	29.3	43.1	49.2	63.3
1	32.3	45.3	56.6	63.7
2	30.1	45.9	54.1	64.1
3	28.6	43.0	51.9	66.8

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.1.1.2 Effects on number of branches at Kabete

Irrigation rate had no significant effect (P< 0.05) on the number of branches at Kabete (Table 3). All the same, a similar trend as in Embu was observed where the number of branches increased with the increase in irrigation rate up to three litres of irrigation water after which it decreased. Application of three litres of irrigation water once per week produced the highest number of branches (178.5), while application of one litre of irrigation water produced the least branches (161.3). Leaf harvest intensity had no significant effect on the number of branches in Kabete (Table 3). But a similar trend was observed where harvesting of one leaf per branch per fortnight produced the highest number of branches (175.2).

Table 3: Mean number of pumpkin branches at Kabete as influenced by irrigation rate and leaf harvest intensity from 8th to14th week after emergence (WAE)

Irrigation rate in litre (s)/plant/week	8 WAE	10 WAE	12 WAE	14 WAE
1	7.3	16.8	28.6	42.2
2	5.9	16.7	32.7	42.1
3	7.2	16.8	33.2	43.0
4	7.5	16.2	31.8	40.2
LHI/branch/fortnight				
None	7.3	18.3	34.0	41.2
1	7.5	16.9	29.0	43.7
2	5.4	15.0	27.6	38.5
3	7.6	16.2	35.0	44.0

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.1.2 Effects on male and female flowers at various days after emergence

Irrigation had no significant effect (P< 0.05) on the number of male and female flowers in Embu (Table 4). According to the results, application of two litres of irrigation water per week produced the highest number of male flowers (61.7) and also stimulated early flowering. Application of one litre of irrigation water per week produced the highest number of total female flowers (21.0) and the least number of total male (56.2) flowers, while application of three litres of irrigation water produced the least number of total female flowers (18.2).

Leaf harvest intensity had a significant effect (P<0.05) on the number of male and female flowers produced at 80 days after emergence, on female flowers at 108 days after emergence and on total male and female flowers at Embu (Table 4). Harvesting of one leaf per branch once per fortnight and not harvesting produced more male (68.1) and female (23.5) flowers in Embu compared to the other leaf harvest intensities (a ratio of 3:1). Harvesting of three leaves per branch per fortnight produced the least number of total male (47.6) and female flowers (15.7) although the ratio was the same (a ratio of 3:1).

Table 4: Mean number of male and female flowers at Embu as influenced by irrigation rate and leaf harvest intensity from 80th to 108th days after emergence (DAE)

Irrigation rate in litre (s)/week/plant	80 DAE		94 DAE		108 DAE	
	Male	Female	Male	Female	Male	Female
1	22.6	12.7	31.4	15.4	22.3	12.9
2	21.9	12.6	34.8	14.4	25	12.3
3	18.3	11.9	33.3	13.9	25.6	12.4
4	22.5	11.5	29.9	14.3	25.9	12.6
LHI/branch/fortnight						
None	22.8a	12.6ab	32.9	14.1	24.5	13.0b
1	27.0a	14.2a	35.8	15.6	25.4	13.8a
2	21.1a	11.4ab	31.2	14.6	25.2	12.1b
3	14.3b	10.5b	29.6	13.7	23.7	11.5b

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

Kabete

Irrigation rate had a significant effect (P<0.05) on the number of male flowers at 80 days after emergence in Kabete (Table 5) with application of three litres of irrigation water producing significantly more flowers (12.4) compared to the others. Application of three litres of irrigation water per week produced the highest total number of male (49.9) and female flowers (22.3) (a ratio of 2:1), while application of one litre of irrigation water produced the least number of male (39.8) and female (17.8) flowers although the ratio remained the same (a ratio of 2:1).

Leaf harvest intensity had a significant effect (P<0.05) on the number of male flowers at the 94th day after emergence (Table 5). Harvesting of three leaves produced the highest number of male flowers (24.3) although this was not significantly different from harvesting of one leaf per branch per fortnight. Harvesting of three leaves per branch per fortnight produced more total male (48.8) and total female (22.4) flowers (a ratio of 2:1) in Kabete compared to the other leaf harvest intensities.

Table 5: Mean number of male and female flowers at Kabete as influenced by irrigation rate and leaf harvest intensity from 80th to108th days after emergence (DAE)

	80 DAE		94 DAE		108 DAE	
Irrigation rate in litre (s)/plant/week	Male	Female	Male	Female	Male	Female
1	10.3b	10.3	20.1	12.5	29.4	15.1
2	10.4b	10.7	18.5	12.2	32.4	17.4
3	12.4a	10.8	23.9	13.9	33.7	17.7
4	10.6b	10.4	17.7	12.5	33.5	16.6
LHI/branch/fortnight						
None	10.5	10.1	17.5b	12.5	34.8	15.4
1	11.7	10.9	20.9ab	13.1	34.0	17.8
2	10.6	10.6	17.5b	12.3	26.8	14.9
3	10.9	10.5	24.3a	13.3	33.5	18.6

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.1.3 Effects on leaf area

Irrigation had no significant effect on the leaf area in Kabete but was slightly significant ($P<0.05$) in Embu. Application of three litres of irrigation water per week gave the highest leaf area in both sites (Table 6). The significant difference observed in Embu could have been by chance since the trend in both sites was similar.

Leaf harvest intensity had a significant effect ($P<0.05$) on the leaf area in Embu with harvesting of one leaf per branch per fortnight producing the leaves with the largest leaf area (Table 6). Leaf area was not significantly different from that of harvesting three leaves and no leaf harvesting. In Kabete, harvesting of three leaves had the highest leaf area (446 cm^2) although it was not significantly different from the others.

Table 6: Mean leaf area in cm^2 at Embu and Kabete as influenced by irrigation rate and leaf harvest intensity

Irrigation rate litre(s) /week/plant	Embu	Kabete
1	502.3a	438.9
2	440.5b	436.5
3	524.0a	446.0
4	497.3a	374.5
LHI/branch/fortnight		
None	491.1ab	421.1
1	511.8a	403.8
2	468.8b	410.5
3	492.4ab	460.3

*Means followed by the same letter(s) within a column are not significantly different ($P<0.05$) according to the Tukey's Studentized Range Test

4.1.4 Effect on number of aborted flowers

Irrigation rate had no significant effect ($P< 0.05$) on the aborted flowers in both sites (Table 7). Nevertheless, application of low water rates (one and two litres of irrigation water) resulted in more flower abortion compared with application of three and four litres of irrigation water. Irrigation rate of one litre of irrigation water per week had the highest flower abortion of 11.0 and 9.9 in Embu and Kabete, respectively. Application of four litres of irrigation water per week had the lowest aborted flowers of 8.4 and 8.3 in Embu and Kabete, respectively. The number of flowers aborted decreased with the increase in irrigation rate.

Leaf harvest intensity had a significant effect (P<0.05) on the aborted flowers in Embu (Table 7). The same trend was observed at Kabete site although it was not significantly different. This greatly affected the total fruit yields. Flower abortion was higher in treatments where three leaves were harvested per fortnight (14.0 and 10.8) in Embu and Kabete, respectively. Harvesting of one leaf per fortnight had the least aborted flowers (5.7) in both sites. The number of flowers aborted increased with the increase in leaf harvest intensity.

Table 7 : Mean number of aborted female flowers at Embu and Kabete as influenced by irrigation rate and leaf harvest intensity

Irrigation rate in litre(s) /week/plant	Embu	Kabete
1	11	9.9
2	9.9	8.8
3	8.2	5.7
4	8.4	8.3
LHI/branch/fortnight		
None	5.7c	5.7
1	8.1ab	6.8
2	9.7ab	9.3
3	14.0a	10.8

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.2 Effect of Irrigation Rate and Leaf Harvest Intensity on Yields

4.2.1 Effect on number of harvested leaves

Irrigation had no significant effect (P< 0.05) on the number of leaves harvested in both sites (Table 8 and 9). The amount of water applied per week did not influence the number of harvestable leaves produced per branch per fortnight. Application of two litres of irrigation water per week at Embu gave the highest number of total harvestable leaves (82.3) while one litre of irrigation water per week gave the highest total harvestable leaves at Kabete (77.9). Four litres of irrigation water per week gave the lowest number of harvestable leaves (73.6) at Embu and (68.4) at Kabete. At Kabete site, irrigation had a significant effect on the number of leaves harvested in the 16th week after emergence (24.7). Irrigation of one litre of water per week had the highest number of harvestable leaves (24.7) although this was not significantly different from application of two and three litres of irrigation water per week. Similarly, application of four litres of irrigation water per week produced the lowest total number of harvestable leaves (68.4).

Leaf harvest intensity had a significant effect (P<0.05) on the number of leaves harvested (Table 8 and 9). Harvesting of two and three leaves per fortnight significantly produced the highest number of harvestable leaves (101.4 and 115.4) respectively at Embu. Harvesting of three leaves per fortnight significantly produced the highest number of harvestable leaves (121.8) at Kabete. The number of harvestable leaves increased with the increase in the leaf harvest intensity.

Table 8: Mean number of number of leaves harvested at Embu as influenced by irrigation rate and leaf harvest intensity from 8th to16th week after emergence (WAE)

Irrigation rate in litre(s)/week /plant	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE
1	17.5	25.6	26.3	26.3	21.8
2	17.3	24.7	29.4	28.9	21.9
3	15.2	25.1	28.3	25.7	21.4
4	16.2	23.7	27.6	26.9	20.3
LHI/branch/fortnight					
None	10.0b	10.0c	10.0c	10.0c	10.0c
1	17.6a	24.7b	29.5b	27.5b	20.5b
2	19.4a	29.2ab	36.3a	32.6ab	27.1a
3	19.1a	35.1a	35.6a	37.8a	27.8a

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

Table 9: Mean number of leaves harvested at Kabete as influenced by irrigation rate and leaf harvest intensity from 8th to16th week after emergence (WAE)

Irrigation rate in litre(s)/week/plant	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE
1	14.9	24.9	26.2	28.0	24.7a
2	14.4	22.0	28.4	27.9	23.1ab
3	14.4	22.9	26.0	29.2	22.4ab
4	15.1	21.9	26.3	25.8	20.5b
LHI/branch/fortnight					
None	10.0	10.0c	10.0d	10.0c	10.0d
1	15.8	20.9b	25.6c	26.9b	22.4c
2	16.1	26.1b	31.9b	32.7b	26.7b
3	17.1	34.7a	39.4a	41.3a	31.6a

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.2.2 Effects on weight of harvested leaves

Irrigation rate had no significant effect (P< 0.05) on the weight of harvested edible leaves (Tables 10 and 11). The trend showed that application of three and four litres of irrigation water once per week had the highest leaf weight compared to the other treatments. This result indicated that amount of water increased the total weight of harvested leaves in 16 WAE, even if not significant.

Leaf harvest intensity had a significant effect (P<0.05) on weight of harvested leaves for each fortnight and on total weight of harvested leaves in 16 WAE (Tables 10 and 11). Harvesting of three leaves per branch once per fortnight gave the highest total weight harvested leaves in 16 WAE (1598.7 g) in Kabete, compared with the other treatments.

Table 10: Mean weight of leaves harvested at Embu as influenced by irrigation rate and leaf harvest intensity from 8th to16th week after emergence (WAE)

Irrigation rate in litre(s)/week /plant	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE
1	159.3	242.6	265.7	217.4	159.6
2	155.6	267.0	325.9	242.1	147.8
3	120.0	306.4	300.7	255.9	170.9
4	158.0	302.9	341.4	258.1	148.1
LHI/branch/fortnight					
None	10.0c	10.0c	10.0c	10.0c	10.0c
1	145.9b	309.4b	344.6b	244.8b	135.8b
2	197.8ab	405.5a	448.1ab	311.4ab	224.4a
3	239.1a	394.0ab	431.0a	407.3a	256.3a

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

Table 11: Mean weight of leaves harvested at Kabete as influenced by irrigation rate and leaf harvest intensity from 8th to 16th week after emergence (WAE)

Irrigation rate in litre(s)/week /plant	8 WAE	10 WAE	12 WAE	14 WAE	16 WAE
1	56.5	124.9	151.7	242.5	288.1
2	62.3	139.7	194.1	233.5	281.9
3	69.8	148	176.3	268.8	303.8
4	68.4	167.9	202.5	234.4	254.4
LHI/branch/fortnight					
None	10.0b	10.0c	10.0c	10.0c	10.0c
1	68.6a	109.5b	164.3b	216.0b	320.0b
2	77.9a	198.6a	229.4b	295.6b	300.6b
3	100.6a	262.3a	320.8a	457.5a	497.5a

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.2.3 Effect on number of fruits

Irrigation rate had no significant effect ($P< 0.05$) on the number of fruits per plant (Table 12). Application of one litre of irrigation water per week produced the highest number of fruits (11.9) in Embu while application of three litres of irrigation water per week produced the highest number of fruits in Kabete (12.6). Application of two litres of irrigation water once per week produced the lowest number of fruits (11.3 and 11.6) in Embu and Kabete, respectively.

Leaf harvest intensity had a significant effect ($P<0.5$) on the number of fruits in Embu (Table 12). Harvesting of one leaf per branch per fortnight significantly increased the number of fruits produced (12.2) compared with the others although not significantly different from no harvesting and harvesting of two leaves per fortnight. Leaf harvest intensity had no significant effect ($P< 0.05$) on the number of fruits in Kabete. However the trend showed a decrease in the number of fruits as the leaf harvest intensity increased. Harvesting of three leaves per branch per fortnight produced the least number of fruits (10.9 and 10.8) in Embu and Kabete, respectively.

Table 12: Mean number of fruits at Embu and Kabete as influenced by irrigation rate and leaf harvest intensity

Irrigation rate in litre(s)/week /plant	Embu	Kabete
1	11.9	12.3
2	11.3	11.6
3	11.4	12.6
4	11.4	11.7
LHI/branch/fortnight		
None	11.9ab	12.8
1	12.2a	12.5
2	11.1ab	12
3	10.9b	10.8

*Means followed by the same letter(s) within a column are not significantly different ($P<0.05$) according to the Tukey’s Studentized Range Test

4.2.4 Effects on total weight of fruits

Irrigation rate had no significant effect (P< 0.05) on the total weight of fruits (Table 13). Application of four litres of irrigation water per week produced the heaviest fruits (14.2) in Embu, while application of three litres of irrigation water produced the heaviest fruits in Kabete (17.2). Application of two litres of irrigation water per week produced the lowest weight of fruits (12.9) and (13.8) in Embu and Kabete, respectively.

Leaf harvest intensity had a significant effect (P<0.05) on the weight of fruits in both sites with one LHI giving significantly heavier fruits (15.4 and 17.7 in Embu and Kabete respectively) than three LHI (11.9 and 5.2 in Embu and Kabete respectively). However, these results were not significantly different from those of no LHI and two LHI.

Table 13: Mean weight of fruits at Embu and Kabete as influenced by irrigation rate and leaf harvest intensity (kg)

Irrigation rate in litre(s)/week/plant	Embu	Kabete
1	13.9	15.9
2	12.9	13.8
3	13.2	17.2
4	14.2	14.1
LHI/branch/fortnight		
None	14.3ab	16.2ab
1	15.4a	17.7a
2	12.5ab	11.9ab
3	11.9b	5.2b

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.2.5 Effects on weight of 1000 dry seeds

Irrigation had no significant effect (P< 0.05) on the weight of 1000 dry seeds. (Figure 3 and 4). Leaf harvest intensity had no significant effect (P< 0.05) on the weight of 1000 dry seeds. In both sites, treatments where one or no leaf was harvested gave higher weight of 1000 dry seeds compared to treatments where more leaves were harvested.

