EFFECTS OF PLANT POPULATION AND HARVESTING INTERVAL ON THE GROWTH AND LEAF YIELD OF SLENDERLEAF (*Crotalaria brevidens*) IN KISII COUNTY, KENYA.

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DECLARATION AND RECOMMENDATION

This thesis is my original work and has not been presented for a degree or any other award in any other University.

Signed………………………… Date……………………….

Granduel Jemutai Momanyi (AGR-3-1034-1/2017)

This thesis has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this project to my Parents Mr. Stanley Bowen (Late) and Mrs. Emily Bowen, for their first instruction, mentorship, and encouragement in agriculture.

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ABSTRACT

Slenderleaf (*Crotalaria brevidens*), also known as rattle pod, is a prominent species of Crotalaria used as a vegetable in Kenya. It is a highly nutritious leafy vegetable, good sources of provitamin A, Vitamin C, carotenoids, iron protein, and calcium. At an average of 3 tons per hectare production of slender leaf in Kenya is low compared to an average potential of 11 tons per hectare. Previous studies done evaluated the influence of nitrogenous and phosphoric nutrients on slenderleaf growth. Notwithstanding, but no work has been carried out in Kenya on the effect of plant population and fresh leaf harvesting interval on the yields of the slenderleaf. One of the major limitations of slender leaf production is the inadequate comprehensive technical production package. The aim of the study was to determine plant population and harvesting interval effects on the fresh leaf yield and grain seed yield of the slender leaf with the aim of increased growth and yield. The experiment carried out from July to December 2018 at Kisii Agricultural Training Centre (KATC) in Kisii County. An experiment of Randomized complete block design (RCBD) comprising of three repetitions was carried out with the following treatments; three different levels of plant population (S1 = 30 cm x 30 cm, S2 = 30 cm x 20 cm and S3 = 30 cm x 15 cm) and four levels of leaf harvesting intervals (H1 = 7, H2 = 28 days, H3 = 49 days and H4 at maturity). Data on plant height, number of branches, fresh leaf weight, dry leaf weight, number of pods, and seed weight was collected and analyzed using the SPSS 21.0.Analysis of Variance(ANOVA) was done to identify the significant means between treatments and Post hoc test using Least Significant difference(LSD) was used to separate at $P \leq 0.05$. The results indicated that fresh leaf yield is depended upon the harvesting interval (intensity) and spacing ($p<0.05$). Harvesting interval was significant and had a greater effect on fresh leaf yield ($p<0.05$) as opposed to plant spacing which had no significance ($p= 0.985$).The highest fresh leaf yield was achieved under treatment 30 cm x 20 cm and 28 days harvesting interval which gave 11,358 kg/ha. Plant population had a great significant on plant growth (plant height and number of branches).Spacing 30 cm x 20 cm at maturity harvesting interval yielded the tallest plants while highest number of branches were realized in spacing 30 cm x 30 cm at maturity harvesting interval. Harvesting interval and plant spacing was significant in pod formation and seed weight per plant where treatment 30 cm x 30 cm and at maturity harvesting interval yielded the highest number of pods. The dry seed yield was greatly influenced by both spacing and harvestings interval with 30 cm x 20 cm and at maturity, producing the highest seed yields of 3,500kg/Ha. It is recommended that by adopting optimum combination of plant population and harvesting interval of 30 cm x 20 cm and 28 days harvesting interval the slenderleaf vegetable can be grown to achieve optimum fresh leaf yields.

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ABBREVIATION AND ACRONYMS

AEZ	:	Agro Ecological Zone
AIV	:	African indigenous Vegetables
ANOVA	:	Analysis of variance
CIDP	:	County Integrated Development Plan
CRF	:	Coffee Research Foundation
FAO	:	Food and Agricultural Organization
GLM	:	General Linear Model
KALRO	:	Kenya Agriculture & Livestock Research Organization
KATC	:	Kisii Agricultural Training Centre
LSD	:	Least Significance Difference
NFSNP	:	National food Security and Nutrition Policy
PAR	:	Photosynthetically Active Radiation
PPD	:	Plant Population Density
SPSSS	:	Statistical Package for Social Scientists

CHAPTER ONE

INTRODUCTION

This chapter defines the details that describe and recognize the importance and historical value of the effects of plant population and harvesting intervals on the growth and yield of slenderleaf. It presents the background of my research study, introduces the research topic, the objectives of the research, hypotheses and gives an overview of the research topic.

1.1 Background

Food plus nutrition insecurity is a significant issue in Kenya and also in Kisii County. This issue leads to high levels of malnutrition in the Country/County. Agriculture remains the mainstay economic activity in Kenya, accounting for over 24% gross domestic product (GDP),75% of employment and 60% export earnings (Kisii County Strategic Plan, 2013-2017). Agriculture sector is the country's supply of food and nutrition. In Kenya, small scale farmers' account for more than 70% of the total production. There are many challenges which are faced by these farmers. They perform agricultural activities with limited resources due to low economic ability, lack of adequate inputs, credit access and marketing skills. The farming situation in Kenya and many parts of the world has been complicated further by climate change which has exhibited itself through unreliability of rainfall in terms of duration and distribution. This may lead to frequent drought and floods affecting the production of food and therefore food and nutrition security for the country whose farming greatly depends on rain fed (Mburu et al., 2015). Agriculture in Kisii County mostly depends on rain fed and faces the same challenges as those of the national.

In every household in Kenya and also Kisii, vegetables comprise a critical component in the human diet. Kitchen gardens, mostly in small front or backyards, are used for the cultivation of vegetables. There are two groups of vegetables, which include the exotic types and the African indigenous type. The commonly introduced variety of vegetables includes Kales, Cabbages, Spinach, Cucumber and eggplant just to mention a few. While some of the indigenous vegetables include spider plant (*Saga*- Kisii), Black nightshade (*Rinagu* in Kigusii), Amaranthus (*Terere* in Kikuyu), Pigweed (*Mchicha* in Swahili), Jute plant (Murere in Luhya) and Slender leaf (*Omuto* in Kisii, .*Mito* in Luo). Kenya communities have grown and utilized the African indigenous vegetables traditionally. These vegetables have many unexploited advantages together with many unexploited potentials. African indigenous vegetables (AIV) or African Leafy Vegetables (ALV), slender leaf included, can be grown with ease and can withstand harsh climatic conditions and disease attack and provision of nutrients to the human bodies. African indigenous vegetables (AIV) grow faster and often are ready for harvest within 4 weeks after planting. They can withstand a number of biotic and abiotic stresses very well. They also respond positively to organic manure. African indigenous vegetables have substantial potential as a cash income earner, empowering the community rural poor to earn a living (Muhanji et al., 2011). It has a high nutritive value; 100g of fresh vegetable contains minerals calcium and iron; together with vitamins that can offer 100g daily requirements together with proteins of 40% (Muhanji et al., 2011). This aspect makes them a treasured supply of nutrients, considerably contribute to the intake of proteins, vitamins and also mineral in the rural areas (Kaul & Das, 2011). AIV is affordable to most people both in rural and urban areas. It has been proven by research that this vegetables provide the much needed nutrients in the human body. For example, a diet that lacks fruits and vegetable in it can lead to non - transmittable diseases like cancer and cardia - vascular diseases (The World Health Organization [WHO], 2006). Thus, growing and consuming these vegetable is an important step in solving health related issues in the community.

Unfortunately, a large number of African indigenous vegetables which were formerly cherished for consumption are ignored, under exploited and endangered with extinction due to continuous changes in environment, economy and sociocultural issues (Padulosi, 2004). This relatively explains why Africa which is one of the regions greatest gifted in biodiversity (Wieringa and Poorter, 2004), still is the continent where malnutrition and food deficiency diseases affects its people (The Food and Agriculture Organization [FAO], 2002).