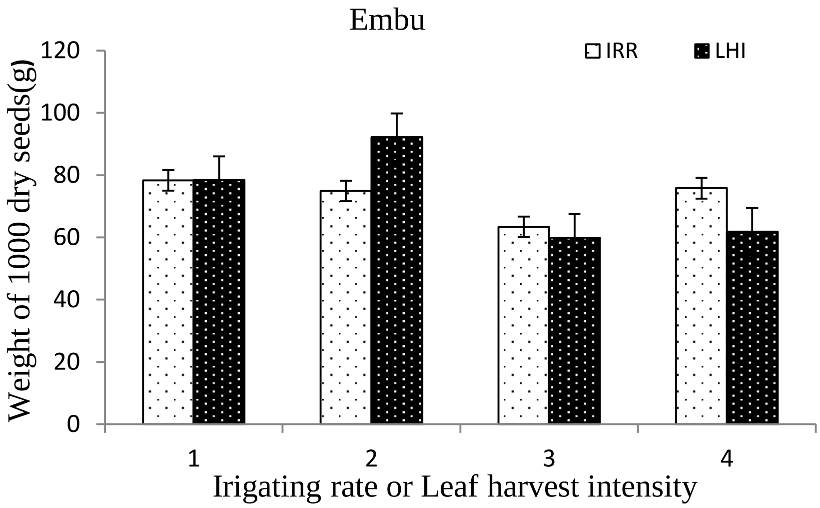

Figure 3: The mean weight of a thousand dry seeds at Embu as influenced by irrigation rate and leaf harvest intensity.

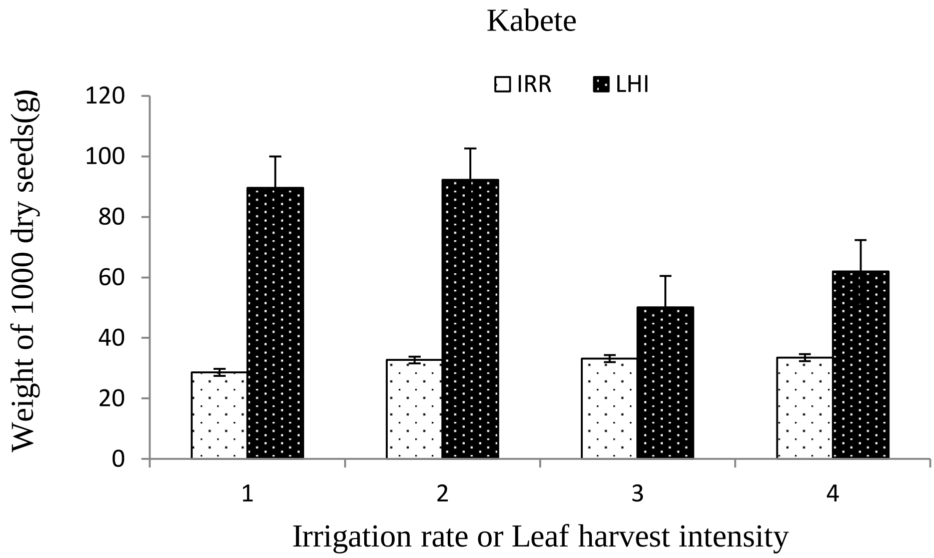

Figure 4: The mean weight of a thousand dry seeds at Kabete as influenced by irrigation rate and leaf harvest intensity.

4.3 Effects of Irrigation Rate and Leaf Harvest Intensity on Quality Parameters

4.3.1 Effects on fruit size

Irrigation rate had no significant effect ($P < 0.05$) on the mean fruit size (Figure 5 and 6). Application of four litres of irrigation water per week produced larger fruits in Embu while one litre of irrigation water per week produced larger fruits in Kabete. Leaf harvest intensity had no significant effect ($P < 0.05$) on the fruit size (Figure 4). Harvesting of one leaf per branch or no harvest produced larger fruits in both sites

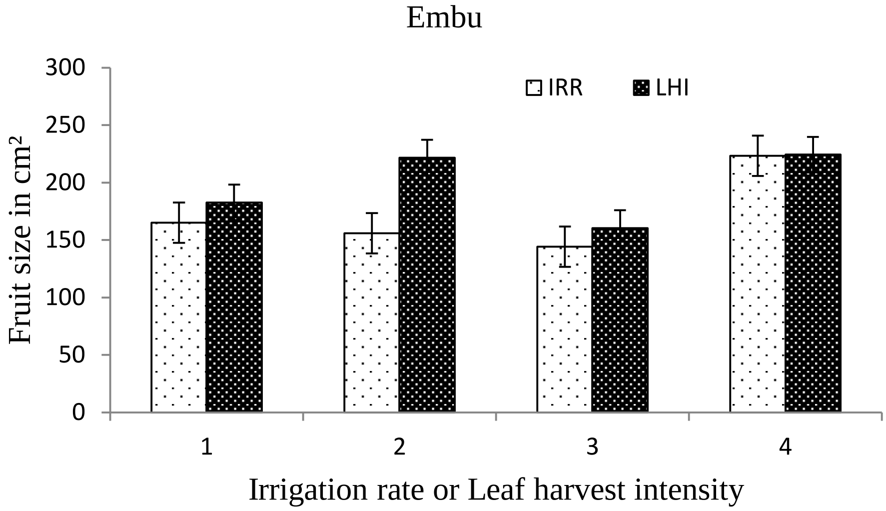

Figure 5: The mean fruit size in cm^2 at Embu as influenced by irrigation rate and leaf harvest intensity.

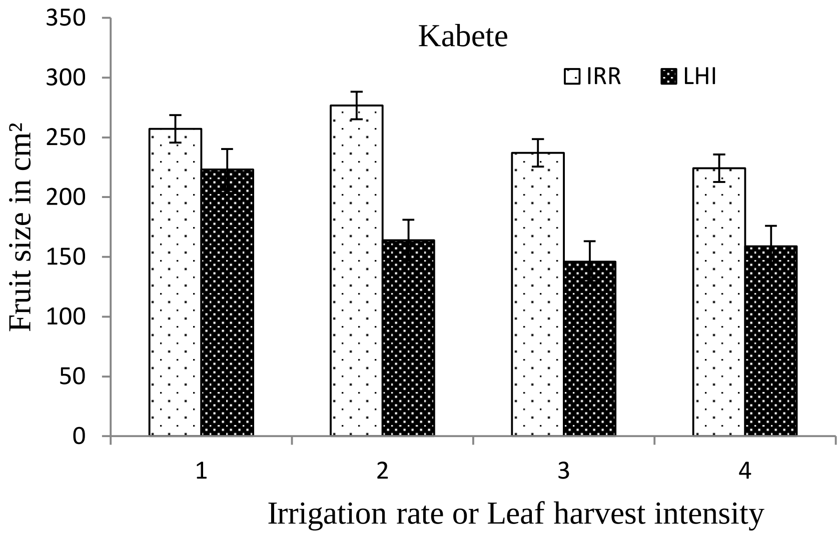

Figure 6: The mean fruit size in cm^2 at Kabete as influenced by irrigation rate and leaf harvest intensity.

4.3.2 Effects on number of seeds

Irrigation had no significant effect ($P< 0.05$) on the number of seeds per fruit (Table 14). The trend indicated that higher water rates produced more seeds than those receiving lower water rates. Application of four litres of irrigation water produced the highest mean number of seeds in Embu (309.7) and three litres 242.6 at Kabete (242.6). Application of three and four litres of irrigation water per week produced more seeds than application of one and two litres of irrigation water.

Leaf harvest intensity had a significant effect (P<0.05) on the number of seeds per fruit at Kabete site (Table 14). In treatments where no leaves were harvested and where only one leaf was harvested, the number of seeds was higher compared to treatments where more leaves were harvested. A similar trend was observed at Embu site.

Table 14: Mean number of seeds at Embu and Kabete as influenced by irrigation rate and leaf harvest intensity

Irrigation rate in litre(s)/week /plant	Embu	Kabete
1	242.0	182.5
2	212.7	195.1
3	263.7	242.6
4	309.7	232.8
LHI/branch/fortnight		
None	274.6	282.7a
1	301.1	284.2a
2	243.5	140.1b
3	208.9	146.1b

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.3.3 Effects on edible fruit flesh thickness

Irrigation rate had no significant effect (P< 0.05) on the edible flesh thickness in both sites (Figure 7 and 8). The result showed that the lower water rates (one and two litres of irrigation water per week) produced a thicker flesh thickness than application of three and four litres of irrigation water per week. Leaf harvesting intensity had no significant effect (P< 0.05) on the fruit edible flesh thickness (Figure 7and 8). All the same, the trend showed that harvesting of one leaf or no leaf harvesting produced fruits with thicker edible flesh in both sites when compared with those where two or three leaves were harvested. In both sites, harvesting of two leaves produced thicker edible flesh than the others.

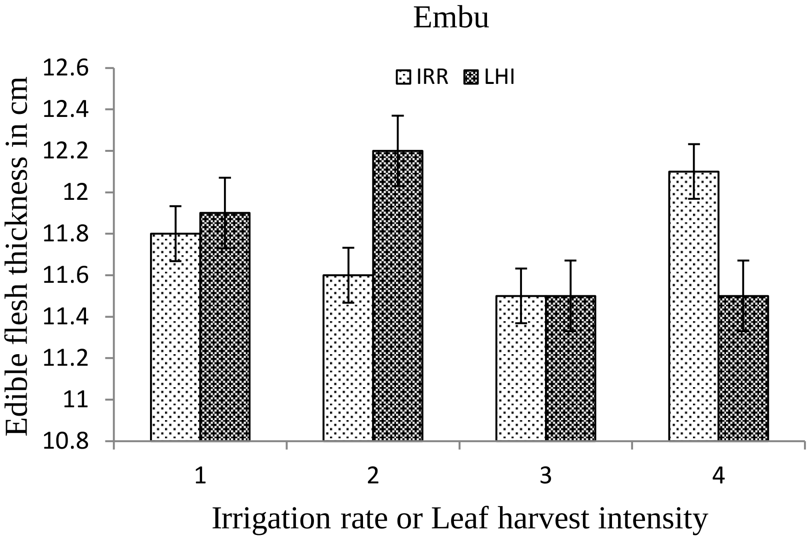

Figure 7: Mean pumpkin edible fruit flesh thickness in cm at Embu as influenced by irrigation rate and leaf harvest intensity

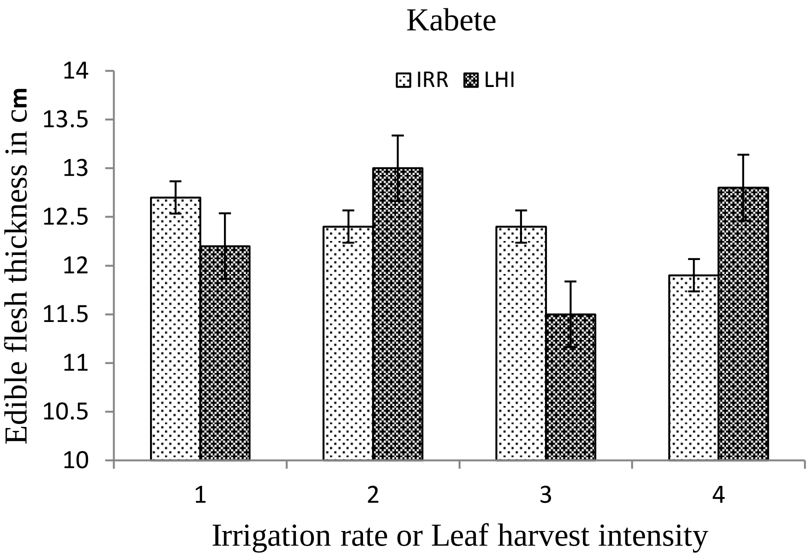

Figure 8: Mean pumpkin edible fruit flesh thickness in cm at Kabete as influenced by irrigation rate and leaf harvest intensity.

4.3.4 Effects on seed viability and seedling growth

4.3.4.1 Seed viability (germination percentage)

Irrigation rate had no significant effect ($P < 0.05$) on the viability of seeds in both sites (Figures 9 and 10). Germination started on the 5th day but higher germination was registered on 6th and 7th day after sowing and was completed by the 12th day.

Leaf harvest intensity had no significant effect (P< 0.05) on the germination percentage (Figure 9 and 10) although seeds for one harvested leaf in Embu and no harvesting in Kabete had the highest germination percentage.

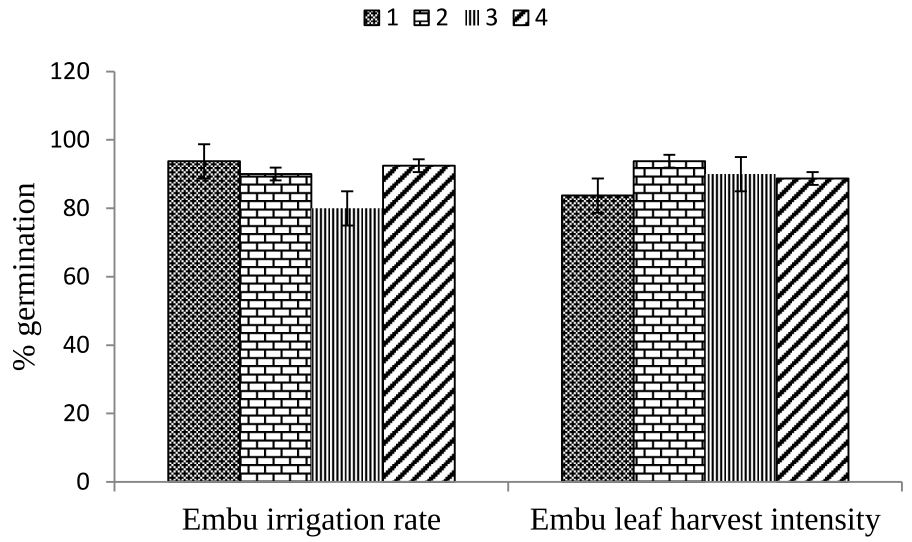

Figure 9: Mean germination percentage at Embu as influenced by irrigation rate and leaf harvest intensity. The 1, 2, 3 and 4 represent irrigation rates or leaf harvest intensity

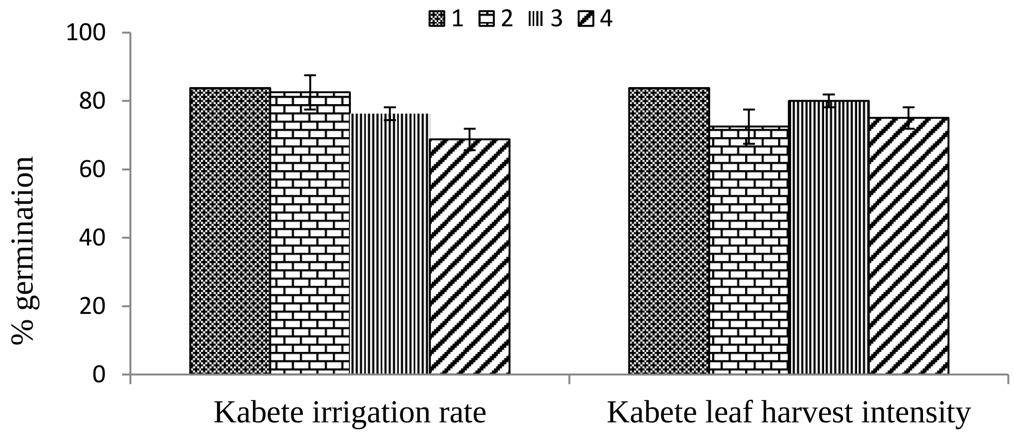

Figure 10: Mean germination percentage at Kabete as influenced by irrigation rate and leaf harvest intensity. The 1, 2, 3 and 4 represent irrigation rates or leaf harvest intensity

4.3.4.2 Seedling stem size and root length

Irrigation had a significant effect (P<0.05) on the diameter (girth) of the seedling stems at Kabete site (Table 15). Application of three litres of irrigation water per week gave the thickest stem girth (1.1 cm) compared with the other rates. Similarly, application of the same rate (three litres of irrigation water per week) at Embu site gave the thickest stem although it was not significantly different from the other rates.

Irrigation had a significant effect (P<0.05) on the length of seedling roots, with application of two litres of irrigation water producing the longest roots (7.0 cm). This was also similar to Kabete site where application of two litres of irrigation water per week gave the longest root length (4.5 cm), although not significantly different from the other rates. Higher water rates resulted in short roots compared to the lower rates. Application of higher rates increased length of seedling stems in both sites, although not significantly.

Leaf harvest intensity had a significant effect (P<0.05) on the diameter of the seedling stems in Kabete site (Table 15). The 0 LHI gave the thickest stems compared to the other treatments in Kabete

Table 15: The means on seedling growth at Kabete and Embu as influenced by irrigation rate and leaf harvest intensity

	Kabete			Embu		
Irrigation rate in litre(s)/week/plant	Stem length	Root length	Stem girth	Stem length	Root length	Stem girth
1	6.3	4.4	1.0b	7.9	5.8ab	1.2
2	6.4	4.5	1.0b	7.6	7.0a	1.6
3	6.9	3.6	1.1a	8.0	4.5b	2.1
4	7.3	3.5	1.0b	8.3	4.4b	2.1
LHI/branch/fortnight						
None	6.7	4.0	1.1a	8.0	5.1	1.7
1	6.8	3.6	1.0b	8.0	5.2	1.7
2	6.8	4.1	1.0b	7.6	5.8	1.7
3	6.6	4.3	1.0b	8.2	5.6	1.8

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.4 Effects of Interaction between Irrigation Rate and Leaf Harvest Intensity on various parameters

This section describes JMP and correlation analysis results done to test effect of interaction and the relationship between various treatments.

4.4.1 Effects on growth

4.4.1.1 Effect on number of branches

Interaction between irrigation rate and leaf harvest intensity had no significant effect ($P < 0.05$) on the number of branches (Figure 11 and 12). Three litres of irrigation water and no leaf harvest and four litres of irrigation water with one LHI gave the highest number of branches in Embu. Although these results were not significantly different from the interaction of one litre of irrigation water with one LHI, two litres of irrigation water with two LHI, four litres of irrigation water with two LHI, three litres of irrigation water with one LHI and four litres of irrigation water with two LHI or three LHI. However, a correlation analysis done between IRR, LHI and total number of branches respectively showed that irrigation had a positive correlation at 5% level whereas LHI had no correlation with total number of branches. At Kabete application of one litre of irrigation water interacted with harvesting of one leaf producing the highest number of branches. However, there was no correlation between IRR and LHI with number of branches. Generally the results show that applying three or four litres irrigation water per week combined with any leaf harvest intensity increased the number of branches in both sites.

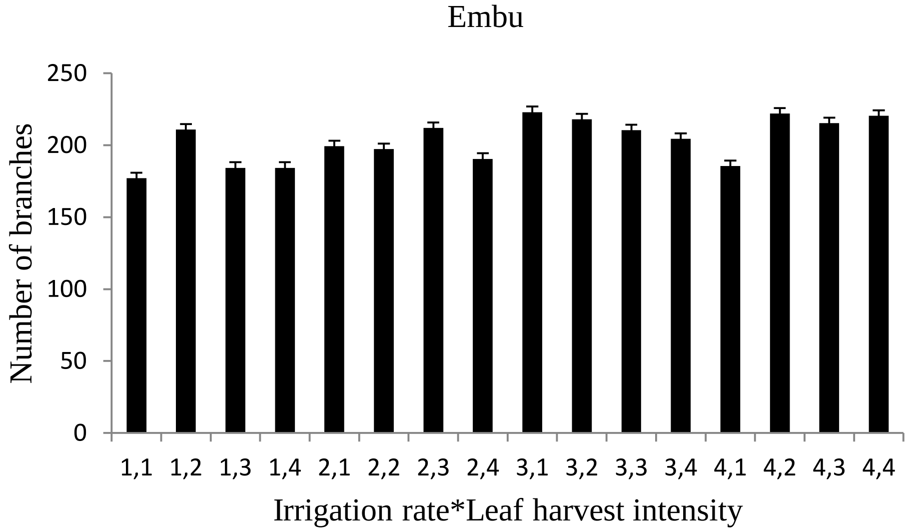

Figure 11: Mean number of branches at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

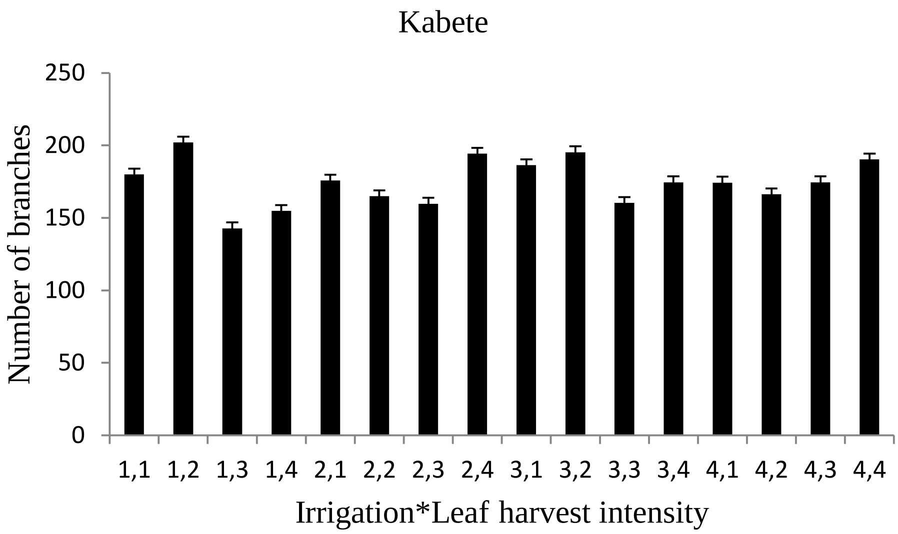

Figure 12: Mean number of branches at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.4.1.2 Effects on number of male flowers

The interaction between irrigation rate and leaf harvest intensity had a significant effect ($P<0.05$) on the number of male flowers (Table 16). Application of two litres of irrigation water with one LHI produced the highest number of male flowers at Embu (76.0). A correlation analysis between LHI and IRR rate with number of male flowers indicated a negative correlation between LHI and the number of male flowers at 5% significant level while there was no correlation between IRR and number of male flowers. Application of three litres of irrigation water with one LHI gave the highest number of male flowers at Kabete (64.3), although not significantly different from the other treatments. There was no correlation between IRR and LHI with number of male flowers at Kabete. Harvesting of one or no leaf with any irrigation rate gave the highest number of male flowers in both sites with harvesting of three leaves giving the lowest number of flowers. Number of male flowers decreased with increased number of leaves harvested.

Table 16: Mean number of male flowers at Embu and Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

Irrigation rate*Leaf harvest intensity	Embu	Kabete
1,1	59.5abcd	40.3
1,2	64.3abc	48.3
1,3	54.3bcd	31.3
1,4	46.8cd	39.3
2,1	59.0abcd	41.0
2,2	76.0a	38.0
2,3	57.5abcd	28.5
2,4	54.3bcd	58.0
3,1	64.5abc	52.5
3,2	65.0abc	64.3
3,3	57.8abcd	38.0
3,4	41.3d	45.0
4,1	57.5abcd	37.3
4,2	67.3ab	35.8
4,3	60.5abc	41.5
4,4	48.0cd	52.8

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

4.4.1.3 Effects on number of female flowers

The interaction between irrigation rate and leaf harvest intensity had no significant effect (P< 0.05) on the number of female flowers (Figure 13 and 14). Application of one litre of irrigation water per week combined with one LHI gave the highest number of female flowers in Embu. However, a correlation analysis showed a significant negative correlation between LHI and number of female flowers at 5% level and no correlation between IRR and number of female flowers. Application of three litres of irrigation water per week with one LHI in Kabete gave the highest number of female flowers. The number of female flowers increased up to two LHI with any irrigation rate after which the number reduced. This showed that high soil water levels negatively affected the production of female flowers.

Embu

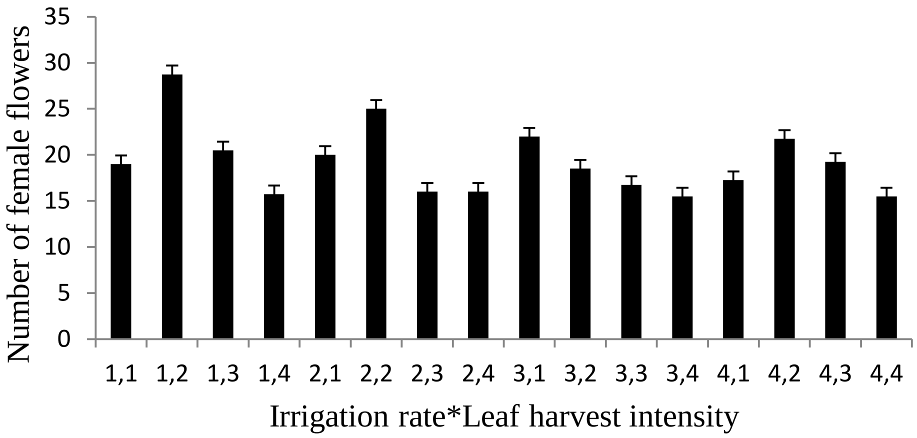

Figure 13: Mean number of female flowers at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

Kabete

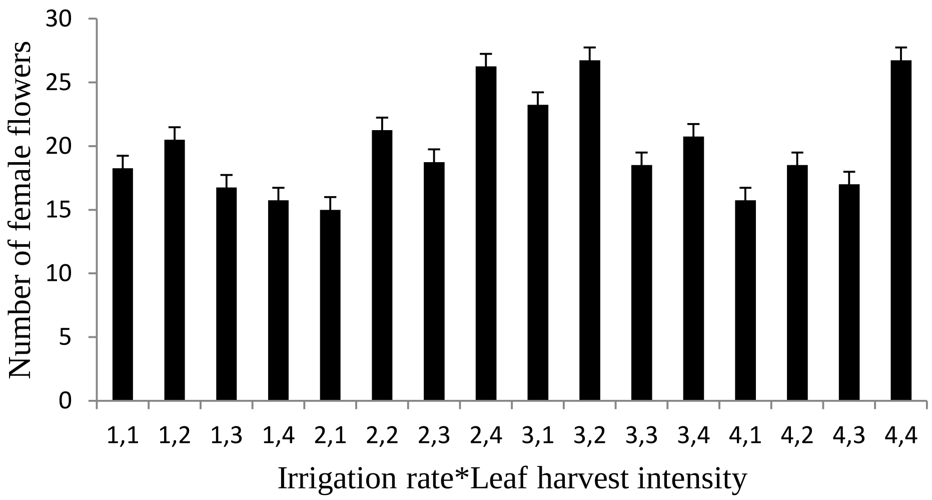

Figure 14: Mean number of female flowers at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.5 Effects of Interaction between Irrigation Rate and Leaf Harvest Intensity on Yields

4.5.1 Effects on number and weight of the harvested leaves

The interaction between irrigation rate and leaf harvest intensity had a significant effect ($P<0.05$) on the number of leaves harvested (Table 17). Interaction between harvesting of two and three leaves with any rate of irrigation water produced significantly higher number and weight of the harvested leaves. Interaction between the applications of two litres of irrigation water with harvesting of three leaves gave the highest number (129.3) and weight

(1885.8 g) of harvested leaves in Embu site. There was a significant positive correlation between LHI and number and weight of leaves at 5% level and no correlation between IRR rate and number and weight of leaves respectively. Similarly interaction between two litres of irrigation water with three LHI produced significantly higher number (129.8) and weight (1803.75 g) of harvested leaves in Kabete site.

Table 17 : Mean number and weight of harvested leaves (g) at Kabete and Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

		Number of harvested leaves		Weight of harvested leaves(g)	
IRR	LHI	Embu	Kabete	Embu	Kabete
1	1	10.0 c	10.0 e	10.0 d	10d
1	2	83.8 ab	76.8 bcd	1164.5 bc	910.5abc
1	3	101.9 ab	94.3 abcd	1492.8 abc	884.25bc
1	4	114.3 ab	130.5 a	1351.0 abc	1490abc
2	1	10.0 c	10.0 e	10.0 d	10d
2	2	83.3 b	69.8 cd	1081.0 c	715.5bc
2	3	106.5 ab	88.8 abcd	1416.8 abc	956.5abc
2	4	129.3 a	129.8 a	1885.8 a	1803.75a
3	1	10.0 c	10.0 e	10.0 d	10d
3	2	75.0 b	72.3 cd	1153.0 bc	988.75abc
3	3	100.8 ab	92.5abcd	1599.5 abc	1080abc
3	4	113.5 ab	119.0 ab	1693.0 abc	1627.5abc
4	1	10.0 c	10.0 e	10.0 d	10d
4	2	83.0 b	62.5 d	1163.8 bc	738.75bc
4	3	96.8 ab	93.0 abcd	1679.8 abc	1327.75abc
4	4	104.8 ab	108.0abc	1820.8 ab	1473.5abc

*Means followed by the same letter(s) within a column are not significantly different ($P<0.05$) according to the Tukey's Studentized Range Test

4.5.2 Effects on number of fruits

Interaction between irrigation rate and LHI had no significant effect ($P< 0.05$) on the number of fruits (Figure 15 and 16). Application of one litre of irrigation water with one LHI produced higher number of fruits at Embu (13.0). A negative correlation between LHI and number of fruits at 5% significant level was noted whereas there was no correlation between IRR rate and number of fruits. Interaction of three litres of irrigation water with one LHI produced higher number of fruits at Kabete (14.3) compared to the other treatments. Interaction between any irrigation rate and three LHI produced fewer fruits than the other treatments.