Slenderleaf (Crotalaria *brevidens)*, commonly known as *marejea* (Swahili), *kipkururiet* (Kipsigis),*kamusuusuu* (Kamba), *kimiro* (Luhya) , *mito* (Luo), *Omuto* (Kisii) and internationally referred to a vegetable of small-scale production. A legume of Fabaceae family, contains 600 species that grow wildly in tropical and sub-tropical regions (Mosjids & Wang, 2011). The genus crotalaria with over 500 species of herbs and shrubs; has been domesticated and cultivated in Africa as a vegetable in several countries including most of the east African Countries Sudan, Kenya, Uganda, and Tanzania (Buleti et al. 2015).It is one of the ignored top ten important AIV in Kenya (Abakutsa-Onyango, 2004). The slenderleaf is among the African indigenous vegetables (AIV) that has for several years been planted while their young leaves and shoots are consumed as vegetables. The young leaves of slenderleaf are a good source of a number of vitamins and minerals as reported by (Abukutsa-Onyango, 2004). Hundred grams fresh weight of slender leaf contributes 4.2-4.9 mg protein, 270 mg calcium, 4mg Iron, 2.9-8.7 mg beta carotene, 115-129 mg ascorbic acid (Sikuku et al., 2013). It is a whole purpose crop in agriculture, and it has a medicinal effect. It has high levels of antioxidant activities factors, expressed as bioactive components, just like any other AIV. The consumption of slender leaves can contribute to alleviating some of the malnutrition problem, which is a significant challenge in Kisii County. It is a good source of some of the critical micronutrients whose deficiency is of public health concern.

Slenderleaf performs well at altitudes of 500-2700 meters above sea level. Shekinah and Stute (2018) observed that slenderleaf does well in fairly-drained soils with pH range of 5-7.5.The recommended rate of farm yard manure that slender leaf vegetable will respond well is 20 t/ha (Gido et al., 2017). For high leaf production in slender leaf species, the application of 60 kg P2O5 per hectare is recommended. It is also recommended that the growth of slenderleaf should preferably be done during the warm months to avoid yield reduction caused by powdery mildew that would cause economic damage (Nduhiu, 2017). Currently, slender leaf seeds are drilled in rows spaced out at 30 cm, and later thinned to maintain a spacing of 15-20 cm between the plants at six weeks after germination. It performs well in low nitrogen soils and drought conditions (Buleti et al., 2015).

The low production of slenderleaf vegetables in the Kenya, average of 3 tons per hectare, has been associated with poor quality seed, moderate application of modern technologies, and declining soil fertility (Gido et al., 2017). Farmers to increase slender leaf yields must adopt appropriate strategies and techniques and should embrace good agricultural practices. Consequently, the study was essential to find out the best agronomic practices for the cultivation of slenderleaf vegetable.

Ideal plant population or crop density results in optimum yields, whereas too high or too low plant population may lead to lower yields or quality. Spacing determines the number of crops planted in a unit area. Inter-row spacing is the distance between rows of plants and within the rows and intra row spacing is the distance between different plants in the same row. Plant spacing aims at the plant getting the most food out of the least amount of space while allowing the plant to thrive, thus making room for the harvest to grow (Baley, 2013). Adequate spacing enables plant to grow to maturity and leave enough space for airflow between plants for disease prevention.