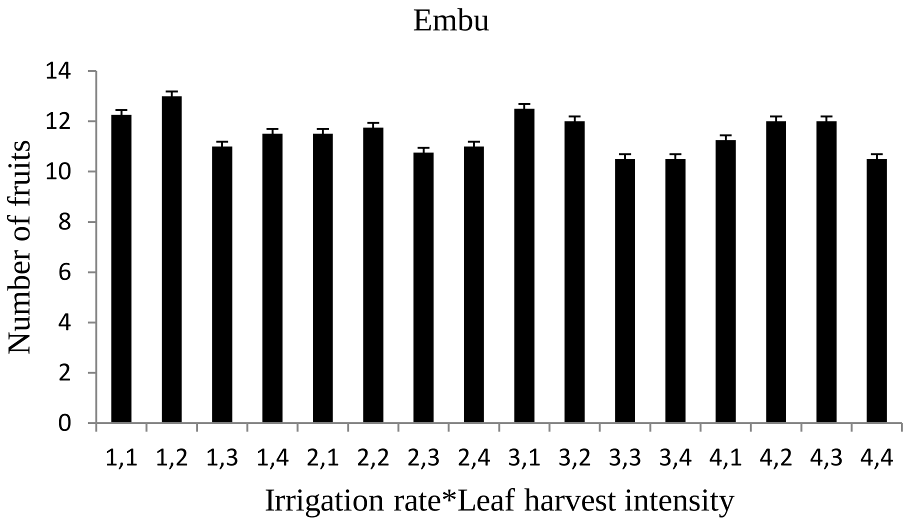

Figure 15: Mean number of pumpkin fruits at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

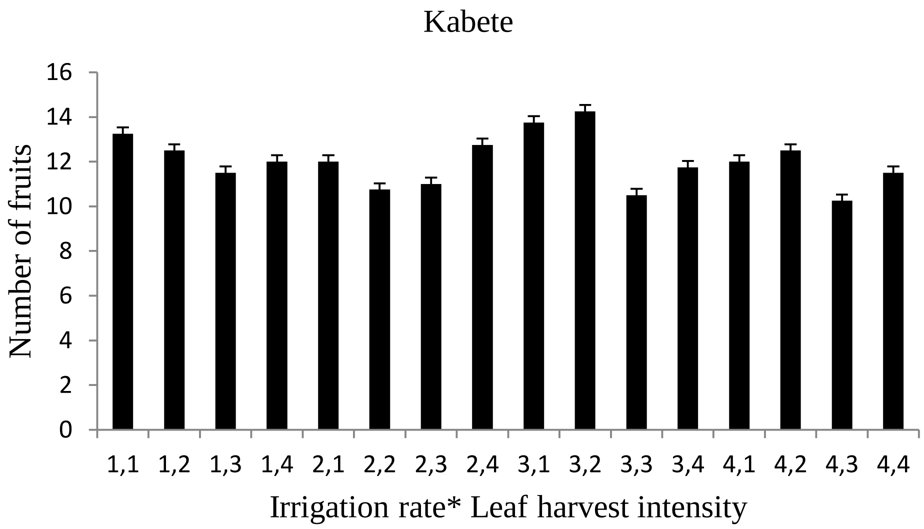

Figure 16: Mean number of pumpkin fruits at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.5.3 Effects on weight of fruits

Interaction had no significant effect ($P < 0.05$) on the weight of fruits (Figure 17 and 18). However, application of one litre of irrigation water with one LHI produced the highest weight of fruits at Embu (16.9 kg). A negative correlation between LHI and weight of fruits was observed while there was no correlation between IRR rate and the weight of fruits. Application of three litres of irrigation water with one LHI gave the highest fruit weight at Kabete (22.79 kg). Generally the trend in both sites showed that fruit weight was high for any irrigation rate and low leaf harvest intensity. But as the number of leaves harvested increased, the weight reduced

Embu

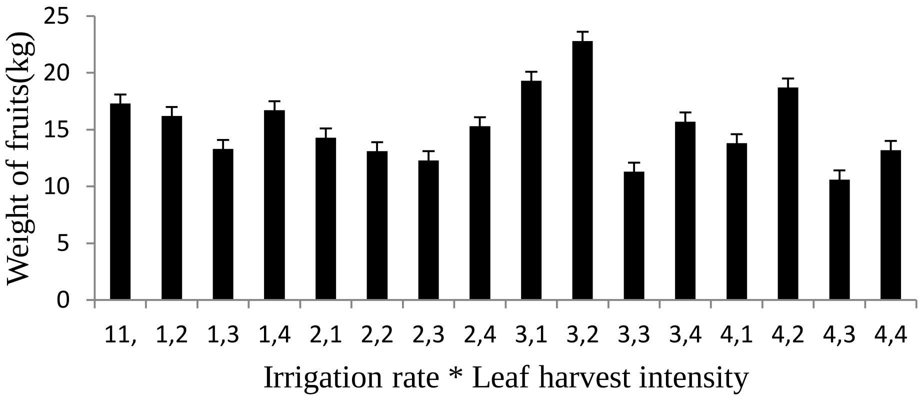

Figure 17: Mean weight of pumpkin fruits in kg in Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

Kabete

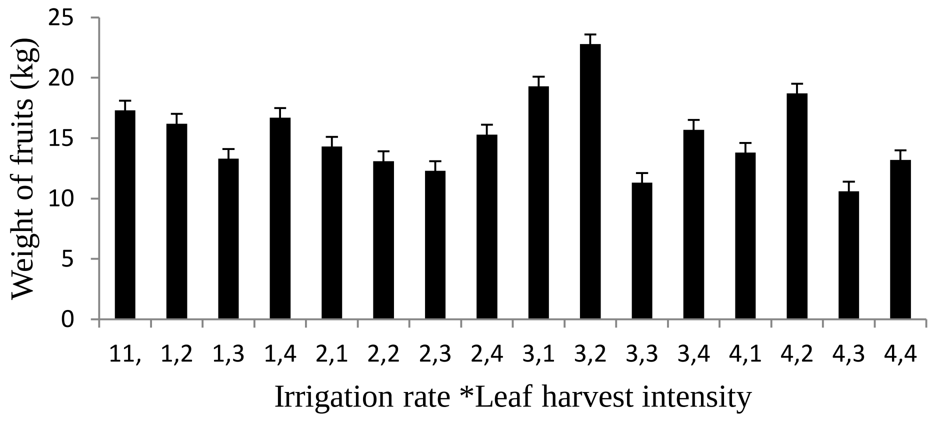

Figure 18: Mean weight of pumpkin fruits in kg at kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.5.4 Effects on weight of 1000 dry seeds

There was no significant effect (P< 0.05) between interaction of irrigation rate and leaf harvest intensity on the mean weight of 1000 dry seeds (Figure 19 and 20). Interaction between four litres of irrigation water with one LHI gave the highest mean weight (116.1 g) of 1000 dry seeds in Kabete site. The interaction between two litres of irrigation water with three LHI gave the highest mean weight (122.1 g) of 1000 dry seeds in Embu. However, there was no correlation between IRR, LHI and weight of a thousand dry seeds in Embu.

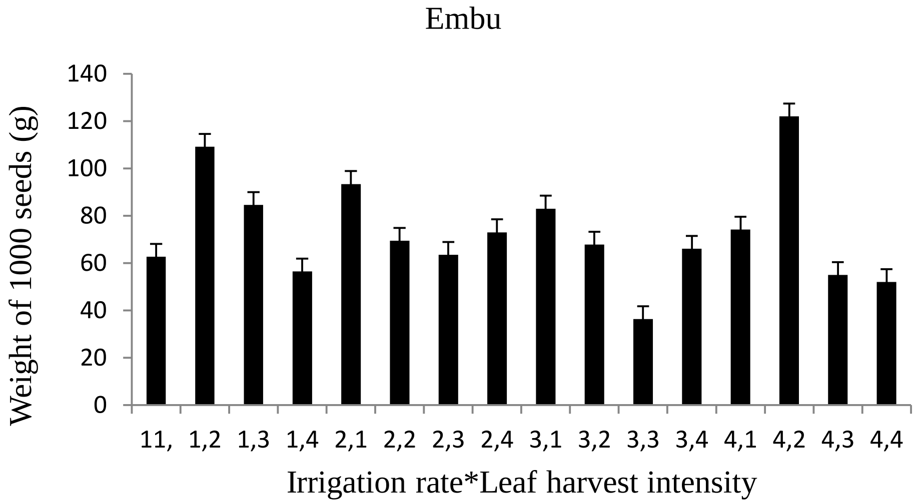

Figure 19: Mean weight of 1000 dry seeds at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

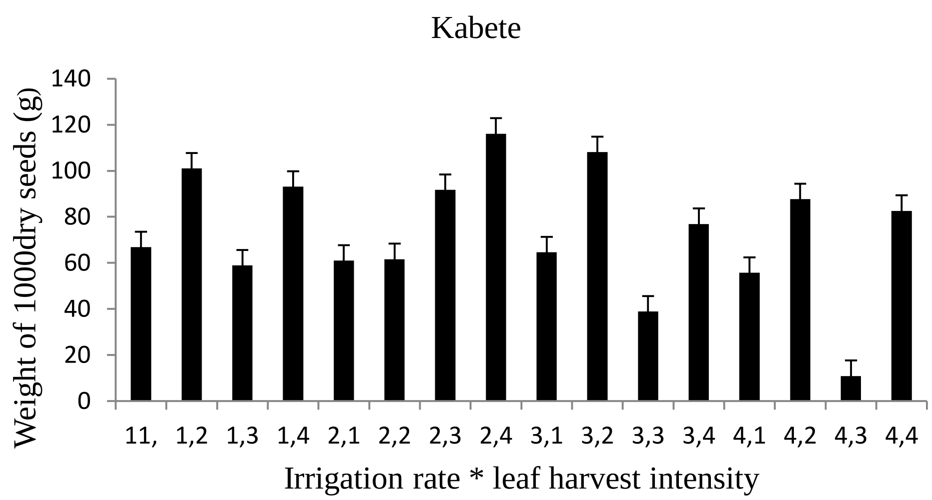

Figure 20: Mean weight of 1000 dry seeds at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.6 Effect of Interaction between Irrigation Rate and Leaf Harvest Intensity on Quality

4.6.1 Effect on the size of fruits

The interaction between irrigation rate and leaf harvest intensity had no significant effect ($P < 0.05$) on fruit size (Figure 21 and 22) However, application of four litres of irrigation water with one LHI had a positive effect on the size of fruits in Embu (361.29 cm ^{2}). There was no correlation between IRR and LHI with size of fruit. Application of three litres of irrigation water interacted positively with one LHI gave the highest fruit size in Kabete (483.9 cm ^{2}). In interactions where more leaves were harvested (two and three) the size of fruit was smaller than in the interactions where no or one leaf was harvested with the same irrigation rate.

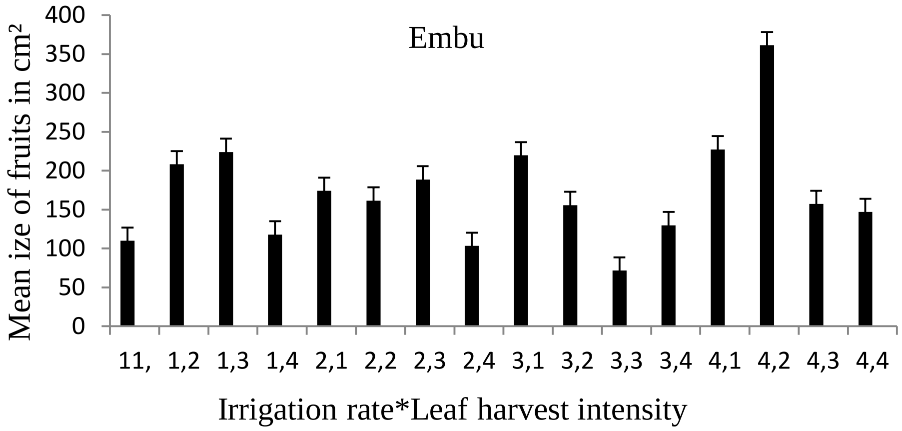

Figure 21: Mean size of fruit in cm ^{2} at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

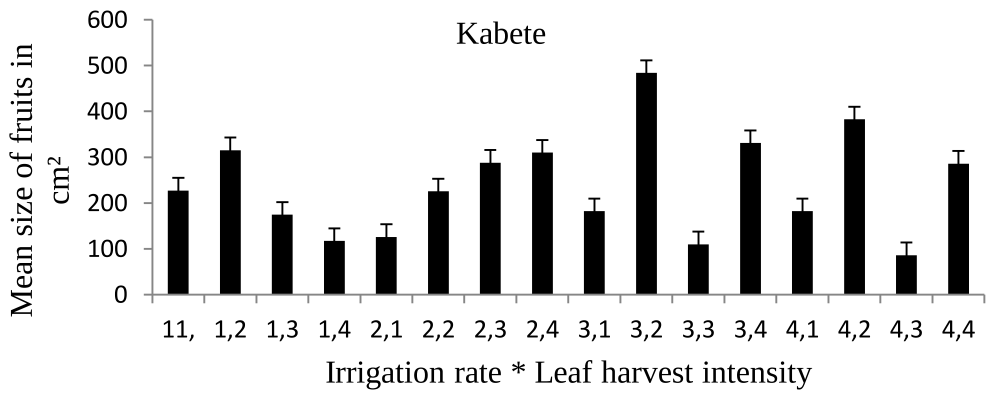

Figure 22: Mean size of fruit in cm ^{2} at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.6.2 Effect on the edible fruit flesh thickness

Interaction of irrigation rate and leaf harvest intensity had no significant effect on the edible flesh thickness (P< 0.05) (Figure 23 and 24). According to the results, the difference between the various combinations was negligible. All the same, application of four litres of irrigation water with one LHI in Embu site and application of three litres of irrigation water with one LHI in Kabete had a positive effect on the edible fruit flesh thickness. There was no correlation between IRR and LHI on the edible fruit fresh thickness.

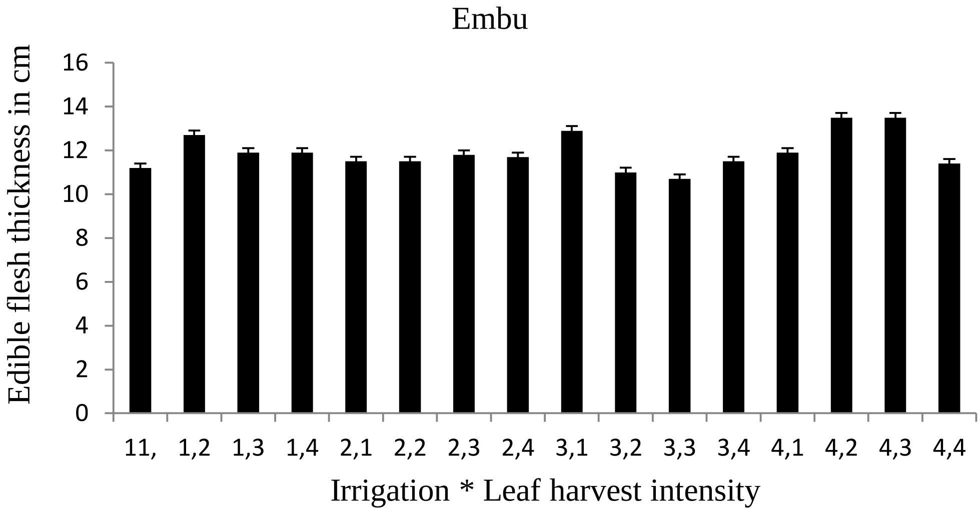

Figure 23: Mean edible fruit flesh thickness at Embu as influenced by the interaction between irrigation rate and leaf harvest intensity

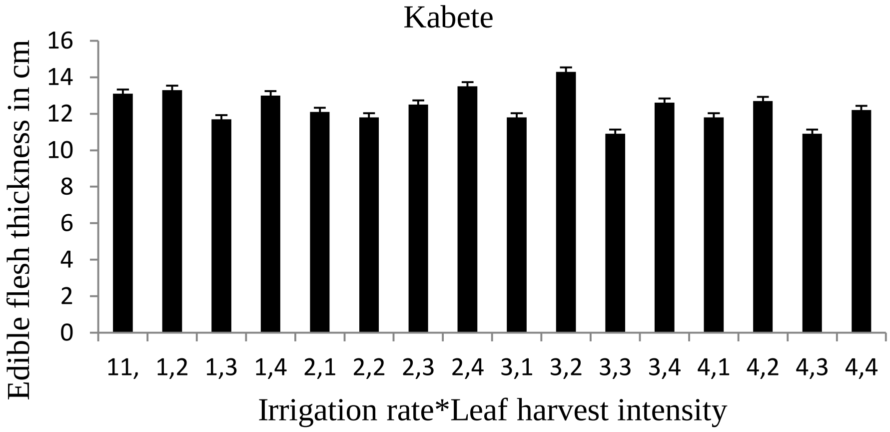

Figure 24: Mean edible fruit flesh thickness at Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

4.6.3 Effect on the number of seeds

Interaction of irrigation rate and leaf harvest intensity had a significant effect (P<0.05) on the number of seeds (Table 17). Application of four litres of irrigation water with one LHI produced higher number of seeds. There was no correlation between IRR and LHI with number of seeds at Embu. Three litres of irrigation water with one LHI produced higher number of seeds in Kabete.