There is limited research on slender leaf agronomy and performance in different regions of Kenya, and the current study is part of the managed cultivation of slenderleaf under field conditions. The effect of nitrogen, phosphorus, and the impact of poor seed are the few agronomical studies on the slenderleaf that have been carried out in Kenya (John, 2010). In contrast, there is little or no information on plant population and harvesting interval effect on the growth and yield of the slender leaf. The study was conducted in order to determine the effect of plant population and harvesting interval effect on the fresh leaf yield of the slender leaf at three different planting spacing of (30 cm x 30 cm, 30 cm x 20 cm and 30 cm x 15 cm) and different harvesting intervals (7days, 28 days, 49 days and at Maturity). The current spacing of 30 cm x 30 cm, being used by most farmers in Kisii, could be too broad, giving low plant population leading to low yields. The current spacing could also be too wide for Kisii County, where land sizes have significantly decreased, and causing high enterprise competition for the available land. The study aimed to establish the optimum slenderleaf spacing and harvesting interval of fresh leaf for increased yields.

1.2 Statement of the Problem

There is low production of slenderleaf vegetables in the country and more so Kisii County. The demand for indigenous vegetable, slenderleaf included, is high and there is high malnutrition among the population of Kisii which can be corrected with the consumption of slenderleaf vegetable together with other indigenous vegetables. .The Slenderleaf potential has never been achieved due to poor quality seed, moderate application of modern technologies (including different spacing and harvesting interval), and declining soil fertility. Various spacing recommendations are used in planting the vegetables in question using 30 cm by drill and thinned to 10-15 cm six weeks after harvest (Buleti et al. 2015). Most farmers and extension service providers (including MOA plot, Kisii showground) use 30 cm x 30 cm spacing (DAO Annual Report, 2010). Kenya Agricultural & Livestock Research Organization (KALRO) recommends 30 cm x 30 cm spacing (Soil Test Report, 2018). The removal of its tender leaves harvests the slenderleaf without following any harvesting interval. Although the effect of poor seed and the nitrogen and phosphorus impact on the growth of slenderleaf foliage has been researched on in the country, there is no literature available on the recommended spacing and leaf harvesting interval in Kenya, Kisii County (Nduhiu et al., 2017). This inadequacy necessitated the study on plant population and harvesting interval effect on the slenderleaf yield. The findings from this study will assist the extension service providers in coming up with recommendations tailored to the small-scale farmers in Kisii County, where land sizes are on a decreasing trend. They will also increase the chances of increased production, improved nutrition, and commercialization of slenderleaf as a high-value crop in the region (Evers &

Parsons, 2010). The knowledge will also be used by policymakers in formulating policies to address the declining production of indigenous vegetables, including slenderleaf.

1.3 Objectives

Broad Objective:

To develop a package on the appropriate plant spacing and harvesting interval for optimum output of slenderleaf.

Specific Objectives

The objectives of the study were:-

i. To establish the effect of different plant spacing on the growth and leaf yield of slenderleaf.

ii. To determine the effect of different harvesting interval on the growth and leaf yield of slenderleaf.

iii. To determine the effect of different harvesting interval on the seed yield of the slenderleaf.

1.4 Hypotheses

This study sought to test the following hypothesis:-

i. Plant population has effect on the growth and leaf yield of Slenderleaf (Crotalaria brevidens)

ii. Harvesting interval significantly affect the growth and leaf yield of Slenderleaf (Crotalaria brevidens)

iii. Harvesting interval has significant difference on seed yield of Slenderleaf (Crotalaria brevidens)

1.5 Justification of the Study

Improving the yields of African indigenous vegetables (AIV), exceptionally slenderleaf, can improve the low micronutrient levels of children and mothers. High production of the slender leaf can return income for the rural population and improve nutritional security because it can be accessed quickly. This is one of the Big 4 agenda which the government seeks to deliver to foster economic development. It is also cheap and reliable, coupled with other benefits and abilities that have not been utilized fully. Slenderleaf is also considered as a food security vegetable because it tolerates drought conditions (It grows in areas with altitudes from 500 m to 2700 m above sea level).