Table 18: Mean number of seeds at Embu and Kabete as influenced by the interaction between irrigation rate and leaf harvest intensity

IRR	LHI	Embu	Kabete
1	1	214.5 cde	132.3 h
1	2	224.3 cde	342.8 b
1	3	302.5 bc	181.0 g
1	4	226.8 cde	275.0 cd
2	1	303.5 bc	134.5 h
2	2	294.5 bc	127.3 h
2	3	296.3 bc	224.5 ef
2	4	160.5 ef	294.5 c
3	1	333.0 b	196.5 fg
3	2	214.0 cde	433.3 a
3	3	118.3 f	85.3 ij
3	4	185.5 def	255.3 de
4	1	247.5 bcde	121.3 hi
4	2	471.5 a	233.3 ef
4	3	257.0 bcd	69.5 j
4	4	262.8 bcd	306.0 bc

*Means followed by the same letter(s) within a column are not significantly different (P<0.05) according to the Tukey's Studentized Range Test

CHAPTER FIVE

DISCUSSION

5.1 Effects of Irrigation Rate on Growth, Yields and Seed Quality

5.1.1 Effects on growth

High irrigation rate promoted higher growth probably through enhancement of both the uptake of nutrients from the soil and the translocation of assimilates to the growing areas (sinks) (Karam et al., 2009). The high irrigation water increased the production of branches which are essential in leaf production in pumpkin plants. Treatments that promote branch growth are highly valued in pumpkin. The highest irrigation rate of four litres of irrigation water once per week may have been too much, probably leading to anaerobic soil conditions that impede root functions such as respiration, nutrient uptake and translocation (Faust, 1989). This condition in multi-purpose pumpkin is manifested in stunted overall plant growth.

The soil moisture content affected the number of male and female flowers produced. The number of flowers increased with the rate of water applied up to two litres of irrigation water after which the number decreased as the water rate increased. Lack of significant difference on leaf area agreed with the findings of Fandika *et al.* (2011), who concluded that leaf area of pumpkin cultivars remains constant even under different irrigation treatments. The authors found that with or without irrigation, different cultivars of pumpkin differed in leaf area, while a cultivar maintained its leaf area

Water is essential in promoting of development of flowers into fruits. The heavy abortion of female flowers in treatments receiving low water rates indicated that more water was required to sustain development of these flowers into fruits. This was probably because water is utilized in keeping flowers turgid, thereby preventing their abscission**.** These results agreed with those of Napier (2009) and Walker (2011) who concluded that irrigation is crucial during times of flowering, fruit set and fruit fill. The authors observed that if plants are stressed at these times, flowers and young fruits prematurely abscise.

5.1.2 Effects on yields

Lack of significant effect of irrigation rates on the number of harvestable leaves was attributed to the fact that pumpkin can be classified as drought tolerant crop and could continue to grow on low levels of soil moisture (Radovich *et al*., 2011). The one, two and three litres of irrigation water applied once per week were enough to facilitate production, while the four litres of irrigation water may have been too much since it resulted to low number of leaves. The trend observed in the weight of harvested leaves as the irrigation water increased indicates that higher soil moisture rates favored the partitioning of assimilates to leaves. These findings agreed with those of Asoegwu (1988) in an experiment to determine the effect of irrigation on leaf and pod production in fluted pumpkin where higher soil water content enhanced vegetative growth.

The lack of significant effect of irrigation rate on the number of fruits was similar to that reported by Ghanbari *et al.* (2007) that irrigation interval had no significant effect on the number of pumpkin fruits per unit area. The results were also similar with those of Yi-jie Li *et al*. (2011) who studied growth and photosynthetic responses of *Lycoris haywardii* Traub to watering frequencies and observed no significant difference in bulb number in all the treatments. Lack of a significant effect of irrigation rate on the weight of fruits was similar with the findings of Maynard (2006) on drip irrigation effects on yield and fruit size of jack-o-lantern pumpkins that showed that irrigation had no effect on average weight per pumpkin, although the weight depended on cultivar. The results, however, disagreed with those of Al-Omran *et al*. (2005) who reported that at high irrigation rates (non-stressed), fruit yield of *Cucurbita* pepo were high and decreased significantly at low irrigation rates. The results also disagreed with those of Ertek *et al*. (2004) who concluded that irrigation interval of 5 days gave higher yields of *Cucurbita pepo* than of 10 days interval. The authors found that increasing the frequency of irrigation, increased fruit number and consequently fruit yield.

Irrigation rate did not affect weight of 1000 dry seeds. These results were similar with those of Ghanbari *et al.* (2007) who observed irrigation interval have no significant effect on the weight of 1000 dry seeds. The results were also similar to those of Xia (1994), who reported that mean seed weight was a relatively stable yield component in water stress treatments at different developmental stages of fababean (*Vicia faba* L.).

5.1.3 Effects on quality

Irrigation rate had no significant effect on the fruit size. The results were similar to those of Searle (2003) who concluded that fruit size is generally controlled by genetics, but any factor that limits plant growth adversely affects fruit size. The factors include water, temperature, insects, diseases, pollination, fertility, soil type, plant population, and weeds, among others. While irrigation is needed in more valuable crops, when plants are under moisture stress, extra water can help maintain or improve good fruit size.

The trend shown on the number of seeds per fruit was similar to that reported by Nadjafi and Razvani (2002) and Ghanbari *et al.* (2007) that irrigation interval had significant effect on the number of seeds per fruit, with fruits receiving weekly (7days) application having more seeds. The 7 day frequency can be equated to application of 4 litres in the present experiment. In crop physiology, hormonal activity in the growing fruits causes the fruit mesocarp to act as a stronger physiological sink than the other organs for photosynthetic materials. Most likely under higher irrigation levels, higher transmission rate of assimilates and dry matter to the fruit mesocarp could result, thereby expanding the fruit pericarp. Ultimately, excessive growth of the fruit decreases the number of seeds per fruit (Yousefi, 2012). However, Jahan *et al*. (2010) stated that pumpkin is a sink-limited herb and there is no link between increase in fruit dimension and higher seed production.

The lack of significant difference in germination percentage and rate indicated that the quality of seeds is not determined by the level of soil moisture and leaf harvest intensity, but by other factors that were not considered in this experiment. This result agreed with the findings of Ghanbari *et al.* (2007) who concluded that irrigation intervals had no significant effect on germination index and percentage of pumpkin.

5.2 Effects of Leaf Harvest Intensity on Growth, Yields and Seed Quality

5.2.1 Effects on growth

Leaf harvesting reduced the photosynthetic area needed to drive branch growth, resulting in lower total number of branches in treatments where more leaves were harvested. The leaves form the photosynthetic machinery of the plant and their removal constitutes a reduction in photosynthetic tissue and photo-assimilates needed in crop growth. Ibrahim *et al*., (2010) and Barrett (1987)) reported that defoliation alters hormone balance, starch, sugar, protein and chlorophyll contents of source leaves, as well as stomatal resistance and senescence rate.

Similarly, the negative effect of leaf harvesting on the number of male and female flowers could be as a result of reduced photosynthetic process. The significance of leaf harvest intensity on flower abortion can be attributed to the fact that leaf harvesting reduced photosynthetic area resulting in less assimilates being partitioned to the flowers for fruit development. These results agreed with those of Ibrahim *et al*. (2010) and Saidi *et al*. (2009), who concluded that plant leaf harvesting can directly and indirectly affect growth, biomass production and partitioning. Leaf harvesting reduced photosynthetic area resulting in less assimilates being partitioned to the flowers for fruit development Pumpkin is a monoecious plant and in contrast to hermaphroditic species, monoecious species can separate allocation to male and female functions more easily (Thomson *et al*., 2004; de Jong *et al*., 2008). Depletion of resources through leaf harvesting which can be likened to folivory (leaf herbivory) differentially influences male and female functions. In the present study, the plants produced a lot of male flowers. According to Diggle (2002), a variety of factors must be at play in determining how folivory alters the relative allocation of resources to male and female functions. If pistillate and staminate flowers are produced at different positions within the inflorescence, one of the two types of flowers may receive a greater amount of resources than the other solely due to 'architectural effects'. Furthermore, if pistillate flowers are produced earlier than staminate flowers, the latter may suffer a pre-emption of resources due to plastic responses in the reallocation of resources to develop fruits by pistillate flowers (Diggle, 2002; Diggle and Miller, 2004). The abortion of female flowers may therefore have been caused by plant regulatory systems to shed off excess fruits and leave only few fruits that it can manage to feed.

5.2.2 Effects on yields

Increasing leaf harvest intensity significantly increased the number of harvestable leaves. The impact of leaf harvest intensity on the number of harvestable leaves was similar to that of Olasantan (2007) on apical shoot harvest effect on apical shoot and fruit yields of pumpkin. The author found that harvesting of 30-cm-long tip shoots at one week interval produced the greatest number of apical shoots and apical shoot yields compared to 60-cm and 90-cm-long tip shoots. The harvesting of 30 cm long tip shoots can be compared to the picking of 3 leaves per branch, which gave higher number of harvested leaves. The number of harvestable leaves was highest at the 14th week which also marked the beginning of flowering. Although the number of leaves increased, their sizes were small and un-attractive for marketing.

The significant effect observed in the weight of harvested leaves where the weight of harvested leaves increased with increase in leaf harvest intensity, was similar to that of Madakadze *et al*. (2004), who concluded that plants that had a leaf harvesting frequency of 7 days had significantly higher leaf yields (21.54 tonnes/ha) compared to 14 and 21 days harvesting frequencies (13 and 16 tonnes/ha, respectively). The leaf harvest intensity of 3 leaves per branch in the present erxperiment can be equated to the 7 days harvesting frequency in the experiment by Madakadze *et al*. (2004). Saidi *et al*. (2009) also concluded that the leaf vegetable yield of cowpeas was significantly affected by leaf harvest intensity, cropping regime and leaf harvest frequency.

The significant effect of leaf harvest intensity on the number of fruits observed in the present experiment revealed that harvesting of less or no leaves at all gave the plant adequate foliage to support photosynthesis that sustained recovery and sufficient growth (Saidi *et al.*

2010). The present results were in agreement with those of Olasantan (2007) on apical shoot harvest effects on growth, apical shoot and fruit yield in which harvesting of 30-cm-long apical shoots at 1-week intervals reduced the numbers of fruits by 20% to 50% compared to the harvesting of 60-cm and 90-cm-long apical shoots. The present results were also in agreement with those of Valverde *et al*. (2006) on effect of leaf harvesting on demography of the tropical Palm **(***Chamaedorea elegans*). In the tropical Palm, the lowest growth rate values (1.03 and 1.04 for 1997-98 and 1998-99, respectively) were obtained in the high intensity defoliation plot, and as harvest intensity increased, fecundity decreased as a result of low fruit production. Leaf harvesting negatively affected the weight of fruits. The results implied that the higher the number of leaves on the plant provided higher the photosynthetic area that probably resulted in more assimilates being partitioned into fruit development. Saidi *et al*. (2009) also concluded that the number of cowpea pods per plant was also significantly affected by leaf harvesting frequency, with the highest number of pods produced in the control where no leaf harvesting was done. They also concluded that in cowpea the processes of producing reproductive structures and filling grains are strong energy sinks whose demand for photo-assimilates is not met when photosynthetic area is depleted, thereby resulting in lower yields

The lack of a significant effect of leaf harvest intensity on the weight of 1000 dry seeds probably implied that leaf harvesting reduced the amount of assimilates partitioned into seed production through reduction in photosynthetic area. According to KÓpondo *et al*. (2005), seed production of most indigenous leafy vegetables is low since most of the production is for leaf consumption and not seed. Sustainable production of indigenous leafy vegetables requires sustainable supply of high quality seeds as well as a strong market demand of the vegetables. Achieving a balance between leaf and seed yields in plants where the leaves are eaten requires both sound cultural practices and good leaf harvesting practices that do not reduce the active photosynthetic area of the plant to jeopardize seed yields.

5.2.3 Effects on quality

The significant effect of leaf harvest intensity on number of seeds were in agreement with observations of Madakadze *et al.* (2004), who reported that more frequent harvesting of 7 days significantly reduced seed yields to 1.2 tonnes/ha, compared to 2.7 tonnes/ha obtained for 14 days and 21 days harvesting frequencies. When leaves are harvested, the plant concentrates on recovering the lost leaf area that is essential for photosynthesis rather than reproduction, resulting in reduced seed yields. Older leaves left on the plant are less efficient in photosynthesis, thereby reducing seed yields. The low frequency (21 days) in the cowpea experiment is equivalent to harvesting of 3 leaves, which was the highest intensity in the present study. Saidi *et al*. (2009) also concluded that the number of cowpea seeds per pod was higher in control treatments, where no leaf harvesting was done and lowest in cowpea subjected to leaf harvesting starting at two weeks after emergence and the number of seeds increased with decrease in leaf harvest frequency from 7 days to 14 days.

5.3 Effect of Interaction between Irrigation Rate and Leaf Harvest Intensity on Growth, Yields and Seed Quality of Multi-Purpose Pumpkin

5.3.1 Effect on growth

Interaction had no significant effect on the number of branches, although the trend revealed that irrigation of three or four litres of irrigation water combined with any leaf harvest intensity increased the number of branches in both experimental sites. This meant that water is essential for crop growth and higher soil moisture can give the plant the ability to withstand stress subjected through high leaf harvest intensity.

The results on male flowers showed that application of two or three litres of irrigation water with low (none or one leaf) leaf harvest intensity produced more male flowers. Male flowers are essential in fruit and seed production and development through production of pollen for pollination. According to Marr *et al*. (2004), the more the pollination takes place, the more seeds develop, producing growth regulating compounds that enhance fruit size.