In Kenya, slenderleaf vegetable is grown but its potential of 10-12 tons per hectare has not been achieved due to low application of modern technologies being one of the reasons. The slenderleaf is planted using different spacing recommendations. Most farmers and extension service providers (including MOA plot, Kisii showground) use 30 cm x 30 cm spacing (DAO Annual Report, 2010). Kenya Agricultural & Livestock Research Organization (KALRO) recommend 30 cm x 30 cm spacing (Soil test report, 2018). The slenderleaf is harvested by the removal of its tender leaves with no recommended harvesting interval. Therefore, this study is intended to gather information on the most appropriate plant spacing and fresh leaf harvesting interval required form high yield production of slenderleaf vegetable to develop a package for the extension service providers. The study will also give us information on the treatment that will provide the highest seed weight, which can be used for future planting. This will go a long way in addressing the declining food and nutritional level (Malnutrition) and thus improve food security. The information will also address the declining income from farming and food shortages in the country. The findings will be used as a reference for training and further research work.

CHAPTER TWO

LITERATURE REVIEW

This chapter describes and accounts for what other scientists and authors have established and documented in the fields of harvesting interval and spacing and its interactions with yields of slender leaf vegetables along with findings on other African Indigenous vegetables**.**

2.1 Limitation of African Indigenous Vegetables (AIV) in Project Area

According to Kisii County Integrated development plan 2018 – 2022, agriculture forms the backbone of the county's economy with over 70 percent of the population depending on agriculture for their livelihood for both as a source of food and income. This sector, however, is faced with various challenges including high population density, declining farm sizes, outdated farming practices, and poor eating habits. These have in turn affected drastically the county residents' food security and creation of wealth. Therefore, this demand for new and innovative ways of farming for food crops including the African Indigenous vegetables whose demand at the County is high. The demand for vegetables, especially the African indigenous type is very high and thus the need for this study.

Further, the County consists of mostly farmers who own small pieces of land averaging 0.4 hectares and not economically viable for mechanization thus leading to low production. For the farmers to improve their yields and income there is need of promotion of innovative modern agricultural practices and of high value crops in order to maximize output.

The production of African indigenous vegetables, including slender leaf, is low within the Country. Various reports show that the popularity of many AIV species is declining across the

Sub Saharan African continent (Vorster et al., 2007; Vuyiswa et al., 2012; Nekesa & Meso, 1997; Smith & Eyzaguirre, 2007). The area devoted to AIV in Kenya and the income generated from AIV has shown an increasing trend but the production status is low compared to the exotic vegetables. The area under AIV in 2013 was 85,550 Ha with a yield of 176.736 MT and total value of Ksh 3.579 billion as opposed to exotic vegetable production with an area of 252,651 Ha with a yield of 4,202,393 MT and a total value of Ksh 65.992 billion in the same year (KALRO, 2013). Of the whole vegetable value, exotic vegetables, Asian vegetables and AIVs account for 94%**,** 1% and 5% respectively. (Alberto, 2015).

2.2 Origin and Distribution

Slender leaf grows in the wild in the tropical and Subtropical areas. It's origin is Northern Nigeria spreading to southern Tanzania and Ethiopia. It has been reported to be planted and utilized in most Countries of East Africa as a vegetable (Le Roux et al., 2013). The center of diversity for crotalaria species is believed to be Africa. The slender leaf grows in open and wooded grassland, bushland, often on termite mounds, at roadsides, in cultivated grounds, disturbed forests, and near seasonally flooded areas. Warm conditions favor it, and it can tolerate considerably drier conditions once the lateral roots have been established. It grows from 500 m to 2700 m above sea level (le Roux et al., 2013). In international trade slender leaf is referred to a vegetable of small-scale production

2.3 Botany and Ecology of Slender Leaf

The slender leaf is a legume, its genus is crotalaria and family of Fabaceae/ Leguminaceae. The genus crotalaria has about 500 species of which are mostly herbs and shrubs, and of which 400 of these species are found in Africa (Mosjidis & Wang, 2011). The slender leaf can easily be distinguished by the color of the leaves, which are bluish-green, the flowers are usually yellow with very conspicuous reddish-purple veins and grow to a height of 210 cm and have light brown seeds and the small pods are narrow in shape. Its leaves are divided into three narrow leaflets typically 10 cm long by 2 cm wide, which after some time produce seed pods which are inflated and with a hard skin, as large as 5 cm long by 0.7 cm wide, which are black when dry (Muthoni, & Nyamongo, 2010). The number of flowering stems produced by the crotalaria plant is indeterminate and is influenced by availability of water, photoperiod and temperature. A variety of insects and hummingbirds visits the flowers, with two common pollinators being monarch butterflies and bees, which are species-specific (Subramaniam & Pandey, 2013).When the pollinators or mechanical means damage the surface of the stigma that is when fertilization occurs. The number of seeds contained in a single pod range from 5 to 50 seeds depending on species. The seeds are kidney-shaped, and their color varies from olive-green to either yellow-red or brown (Mosjidis & Wang, 2011).

The slender leaf performs best in areas where temperatures during the day ranges between 16-26^{o}C but can also endure 12 - 30^{o}C. It favors a mean annual rainfall of 1,400 – 2000 mm p.a., but may tolerate 1,100-2,700 mm (Mosjidis & Wang, 2011). It grows best in a sunny location, succeeding in light shade. Grows well in a pH range of 6 – 6.5, tolerating 5.5 – 7 (Mosjids & Wang, 2011).

2.4 Cultivation of Slender Leaf

Slender leaf does well, at altitudes of 500-2700 meters above sea level. The plant grows best in well-drained soils with a pH 5-7.5 (Shekinah & Stute, 2018). Crotalaria seeds are drilled in rows of 30 cm apart and later thinned to maintain a 15- 20 cm spacing between the plants. Germination takes 3-4 days. A slender leaf responds well to manure, and an application of 20 ton per hectare is recommended. The initial growth of slender leaf is slow, but the plant is ready for harvesting in eight weeks. The plant matures in eight weeks and can produce seed under tropical conditions (Buleti et al., 2015). Therefore, it performs well in low nitrogen soils and drought conditions.

The Slender leaf has limited effects from a wide range of pests and diseases. The crop, during wet periods, can be destroyed by blight before it starts to flower. Insects including thrips and aphids, though in a small way, may attack the crop. During fruit development the pod borer may penetrate and affect seed development during. Rain water entering through the holes in the pods will cause the seeds to rot (Muthoni, & Nyamongo, 2010).

Harvesting of slender leaf is commonly done by uprooting the whole plant right before the formation of flowers and almost eight weeks after establishment and generally this is when the stems shall be about 40 cm tall. This practice is carried out by farmers when slenderleaf is grown between other crops as a catch crop (Aura, 2011). On the other hand, thinning is done after approximately six weeks and is utilized as a first harvest and ratoon system used thereafter. What is more, the process comprises plucking of the central shoot at the eight-week and subsequently the new side shoots are harvested. Besides, the primary branch is cut at 10 – 15 cm above the soil leaving at least three leaves (Aura, 2011). The side shoots which have formed can again be picked

after nearly two weeks, and with adequate and well distributed rains and use of nitrogenous manures harvesting may be carried out repeatedly for fifteen times. It should also be noted that as the dry spell sets in; there is little shoots development and often farmers pluck the remaining leaves and abandon the crop. Yields of up to 3 tons per hectare have been achieved with an area of 1 m squared. The slender leaf exist symbiotically with soil bacteria nitrogen fixing bacteria; these bacteria lead to the nodules development on the roots and aid in the fixation of atmospheric nitrogen to the plant (Muthoni, & Nyamongo, 2010). Generally speaking, the growing plant utilizes some of this nitrogen and the plants growing closer by also benefit.