Interaction between irrigation rate and leaf harvest intensity had no significant effect on the number of female flowers, although the trend showed that the number of female flowers increased up to the two LHI in combination with any irrigation rate, after which the number reduced. This result showed that high leaf harvest intensity negatively affected the production of female flowers. This may have been caused by the reduced photosynthetic area. This is in agreement with the findings of Ashman (2002), who reported in a review of the effect of herbivores in the evolution of sexual systems that foliar herbivory often causes a plastic shift towards maleness. In this context, sex allocation theory predicts that folivory should decrease preferentially female function because it is more expensive in terms of plant resources (Charlesworth and Morgan, 1991).

5.3.2 Effect on yields

Results in showed that harvesting of three leaves per branch interacted with any irrigation rate produced the highest number and weight of harvested leaves. Although this was the case, these many leaves were not appealing to the eyes. The leaves harvested from treatments in which only one or two leaves were being harvested were large and attractive. These were desirable leaf harvest intensities because most consumers are attracted by the appearance of the commodity before they buy.

Generally, treatments where more leaves were harvested interacted with low irrigation water levels produced lower number of fruits compared to those where none or one leaf was harvested. Application of three litres of irrigation water interacted with low leaf harvest intensity promoted fruit growth probably through increased photosynthetic area and efficient partitioning of assimilates. This result agreed with the findings of Walker (2011) that irrigation is crucial during times of flowering, fruit set and fruit fill.

Lack of significant effect of interaction on the weight of 1000 dry seeds meant that the seed weight may be determined by other factors other than ones considered in this study. Nevertheless, the results showed that higher irrigation rates favored production of heavier seeds and these high irrigation rates gave the plants ability to sustain seed production in plants where more leaves were harvested.

5.3.3 Effect on quality

The interaction of high irrigation rates (three and four litres of irrigation water) with low leaf harvest intensity (none or one) produced larger fruits and thicker edible flesh thickness than the other treatments. The present results showed that the fruit edible thickness depends on the amount of photosynthates produced and partitioned during the fruit development stage. According to Yousefi (2012) higher irrigation rates have presumably higher transmission rate of assimilates and dry matter to the fruit mesocarp that expands fruit pericarp. Interaction of three or four litres of irrigation water with no leaf harvest intensity or with harvesting of one leaf produced more seeds than the other treatments. These treatments showed that the number of seeds produced is determined by the rate of photosynthesis and the ability of the plant to partition assimilates to the seed sinks. Thus increased irrigation rates combined with large photosynthetic area results in more seeds.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Effects of Irrigation Rate on Growth, Yield and Quality of the Pumpkin

Irrigation rate affected the growth yield and quality of multi-purpose pumpkin. Higher irrigation rate produced more branches, more female flowers, more and heavier leaves, more seeds and thicker seedling stem diameter (girth). Low water rates produced more male flowers and seedlings with longer roots.

6.2 Effects of Leaf Harvest Intensity on Growth, Yield and Quality of the Pumpkin

Leaf harvest intensity affected growth, yield and quality of multi-purpose pumpkin. Low harvest intensity produced the highest number of branches. It also affected the time to commencement of flowering with harvesting of two leaves commencing flowering three days earlier than the other treatments. Higher leaf harvest intensity decreased the number of both male and female flowers. Harvesting of three leaves produced the highest number and weight of leaves but their sizes were small and un-attractive compared with those of harvesting one leaf, which were few, large and attractive. Harvesting one leaf increased the number and weight of fruits. Low leaf harvest intensity favored development of thicker fruit edible flesh, higher number of seeds per fruit and produced seedlings with thicker stems.

6.3 Effects of Interaction of Irrigation Rate and Leaf Harvest Intensity on Growth, Yield and Quality of the Multi-purpose Pumpkin

Interaction between higher irrigation rates and any leaf harvest intensity increased the number of branches. Harvesting of more leaves combined with any rate of irrigation produced few flowers. Interaction between three litres of irrigation water and no leaf harvest produced the highest leaf area in both sites. This means that the three litres of irrigation water were the best to achieve optimum leaf area for this multipurpose pumpkin. Higher leaf harvest intensity interacted with any irrigation rate produced higher number and weight of harvested leaves. Interaction between higher irrigation rates and low harvest intensity produced higher number of seeds, fruit size in cm^2 and fruit edible flesh thickness. This means that water and sufficient number of leaves are essential for improved quality of fruits and seeds.

6.4 Recommendations

6.4.1 Leaf harvesting should be avoided or if harvesting is to be done, only one leaf should be harvested per branch once per week in a system where the objective is to produce fruits and seeds. Harvesting of two leaves per branch once per week is recommendable for the production of marketable leaves.

6.4.2 Application of three litres of irrigation water once per week produced the highest number of branches, harvestable leaves and fruits throughout the growth period and had the longest harvesting period. It is therefore advisable to use three litres of irrigation water once per week per plant during the dry season for optimal yields.

6.4.3 Interaction between higher irrigation rates combined with no leaf harvesting or harvesting of one leaf is recommended for farmers producing multi-purpose pumpkin for seeds, large fruits and thicker fruit edible flesh thickness. For the farmers growing multi-purpose pumpkin for leaf vegetable production, application of three litres per plant per week and harvesting of two leaves per branch per fortnight is recommendable.

REFERENCES

AOSA Rules for Testing Seeds. (1993). International Rules for Seed Testing Association. *Seed Science and Technology,* Supplement Number 21.

Ackerson, R.C. and Hebert, R.R. (1981). Osmoregulation in cotton in response to water stress. Alterations in photosynthesis, leaf conductance, translocation and ultra-structure. *Plant Physiology,* 67:484-488.

Al-Omran, A.M., Sheta, A.S., Falatah, A.M., Al-Harbi, A.R., 2005. Effect of drip irrigation on squash (*Cucurbita pepo*) yield and water-use efficiency in sandy calcareous soils amended with clay deposits. *Agricultural. Water Management*. 73:43-55.

Amer, K.H. (2011). Effect of irrigation method and quantity on squash yield and quality. *Agricultural Water Management,* 98(8):1197-1206.

Annual Horticulture Validated Report. (2009). Horticultural Crop Development Authority, Nairobi-Kenya

Ashman T.L. (2002). The role of herbivores in the evolution of separate sexes from hermaphroditism. *Ecology,* 83:1175–1184.

Asoegwu S.N. (1988). Effects of irrigation on leaf and pod production of fluted pumpkin (*Telfairia occidentalis* Hook.) in Southern Nigeria. *Scientia Horticulturae,* 34(3-4):161-168.

Azeez, J.O., Van Averbeke, W, and Okorogbona, A.O. (2010). Differential responses in yield of pumpkin *(Cucurbita maxima* Duch.) and nightshade *(Solanum retroflexum* Dunn.) to the application of three animal manures. *Bioresourse technology,* 101(7):2499-2505

Bates, D.M., Robinson, R.W. and Jeffrey, C. (1990). Biology and utilization of the cucurbitaceae. Cornell University Press, New York, United States. Pp.485.

Bratsch, A. (2009). Pumpkins specialty crop profile 438-100: Virginia Cooperative Extension, Virginia Tech, and Virginia State University.

Caili, F., Shihuani, U. and Quanhong L. I. (2006). A review of pharmacological activities and utilization technologies of pumpkin. *Plants foods for human nutrition,* 16(2): 70-77

Charlesworth, D. and Morgan M.T. (1991). Allocation of resources to sex functions in flowering plants. *Philosophical Transactions of the Royal Society of London B,* 332:91–102.

de Jong T.J., Shmida, A. and Thuijsman, F. (2008). Sex allocation in plants and the evolution of monoecy. *Evolutionary Ecology Research,* 10:1087–1109.

Diggle, P.K. (2002). A developmental morphologist's perspective of plasticity. Evolutionary Ecology. *Evolutionary Ecology Research* 16:267–283.

Diggle, P.K. and Miller, J.S. (2004). Architectural effects mimic floral sexual dimorphism in *Solanum* (Solanaceae) *American Journal of Botany,* 91:2030–2040.

Education and Health Library Editorial Team .(2004).*Encyclopedia of Foods and Their Healing Power* (3 Volume Set) Hardcover – June 1, *2004*

Ertek, A., Sensoy, S., Kueçuekyumuk, C. and Gedik, I. (2004). Irrigation frequency and amount affect yield components of summer squash (*Cucurbita pepo* L.). *Agricultural Water Management,* 67(1):63-76.

Fandika, I.R., Kemp, P.D., Millner, J.P. and Horne, D. J. (2011). Yield and water use efficiency in buttercup squash (*Cucurbita maxima* Duch.) and heritage pumpkin (*Cucurbita pepo* Linn.). *Australian Journal of Crop Science,* 5(6):742-747.

FAOSTAT. (2008). FAOSTAT Agricultural Data. Available from: http://www.faostat.fao.org. (Accessed on 03.04.13).

FAO. (2010). Food and Agriculture Organization of the United Nations. Available at: http://www.faostat.fao.org (Accessed on 18.04.2013).

FAO/WHO, (2002). Living well with HIV/AIDS- A manual on nutritional care and support for people living with AIDS, Rome; Pp 15-16

Faust, M. (1989). Physiology of Deciduous Fruit Trees. Wiley-Interscience, New York, USA.

Fedha, M.S., Mwasaru, M.A., Njoroge, C.K, Ojijo, N.O. and Ouma, G.O. (2010). Effect of drying on selected proximate composition of fresh and processed fruits and seeds of two pumpkin species. *Agriculture and Biology Journal of North America,* 1:1299-1302.

Gao, J. (1999). A comparative study on spatial and spectral resolutions of satellite data in mapping mangrove forests. *International Journal of Remote Sensing,* **20,** 2823-2833.

Genty, B., Briantais, J.M. and Dasilva, J.B. (1987). Effects of drought on primary photosynthetic processes of cotton leaves. *Plant Physiology,* 83:360-364.

Ghanbari, A., Nadjali, F. and Shabahang, J. (2007). Effects of irrigation regimes and row arrangement on yield, yield components and seed quality of pumpkin. *Asian Journal of Plant Sciences,* 6(7):1072-1079

Grubben, G.J.H. and Chigumira-Ngwerume, F. (2004). *Cucurbita moschata* Duch. *In*: Grubben, G.J.H. and Denton, O.A. (Eds.). PROTA 2: Vegetables/Legumes. [CD-Rom]. PROTA, Wageningen, Netherlands.

Hassel, R. (1999). The IPM Scout-Pumpkin fruit set, SC-Pumpkin News. Clemson University, South Carolina. Extension 4, (1)

Horticultural Crop Validated Report. (2010) and (2011). Horticultural Crop Development Authority , Nairobi-Kenya.

Hussain, A. (1994). Crops and their Relation to Environment. *In*: Crop Production. E. Bashir and R. Bantel (Eds.). National Book Foundation, Islamabad.

Ibrahim, U., Auwalu, B.M., and Udom, G.N. (2010). Effect of stage and intensity of defoliationon the performance of vegetable cowpea (*Vigna unguiculata* (L.) Walp). *World Journal of Agricultural Science,* 6(4):460-465.

Isutsa, D. K. and Mallowa, S. O. (2013). Increasing leaf harvest intensity enhances edible leaf vegetable yields and decreases mature fruit yields in multi-purpose pumpkin**.** *Journal of Agricultural & Biological Science*, 8(8):610-615.

Jaetzold, R. and Schmindt, H., Hornetz, B. and Shisanya,C.(2005). Farm Management Handbook of Kenya -Natural Conditions and Farm Management Information-2nd Edition. Ministry of Agriculture/ German Agency for Technical Cooperation(GTZ). Nairobi.

Johnson, G. (2011). Poor fruit set in pumpkin. Timely Vegetable and Agronomic Crop. Information from University of Delaware Cooperative Extension.

Khattab, R .Y. and Arntfield, S. D. (2009). Functional properties of raw and processed canola meal. LWT-*Food Science and Technology*; 42: 1119-1124

Karam, F., Kabalan, R., Breidi, J., Rouphael, Y.and Oweis, T. (2009). Yield and water-production functions of two durum wheat cultivars grown under different irrigation and nitrogen regimes. *Agricultural Water Management*;96(4): 603-615

Katul, G., Manzoni, S., Palmroth, S. and Oren, R. (2010). A stomatal optimization theory to describe the effects of atmospheric CO2 on leaf photosynthesis and transpiration. *Annals of Botany,* 105: 431–442

KÓpondo, F.B.O., Muasya, R.M. & Kiplagat, O.K. (2005). A review on the seed production and handling of indigenous vegetables (Spider plant, Jute mallow and African nightshade complex). In: Abukutsa-Onyango (Ed.). Proceedings of the 3rd Horticulture Workshop on Sustainable Horticultural Production in the Tropics. 26th November 2003. Maseno University, Maseno, Kenya, pp. 42-48.

Madakadze, R., Kodzanaji, T. and Mugumwa, R. (2007). Effect of plant spacing and harvesting frequency on *Corchorus olitorious* leaf and seed yields. *Africa Crop Science Journal*, 8:279-282.

Marr, C., Schaplowsky, T. and Careycredit, T. (2004). *Commercial Vegetable Production: Pumpkins*, Kansas State University, November 2004. Pp.1.

Maynard, T. (2006). Drip irrigation effect on yield and fruit size of jack-o-lantern pumpkins http://www.hort.purdue.edu/hort/ext/veg. (Accessed on 19.4.13).

Murray, J. (2008). Pumpkin Facts: History, Health Benefits and use of Pumpkins suite 101-com.mht. (Accessed on 19.4.13).

Nadjafi, F. and Rezvani, M.P. (2002). Effects of irrigation regimes and plant densities on yield and agronomic characteristics of Isibgol (*Plantago ovate*). Agriculture Science and Technology, 2:59-65 (In Farsi).

Napier, T. (2009). Pumpkin Production. Prime Fact-964. Industry and investment, State of new South Wales .www.dpi.nsw.gov.au/primefacts. (Accessed on 13.9.13)

Ndoro, O.F., Madakadze R.F., Kageler, S. and Mashingaidze, A.B. (2007). Indigenous knowledge of the traditional vegetable pumpkin (*Cucurbita maxima/moschata*) from Zimbabwe. *African Journal of Agricultural Research*, 2:649-655.

Nicholson, S.E. 2000. The nature of rainfall variability over Africa on time scales of decades to millennia Global and Planet. Change 26:137–158.

Ondigi, A.N., Toili, W.W., Ijani. S.M.A. and Omuterema, O.S. (2008). Comparative analysis of production practices and utilization of pumpkins (*Cucurbita pepo* and *Cucurbita maxima*) by smallholder farmers in the Lake Victoria Basin, East Africa. *African Journal of Environmental Science and Technology,* 2(9):296-304.

Olasantan, F.O. (2007). Apical shoot harvest affects growth and apical shoot and fruit yields of pumpkin. *Journal of Vegetable Science,* 12(3):73-87.

Ouma, J.O., Muriithi, M.F., Mwangi, W.J., Verkuij, H., Gethi, M. and Groove, D.H. (2002). Adoption of maize seed and fertilizer technologies in Embu District Kenya. *International Maize and Wheat Improvement Centre* (CIMMYT), Mexico.

Pearson, K. (2005). How and when does water stress impact plant growth and development? Adapted from a presentation by Dr. Jim Bauder given at the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America 2003 Annual Meetings held in Denver, Colorado.