2.5. Nutritional Importance and Uses of Slender Leaf

The slender leaf is one of the most popular African indigenous vegetable (AIV). The vegetable in question contributes 100% of the daily dietary requirements for various components for instance vitamins A and C, minerals like iron and calcium. In the same vein, when 100g of fresh slender leaf weight is consumed, it contributes to 400% proteins (Aura, 2011). The slender leaf has been alluded to contain medicinal traits that may treat stomach related ailments and malaria (Buleti et al., 2015). Agronomically, slenderleaf has several advantages that include: the ability to produce seed under hot conditions; performs well in nitrogen deficient soils due to its ability to fix atmospheric nitrogen; drought tolerant and can be intercropped and used as fodder and green manure (Buleti et al., 2015). It also prevents the germination of the problematic cereal crop weed, Striga weed (*Striga hermonthica*). It also has the potential use in the lessening of the population of the seeds of striga weed inside the soil (Buleti et al., 2015). The presence of alkaloids and phenolic compounds in the slender leaf attributes to its bitter taste. Slenderleaf was included in the top ten priority African indigenous vegetables (AIV) in the most regions and in the County according to a survey done by Opiyo et al. (2015).

2.6 Slender Leaf Production in Kenya

In Kenya, not many farmers have been involved in slenderleaf production commercially and for the external market. Its production is mainly on subsistence and for the domestic market. The vegetable is frequently intercropped and occupies small parcels of a farm. Most AIV are often grown around the homesteads, together with other crops like bananas, cassava and sorghum. The biggest percentage of the slenderleaf production is rain-fed. In dry seasons, farmers do crop water supplementation (often bucket irrigation) and as well grow crops in wetlands along rivers in order to meet vegetable needs.

Between the year 2012 to 2014, slenderleaf in Kenya increased from 370 to 533 Ha; yield from 2,780 to 5,100 MT; and value also increased from KES 58.2 to 119.1 million (GoK, 2015), (Appendix 9), presenting a 44, 83, and 105 percent increase in 2014 as compared to 2013 and 2012. However, there is inadequate supply of certified seed for slenderleaf and more so the crop is grown using less inputs thus its productivity is reduced. Trans Nzoia and Siaya were the leading Counties in slenderleaf production and they accounted for a combined total output of 69 per cent. The volume and total revenue continue to increase, which demonstrates a substantial increase in demand and utilization of slenderleaf vegetable in Kenya, as shown in appendices 9 and 10 (GoK, HCDA & AFA , 2015).

Low quality seed: Farmers often use own seed produced from previous season(s) and may store for up to three years. Buleti et al. (2015) conduct research on storage of slenderleaf seeds and concluded that seed storage up to two years can be done without significantly reducing germination percentage.

Absence of technical packages for optimal growth of slenderleaf. These includes, lack of optimal plant spacing and fresh leaf harvesting interval, poor soil fertility, lack of utilization packages, lack of preservation and processing packages. The small land sizes of the farmer. This calls for appropriate technical practices to be applied for optimal production of slenderleaf. This study will go a long way in addressing the constraint of plant population and leaf harvesting interval for optimum growth and yields of slender leaf.

2.7 Plant Population effects on Growth and Yield of Plants

Plant population is about the number of plants planted in a unit area. It is about the distance between one plant and another (Shackleton, 2010). There are two types of plant spacing, inter row spacing which is the distance between rows of plants and within the rows and intra row spacing which is the distance between different plants in the same row. Plant population/ density is an essential aspect in agronomy in the manipulation of micro environment of the field affecting the growing of the crop, development and yield establishment (Mabapa et al., 2017). To a certain extent, increase of plant population density (PPD) will lead to a decreased growth and yield per plant, but decrease of plant population density (PPD) will lead to an increased yields per plant. Different spacing is required by each plant according to its growth habits. Plants must be placed close enough so that there is no waste of precious garden space, but apart enough so that they have room to grow (Mabapa et al., 2017). It is recommended that spacing is based on the way the plants grow and the food that will be harvested to have a good basic plan for proper garden placement. Thus, different vegetables types need different spacing to ensure healthy growth and a good crop.