Provesi, G.J., Dias, O.C., de Mello, D.R., Amboni, C. and Amante, E.R. (2011). Characterization and stability of quality indices on storage of pumpkin (*Cucurbita moschata* and *Cucurbita maxima)* purees. *International Journal of Food Science and Technology*, 47:67-74.

Radovich, T. (2011). Pumpkin and squash: Farm and Forestry Production Profile for Pumpkin and Squash: Specialty Crops for Pacific Island. http://www.agroforestry.net/Scp5. (Accessed on 26.1.13)

Ramalho, J. C., Zlatev, Z. S., Leitão, A. E., Pais, I. P., Fortunato, A. S. and Lidon, F. C. (2014). Moderate water stress causes different stomatal and non-stomatal changes in the photosynthetic functioning of *Phaseolus vulgaris* L. genotypes. *Plant Biology*, 16: 133–146

Saidi, M., Itulya F.M., Aguyoh, J. and Ngouajio, M. (2009). Leaf harvesting time and frequency affect vegetative and grain yield of cowpea. *Agronomy Journal*, 102:827-833.

Saidi, M., Itulya, F.M., Aguyoh, J. and Ngouajio, M. (2010). Effects of Cowpea Leaf Harvesting Initiation Time and Frequency on Tissue Nitrogen Content and Productivity of a Dual-purpose Cowpea–maize Intercrop. *HortScience,* 45(3):369-375.

Sall, J., L. Creighton and Lehman A. (2003). JMP Start Statistics. A guide to Statistics and Data Analysis Using JMP and JMP IN Software (3rd Ed.) Thomson Brooks/Core. USA.

Schulthesis, J. (2005). Summer squash production. North Carolina Cooperative Extension Services. USA.

Searle, B., Renquist, R. and Bycroft, B. (2003). Agronomic Factors Effecting the Variability of Squash Fruit weight. Agronomy, N. Z., 32.

Sezen, S.M., Yazar, A., Kapur, B. Tekin, S. (2011). Comparison of drip and sprinkler irrigation strategies on sunflower seed and oil yield and quality under mediterranean climate. http://ideas.repec.org/a/eee/agiwat/v98y2011i7p1153-1161.html.(Accessed on 13.1.13).

Stevenson, D.G., Eller, F.J., Wang, L., Jane, J., Wang, T. and Inglett, G.E. (2007). Oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars. *Journal of Agricultural and Food Chemistry*, 55:4005–4013.

Strang, J. (2010). Pumpkin U.K. Cooperative Extension Services University of Kentucky.

Suat, S., Ertek, E., Gedik, I., Cenk, K. (2006) Irrigation frequency and amount affect yield and quality of field-grown melon (*Cucumis melo* L.). *Agricultural Water Management* 88(1-3):269-274. http:/)www.sciencedirect.com. (Accessed on 25.1.13).

Surcică, A. (2010) Pumpkin Pollinators. Penn State Cooperative Extension. USA.

Thomson, V.P., Nicotra, A.B. and Cunningham, S.A. (2004). Herbivory differentially affects male and female reproductive traits of *Cucumis sativus*. *Plant Biology* 6:621–628.

Valverde, T., Mariana-Apolinar, T. and Mendoza-Amarom, S. (2006). Effect of leaf harvesting on the demography of the tropical palm (*Chamaedorea elegans*) in South-Eastern Mexico. *Journal of Sustainable Forestry,* 23:85-105.

Vidal, M.D.G., Jong, D.D., Wien, H.C. and Morse, R.A. (2010). Pollination *and fruit set in pumpkin* (*Cucurbita pepo*) by honey bees. *Revista Brasil. Botany*. 33(1):107-113.

Walker, S. (2011). Commercial pumpkin production for New Mexico State University. Guide H-231. Cooperative Extension Service College of Agricultural, Consumer and Environmental Sciences.

Wien, H. C.; Stapleton, S. C.; Maynard, D. N.; McClurg, C.; Riggs, D.(2004). Flowering, sex expression, and fruiting of pumpkin (*Cucurbita* sp.) cultivars under various temperatures in greenhouse and distant field trials. *HortScience* 2004 39(2): 239-242

Wien, C.H. (2005). Effective pollination in pumpkins. Department of Horticulture, Cornell University, Ithaca, NY 14853.

Woomer, P.L. and Imbuni, M. (2005). Traditional Green Vegetables in Kenya. *Agricultural Technologies* (FORMAT). http//:www.formatkenya.org.(Accessed on 26.1.13)

Xia, M.Z., (1994). Effect of soil drought during the generative development phase of faba bean (*Vicia faba*) on photosynthetic and biomass production. *Journal of Agriculture and Science.* 122:67-72.

Xu,Z.Z and Zhou,G.S. (2006).Combined effects of water stress and high temperature on photosynthesis, nitrogen metabolism and liquid peroxidation of a perennial grass(*Leymus chinensis*). Planta 224:1080-1090

Yi-jie Li, Bao-Zhong, Y. and Zhi-Long Bie. (2011). Response of muskmelon to drip irrigation water inside a plastic greenhouse," *New Technology of Agricultural Engineering (ICAE),International Conference preceedings* pp.333,337, 27-29 May 2011doi: 10.1109/ICAE.2011.5943814

Yongan, C., Bingkui, Z., Enhui,Z., Zunlian, Z. (2002). Control of Sex Expression in Summer Squash (*Cucurbita pepo*L.) Northwest Sci-Tech University of Agriculture and Forestry, Yangling Shaanxi, P.R.China, 712100 Cucurbit Genetics Cooperative Report 25: 51-53

Yousefi, M. (2012). Impact of Zn and Mn foliar application on yield of pumpkin (*Cucurbita pepo* L.) grown under two irrigation regimes. *International Journal of Agricultural. Resources.* Rev. 2(3):102-107.

Appendix I: Soil test reports

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SOIL TEST REPORT

Name	Margaret M. Mwaura
Address	P. O. Box 44600 - 00100, Nairobi
Location of farm	Kithimu. Manyatta, Embu
Crop(s) to be grown	Pumpkin
Date sample received	25-06-12
Date sample reported	09-07-12
Reporting officer (through Director NARL)	A. Chek

	Soil Analytical Data							
Field	NARL							
Lab. No/2012	13331							
Soil depth cm	top							
Fertility results	value	class	value	class	value	class	value	class
* Soil pH	5.52	medium acid						
* Total Nitrogen %	0.23	adequate						
* Org. Carbon %	2.31	moderate						
* Phosphorus ppm	9	low						
Potassium me%	0.84	adequate						
Calcium me%	2.3	adequate						
Magnesium me%	3.65	high						
Manganese me%	0.87	adequate						
Copper ppm	4.13	adequate						
Iron ppm	22.8	adequate						
Zinc ppm	26.2	adequate						
Sodium me%	0.15	adequate						

Interpretation and Fertilizer Recommendations

The soil reaction (pH) is satisfactory for crops' growth. Phosphorus is deficient. Soil organic matter content should be improved. **Recommendations:** At planting time apply 2 tons/acre of well decomposed manure or compost and mix well with the soil. When transplanting apply 120 kg/acre of single superphosphate (SSP). After thinning the crop should be top dressed with 60 kg/acre of calcium ammonium nitrate (CAN) followed by 120 kg/acre of CAN prior to flowering.

NOTE: Test results are based on customer sampled sample(s).
* ISO/IEC **17025 accredited**

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SOIL TEST REPORT

Name	Margaret M. Mwaura
Address	P. O. Box 44600 - 00100, Nairobi
Location of farm	NARL, Westlands, Nairobi
Crop(s) to be grown	Pumpkin
Date sample received	25-06-12
Date sample reported	09-07-12
Reporting officer (through Director NARL)	A. Chek

	Soil Analytical Data							
Field	NARL							
Lab. No/2012	13332							
Soil depth cm	top							
Fertility results	value	class	value	class	value	class	value	class
* Soil pH	5.50	medium acid						
* Total Nitrogen %	0.13	low						
* Org. Carbon %	1.32	low						
* Phosphorus ppm	37	adequate						
Potassium me%	0.56	adequate						
Calcium me%	1.7	low						
Magnesium me%	1.18	adequate						
Manganese me%	0.65	adequate						
Copper ppm	8.00	adequate						
Iron ppm	49.2	adequate						
Zinc ppm	11.0	adequate						
Sodium me%	0.13	adequate						

Interpretation and Fertilizer Recommendations

The soil reaction (pH) is satisfactory for crops' growth. Nitrogen and calcium are deficient. Phosphorus is at deficiency threshold level. Soil organic matter content should be improved. **Recommendations:** At planting time apply 2 tons/acre of well decomposed manure or compost and mix well with the soil. When transplanting apply 120 kg/acre of calcium ammonium nitrate (CAN) mixed with 80 kg/acre of single superphosphate (SSP). After thinning the crop should be top dressed with 60 kg/acre of CAN followed by 120 kg/acre of CAN prior to flowering.

NOTE: Test results are based on customer sampled sample(s).
*** ISO/IEC 17025 accredited**

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Appendix II: Correlation between Irrigation Rate (IRR) and Leaf Harvesting Intensity (LHI) with various parameters

	EMBU		NARL	
Total number of branches	Pearson correlation	Significance	Pearson correlation	Significance
IRR	0.260*	0.038	0.066	0.605
LHI	0.015	0.907	-0.066	0.605
Total male flowers				
IRR	0.014	0.911	0.096	0.448
LHI	-0.381*	0.002	0.041	0.749
Total female flowers				
IRR	-0.131	0.301	0.107	0.400
LHI	-0.255*	0.042	0.135	0.286
Leaf area				
IRR	0.128	0.314	-0.193	0.126
LHI	-0.073	0.569	0.131	0.303
Number of leaves				
IRR	-0.048	0.708	-0.074	0.563
LHI	0.852*	0.000	0.889*	0.000
Weight of leaves				
IRR	0.080	0.532	0.041	0.745
LHI	0.852*	0.000	0.839*	0.000
Number of fruits				
IRR	-0.097	0.448	-0.067	0.598
LHI	-0.290*	0.020	-0.202	0.110
Weight of fruits				
IRR	0.035	0.784	-0.036	0.776
LHI	-0.294*	0.018	-0.165	0.192
Weight of 1000 dry seeds				
IRR	-0.037	0.769	-0.161	0.203
LHI	-0.163	0.199	0.114	0.372
Size of fruit				
IRR	0.118	0.354	-0.156	0.220
LHI	-0.172	0.174	0.195	0.122
Edible fruit fresh thickness				
IRR	0.066	0.604	-0.162	0.200
LHI	-0.137	0.279	0.021	0.870
Number of seeds				
IRR	0.076	0.549	-0.070	0.583
LHI	-0.128	0.314	0.179	0.156

Appendix III (a) Rainfall data

Rainfall data for Embu during the crop period									
Date	July	August	September	October	November	December	January	February	March
1	0	0	TR	0	0.2	0	0.3	4.6	
2	TR	0.3	TR	0	14.9	39.1	0	0	
3	3.9	0	0	0	33.8	46.3	0	0	0
4	0.7	0	0	0	28.4	3	0	0	0
5	3	0	TR	0	45.1	0	0	0	0
6	0.7	0	0.2	0	59.6	0	0	0.1	0
7	TR	0	1.2	1.2	0	2.8	0	0	0
8	1	TR	3.5	1.2	0	2.8	0	0	0
9	0.4	2.9	0	0	9.6	0	0	0	0
10	2.4	0	0	0.4	0	0	0	0	9.5
11	5.6	2.9	0	107.4	8.2	0	0	0	0
12	1.5	0.4	0	59.4	0	0	0	0	0
13	2.2	TR	TR	8.8	0	0	0	0	0
14	0	0	0	46.1	0	0	0	0	8.1
15	0.2	0	0	20.4	0	5.2	0.2	0	15.8
16	0	0	0	1.3	0	0	7.4	0	13.5
17	1.5	0.4	0	0	12.8	0	0.8	0	11.8
18	5.1	1.2	0	0	0	20.1	0	0	3.3
19	1	0	0	0.8	0	40.7	0	0	0
20	0.2	11.9	TR	0.2	0	TR	0	0	0
21	0	0.2	0	27.8	0	0	0	0	0
22	TR	0	0	0	0	0	0	0	5.2
23	0	0	0	0	0	6.1	0	0	4.7
24	0	1.5	0	2.6	0	0	0	0	3.1
25	0.7	3.2	0	8.3	0	0	0	0	1.6
26	0	1	1.8	0	7	0.8	0	0	0
27	0	0.9	0	0	0	12.4	0	0	0
28	0	0	0	7.2	51	2,4	0	0	0
29	1.6	TR	2	0	4.8	4.2	0		2.9
30	TR	0.2	0	0	4.7	TR	0		1.7
31	0	0		0	-	0	8.4		0

Appendix III (b) - Rainfall data

Rainfall data for Kabete during the crop period									
Date	July	August	September	October	November	December	January	February	March
1	0	0	1.2	0	1.5	10.7	0	0	0
2	0	0	1	0	3.6	24.1	0	0	0
3	0	0	0	0	0	15.9	0	0	0
4	0.3	0	0	0	0	0	0	0	0
5	1	0	0	0	0	11.3	0	0	0
6	0	1	0	0	0	2	0	0.1	0
7	0.7	1.6	0.9	0	2.7	0	0	0	0
8	1.9	2	1.1	0	8.2	0	0	0	0
9	0	1.9	0	0	9.6	4.6	0	0	0
10	3	1	0.2	0	38.6	1.8	0	0	0
11	3.9	0	0	0	40.9	0	0	0	0
12	1	0	0	10	16.8	0	0	0.2	0
13	0	0.5	0	13.6	7.4	5.3	0	0.7	0
14	0	0.2	0	20.4	3.1	2.9	0	2.1	2
15	0.6	0	0	30.1	1	0.1	0	0	3.8
16	0.5	0	0	12.6	0	0	0	0	7.2
17	1	0	1	6.8	0	0	0	0	1.9
18	4.5	1.2	1.7	0.9	1.6	0	0	0	0
19	3.2	0.3	2.1	0	2.2	0	0	0	0
20	3.7	8.3	1.9	0	2	8.3	0	0	0
21	2	6.6	1.1	3.7	0	6.2	0	0	2.1
22	1.1	3	0	4	0	3.9	0	0	0
23	0	0	0	0	1	0	0	0	1.9
24	0	0.7	0.2	1.5	1.8	0	0	0	3.1
25	0	0	0	0	0	2.2	0	0	0
26	0	0	0	0	7	0.8	0	0	0
27	0	0.3	0	2.5	11.3	0	0	0	1.7
28	0	0	1	5.6	6.3	0	0	0	2.4
29	0.9	0.3	0	3	2.1	3.8	0		6.1
30	0	0.2	0	0	4.7	0	0		3.7
31	0	0.2		0.4		0	8.4		2.5

Appendix IV: Number of harvested leaves ANOVA

Leaf number 1: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	113.7968750	37.9322917	3.62	0.0201
IRR	3	55.5468750	18.5156250	1.77	0.1673
LHI	3	944.4218750	314.8072917	30.02	<.0001
IRR*LHI	9	60.1406250	6.6822917	0.64	0.7593

Coefficient of variation =19.57

Leaf number 1: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	432.1718750	144.0572917	13.28	<.0001
IRR	3	5.9218750	1.9739583	0.18	0.9081
LHI	3	495.5468750	165.1822917	15.23	<.0001
IRR*LHI	9	64.7656250	7.1961806	0.66	0.7369

Coefficient of variation = 22.35

Leaf number 2: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	617.625000	205.875000	2.34	0.0861
IRR	3	30.250000	10.083333	0.11	0.9511
LHI	3	5518.375000	1839.458333	20.90	<.0001
IRR*LHI	9	373.375000	41.486111	0.47	0.8861

Coefficient of variation =37.90

Leaf number 2: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1247.421875	415.807292	5.10	0.0040
IRR	3	90.171875	30.057292	0.37	0.7760
LHI	3	5117.671875	1705.890625	20.92	<.0001
IRR*LHI	9	390.015625	43.335069	0.53	0.8438

Coefficient of variation = 39.39

Leaf number 3: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	220.296875	73.432292	2.67	0.0585
IRR	3	82.046875	27.348958	1.00	0.4033
LHI	3	7254.546875	2418.182292	88.08	<.0001
IRR*LHI	9	193.390625	21.487847	0.78	0.6332

Coefficient of variation =18.81

Leaf number 3: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	523.421875	174.473958	7.46	0.0004
IRR	3	60.171875	20.057292	0.86	0.4698
LHI	3	7481.921875	2493.973958	106.70	<.0001
IRR*LHI	9	110.015625	12.223958	0.52	0.8501

Coefficient of variation =18.11

Leaf number 4: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	181.812500	60.604167	1.94	0.1370
IRR	3	95.187500	31.729167	1.01	0.3951
LHI	3	6983.187500	2327.729167	74.44	<.0001
IRR*LHI	9	270.562500	30.062500	0.96	0.4838

Coefficient of variation =20.74

Leaf number 4: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	117.812500	39.270833	1.02	0.3910
IRR	3	91.812500	30.604167	0.80	0.5015
LHI	3	8386.312500	2795.437500	72.90	<.0001
IRR*LHI	9	243.312500	27.034722	0.70	0.7010

Coefficient of variation = 22.34

Leaf number 5: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	41.312500	13.770833	1.26	0.2980
IRR	3	28.312500	9.437500	0.87	0.4655
LHI	3	3263.062500	1087.687500	99.85	<.0001
IRR*LHI	9	49.562500	5.506944	0.51	0.8627

Coefficient of variation =15.46

Leaf number 5: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	287.562500	95.854167	5.35	0.0031
IRR	3	144.312500	48.104167	2.69	0.0577
LHI	3	4093.312500	1364.437500	76.18	<.0001
IRR*LHI	9	167.312500	18.590278	1.04	0.4257

Coefficient of variation =4.23

Appendix V: Weight of harvested leaves ANOVA

Leaf weight 1: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	64703.6719	21567.8906	3.26	0.0299
IRR	3	17081.4219	5693.8073	0.86	0.4680
LHI	3	477230.6719	159076.8906	24.07	<.0001
IRR*LHI	9	55231.5156	6136.8351	0.93	0.5100

Coefficient of variation =54.85

Leaf weight 1: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	7210.62500	2403.54167	1.51	0.2252
IRR	3	1788.37500	596.12500	0.37	0.7721
LHI	3	71454.37500	23818.12500	14.95	<.0001
IRR*LHI	9	15689.25000	1743.25000	1.09	0.3862

Coefficient of variation = 62.13

Leaf weight 2: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	174413.922	58137.974	5.89	0.0018
IRR	3	44598.047	14866.016	1.51	0.2259
LHI	3	1640200.547	546733.516	55.37	<.0001
IRR*LHI	9	186518.641	20724.293	2.10	0.0497

Coefficient of variation =35.42

Leaf weight 2: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	34671.1719	11557.0573	1.63	0.1953
IRR	3	15447.2969	5149.0990	0.73	0.5412
LHI	3	577969.0469	192656.3490	27.20	<.0001
IRR*LHI	9	78084.1406	8676.0156	1.22	0.3042

Coefficient of variation = 57.00

Leaf weight 3: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	70882.297	23627.432	2.31	0.0892
IRR	3	52491.047	17497.016	1.71	0.1785
LHI	3	1998465.922	666155.307	65.10	<.0001
IRR*LHI	9	71870.391	7985.599	0.78	0.6353

Coefficient of variation =32.80

Leaf weight 3: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	54540.5000	18180.1667	2.58	0.0655
IRR	3	24233.6250	8077.8750	1.14	0.3414
LHI	3	822513.3750	274171.1250	38.85	<.0001
IRR*LHI	9	30674.5000	3408.2778	0.48	0.8784

Coefficient of variation = 46.38

Leaf weight 4: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	39297.922	13099.307	1.21	0.3185
IRR	3	16765.672	5588.557	0.51	0.6744
LHI	3	1375583.422	458527.807	42.21	<.0001
IRR*LHI	9	77369.391	8596.599	0.79	0.6257

Coefficient of variation = 42.82

Leaf weight 4: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	102189.188	34063.063	2.23	0.0981
IRR	3	13044.188	4348.063	0.28	0.8365
LHI	3	1660559.188	553519.729	36.18	<.0001
IRR*LHI	9	115662.563	12851.396	0.84	0.5837

Coefficient of variation =50.53

Leaf weight 5: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	10557.2969	3519.0990	1.26	0.2980
IRR	3	5814.1719	1938.0573	0.70	0.5591
LHI	3	583156.0469	194385.3490	69.84	<.0001
IRR*LHI	9	12773.7656	1419.3073	0.51	0.8595

Coefficient of variation =33.69

Leaf weight 5: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	101817.188	33939.063	1.01	0.3952
IRR	3	20379.688	6793.229	0.20	0.8938
LHI	3	1955442.188	651814.063	19.48	<.0001
IRR*LHI	9	124639.062	13848.785	0.41	0.9210

Coefficient of variation = 64.86

Appendix VI: Number of branches ANOVA

Branch 1: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1728.375000	576.125000	6.80	0.0007
IRR	3	111.875000	37.291667	0.44	0.7252
LHI	3	124.625000	41.541667	0.49	0.6905
IRR*LHI	9	432.750000	48.083333	0.57	0.8159

Coefficient of variation = 30.61

Banch 1: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	50.2968750	16.7656250	1.56	0.2125
IRR	3	53.7968750	17.9322917	1.67	0.1874
LHI	3	57.7968750	19.2656250	1.79	0.1624
IRR*LHI	9	102.0156250	11.3350694	1.05	0.4142

Coefficient of variation =43.45

Branch 2: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	521.1718750	173.7239583	1.98	0.1309
IRR	3	244.1718750	81.3906250	0.93	0.4358
LHI	3	105.1718750	35.0572917	0.40	0.7543
IRR*LHI	9	756.0156250	84.0017361	0.96	0.4879

Coefficient of variation 21.16

Banch 2: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	354.5625000	118.1875000	2.52	0.0703
IRR	3	108.0625000	36.0208333	0.77	0.5188
LHI	3	39.6875000	13.2291667	0.28	0.8384
IRR*LHI	9	324.6875000	36.0763889	0.77	0.6462

Coefficient of variation =38.28

Branch 3 Embu:

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1645.796875	548.598958	4.82	0.0054
IRR	3	382.671875	127.557292	1.12	0.3510
LHI	3	473.546875	157.848958	1.39	0.2592
IRR*LHI	9	912.515625	101.390625	0.89	0.5413

Coefficient of variation = 20.14

Branch 3: kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	851.3750000	283.7916667	3.77	0.0170
IRR	3	248.3750000	82.7916667	1.10	0.3596
LHI	3	345.1250000	115.0416667	1.53	0.2205
IRR*LHI	9	914.0000000	101.5555556	1.35	0.2404

Coefficient of variation = 27.13

Branch 4: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	8041.921875	2680.640625	14.15	<.0001
IRR	3	1678.296875	559.432292	2.95	0.0425
LHI	3	120.921875	40.307292	0.21	0.8870
IRR*LHI	9	804.015625	89.335069	0.47	0.8859

Coefficient of variation = 21.34

Banch 4: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	2710.562500	903.520833	5.91	0.0017
IRR	3	31.812500	10.604167	0.07	0.9760
LHI	3	504.312500	168.104167	1.10	0.3593
IRR*LHI	9	875.812500	97.312500	0.64	0.7600

Coefficient of variation =28.00

Appendix VII: Number of male flowers ANOVA

Male flower 1: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1037.296875	345.765625	6.82	0.0007
IRR	3	202.671875	67.557292	1.33	0.2754
LHI	3	1335.171875	445.057292	8.78	0.0001
IRR*LHI	9	524.265625	58.251736	1.15	0.3495

Coefficient of variation =33.42

Male flower 1: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	44.17187500	14.72395833	4.73	0.0059
IRR	3	46.17187500	15.39062500	4.94	0.0047
LHI	3	14.29687500	4.76562500	1.53	0.2194
IRR*LHI	9	5.89062500	0.65451389	0.21	0.9916

Coefficient of variation = 16.15

Male Flower 2: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	208.6875000	69.5625000	1.29	0.2905
IRR	3	218.3125000	72.7708333	1.35	0.2714
LHI	3	335.3125000	111.7708333	2.07	0.1179
IRR*LHI	9	487.3125000	54.1458333	1.00	0.4528

Coefficient of variation = 22.73

Male Flower 2: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	174.6875000	58.2291667	1.33	0.2757
IRR	3	361.8125000	120.6041667	2.76	0.0531
LHI	3	514.8125000	171.6041667	3.93	0.0143
IRR*LHI	9	607.8125000	67.5347222	1.55	0.1616

Coefficient of variation = 33.00

Male flower 3: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1322.125000	440.708333	11.36	<.0001
IRR	3	133.250000	44.416667	1.14	0.3413
LHI	3	28.125000	9.375000	0.24	0.8668
IRR*LHI	9	208.375000	23.152778	0.60	0.7928

Coefficient of variation = 22.73

Male flower 3: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	717.046875	239.015625	1.95	0.1344
IRR	3	185.171875	61.723958	0.50	0.6810
LHI	3	663.046875	221.015625	1.81	0.1594
IRR*LHI	9	1700.015625	188.890625	1.54	0.1618

Coefficient of variation = 34.24

Appendix XIII: Number of female flowers ANOVA

Female flower 1: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	118.9218750	39.6406250	2.61	0.0631
IRR	3	16.1718750	5.3906250	0.35	0.7859
LHI	3	123.1718750	41.0572917	2.70	0.0567
IRR*LHI	9	191.0156250	21.2239583	1.40	0.2182

Coefficient of variation = 32.03

Female flower 1: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	3.42187500	1.14062500	0.84	0.4807
IRR	3	2.79687500	0.93229167	0.68	0.5664
LHI	3	4.54687500	1.51562500	1.11	0.3541
IRR*LHI	9	5.89062500	0.65451389	0.48	0.8802

Coefficient of variation = 11.10

Female flower 2: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	66.54687500	22.18229167	1.79	0.1633
IRR	3	19.29687500	6.43229167	0.52	0.6720
LHI	3	31.92187500	10.64062500	0.86	0.4703
IRR*LHI	9	65.51562500	7.27951389	0.59	0.8012

Coefficient of variation = 24.33

Female flower 2: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	99.04687500	33.01562500	4.37	0.0088
IRR	3	27.29687500	9.09895833	1.20	0.3193
LHI	3	10.54687500	3.51562500	0.47	0.7081
IRR*LHI	9	42.39062500	4.71006944	0.62	0.7711

Coefficient of variation = 21.54

Female flower 3: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	102.0000000	34.0000000	14.37	<.0001
IRR	3	4.1250000	1.3750000	0.58	0.6305
LHI	3	45.2500000	15.0833333	6.37	0.0011
IRR*LHI	9	17.8750000	1.9861111	0.84	0.5844

Coefficient of variation = 12.25

Female flower 3: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	222.6718750	74.2239583	3.31	0.0284
IRR	3	67.2968750	22.4322917	1.00	0.4016
LHI	3	154.2968750	51.4322917	2.29	0.0909
IRR*LHI	9	325.5156250	36.1684028	1.61	0.1407

Coefficient of variation = 28.36

Appendix IX: Number of fruits and fruit weight ANOVA

Number of fruits: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	56.87500000	18.95833333	12.17	<.0001
IRR	3	4.37500000	1.45833333	0.94	0.4313
LHI	3	19.12500000	6.37500000	4.09	0.0119
IRR*LHI	9	11.50000000	1.27777778	0.82	0.6009

Coefficient of variation = 10.6

Number of fruits: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	34.04687500	11.34895833	2.63	0.0616
IRR	3	11.92187500	3.97395833	0.92	0.4385
LHI	3	35.54687500	11.84895833	2.75	0.0539
IRR*LHI	9	29.26562500	3.25173611	0.75	0.6587

Coefficient of variation = 17.29

Fruit weight: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	309.8831250	103.2943750	10.31	<.0001
IRR	3	16.7206250	5.5735417	0.56	0.6467
LHI	3	126.0781250	42.0260417	4.19	0.0106
IRR*LHI	9	76.8806250	8.5422917	0.85	0.5732

Coefficient of variation = 23.40

Fruit weight: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	16.34671875	5.44890625	2.10	0.1138
IRR	3	2.27046875	0.75682292	0.29	0.8314
LHI	3	25.75421875	8.58473958	3.31	0.0285
IRR*LHI	9	7.57640625	0.84182292	0.32	0.9626

Coefficient of variation = 13.68

Appendix X: Edible fruit flesh thickness ANOVA

Edible fruit Flesh thickness: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	50.36421875	16.78807292	9.04	<.0001
IRR	3	3.23796875	1.07932292	0.58	0.6302
LHI	3	5.43796875	1.81265625	0.98	0.4122
IRR*LHI	9	22.75515625	2.52835069	1.36	0.2336

Coefficient of variation =11.59

Edible fruit Flesh thickness: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	11.90796875	3.96932292	1.27	0.2959
IRR	3	5.72171875	1.90723958	0.61	0.6117
LHI	3	21.96546875	7.32182292	2.34	0.0857
IRR*LHI	9	22.54640625	2.50515625	0.80	0.6166

Coefficient of variation = 14.27

Appendix XI: Number of seeds and weight of 1000 dry seeds ANOVA

Number of Seeds: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	1283094.047	427698.016	12.78	<.0001
IRR	3	80148.672	26716.224	0.80	0.5012
LHI	3	76006.547	25335.516	0.76	0.5240
IRR*LHI	9	237476.016	26386.224	0.79	0.6279

Coefficient of variation = 71.16

Number of Seeds: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	81040.3750	27013.4583	1.15	0.3393
IRR	3	40180.6250	13393.5417	0.57	0.6375
LHI	3	315312.1250	105104.0417	4.47	0.0078
IRR*LHI	9	258384.2500	28709.3611	1.22	0.3057

Coefficient of variation = 71.87

Weight of 1000 dry seeds: Embu

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	75245.26172	25081.75391	11.48	<.0001
IRR	3	2113.99047	704.66349	0.32	0.8090
LHI	3	11076.32297	3692.10766	1.69	0.1826
IRR*LHI	9	14935.25516	1659.47280	0.76	0.6534

Coefficient of variation =63.95

Weight of 1000 dry seeds: Kabete

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	3	7004.12547	2334.70849	0.94	0.4291
IRR	3	5272.10672	1757.36891	0.71	0.5524
LHI	3	20594.26422	6864.75474	2.77	0.0527
IRR*LHI	9	17500.28266	1944.47585	0.78	0.6327

Coefficient of variation = 67.82