Solar radiation interception by a canopy depends on plant arrangement and plant density. Proportionately biomass production of crops is directly proportional to the amount of solar radiation intercepted by the crop canopy (Rahman & Hossain, 2011). The higher plant population (density), the nearer the canopy (implying tiny or no inward radiation reaching the surface of the soil) and increases interception of photosynthetically active radiation (PAR) needed by plants for the production of carbohydrate (Soltani & Sinclair 2011).

Amaglo (2007) working with Moringa (*Moringa oleifera*) and using three plant spacing of 5 cm x 5 cm, 5 cm x 10 cm and 5 cm x 15 cm obtained a significant increase in the growth of plant and number of leaves in all the treatments. Amaglo (2007) observed that, closer spacing showed the highest increase in plant height, whereas wider spacing showing relatively lower increase in height. The opposite trend was observed for the number of leaves per plant. Hence the study indicated that plant population had a significant effect on the growth and the yield of Moringa. A similar effect was observed for leaf production, stem size and overall shoot yield. Goss (2012) also observed that increasing plant density accelerate the rate of plant growth hence the increased heights in closer spacing. Mabapa et al. (2017) working on four varieties of black nightshade reported increase in fresh shoot weight with increase in plant population which was attributed to increase in pant population. Optimum plant population reduces competition and enables maximum crop yield (Mabapa et al., 2017). What is more, competition affects the proportion of the total production allocated to the economically important part of the plant (Mabapa et al., 2017). The major determinant of crop yield is the competition between and within plant species. Without a doubt, plants compete for light, nutrients, space and moisture.

Plant density is a key determining factor for a successful yield in the commercial production of leafy vegetable (Aminifard et al., 2012). As plant density increases, yield per unit tends to increase up to an optimal point where it declines. But also as plant density increases the completion for water and nutrients may occur giving rise to inadequate vegetative growth as well as reduced yields (Aminifard et al., 2012). Equally, low yields may result from low plant densities not maximizing utilization of available resources.

There was a significant impact on seed crop of sunnhemp (*Crotalaria juncea L.*) growth characteristics which were during the two experimental periods on its growth and yield as influenced by spacing and topping practices. Under the influence of wider spacing, basal diameter, number of primary and secondary branches and dry matter accumulation per plant were observed highest. While with the effect of closer spacing the highest plant height was observed. With the increase in spacing there was a gradual decrease of plant height Tripathi et al. (2013) posted similar results of plant height.

From the above conclusions, it is evident that spacing affects leaf yield of several crops. Spacing influences growth rate and crop yield due to inter plant competition for different inputs needed for growth and development. Therefore it becomes necessary for investigation of spacing arrangements in order to understand the mechanism of yield enhancement. Very little information on spacing along with fresh leaf harvesting interval is available in the slender leaf crop. Keeping this information in view the current study is done in order to find out plant population effects on the growth plus yield of slender leaf vegetable.

2.8 Harvesting Interval with Plant population effects on Branch numbers

The more branch production in okra (Abelmoschus esculentus (L) has been attributed to wider spacing that allows for efficient use of growth nutrients, water and light energy. This enables enhanced photosynthesis, production and deposition of carbohydrates as opposed to the closest spacing. The observed gradual decline in number of branches per plant as population density increased was in line with earlier report of Aura (2011) on potato plant, Greater numbers of branches were recorded due to wider spacing and lesser plant density in Okra (Lyon et al., 2010). Closer plant spacing of sunflower has been reported to produce more branches per plant than those of the wider ones. Closer spacing enhances competition between adjacent plants for available nutrients, water, sunlight and spatial space for growth and development. Closer special arrangement lowers branching and node formation and hence reduced flowering and pod set. The report of Moniruzzaman et al. (2010) showed that there was an increase in the height of plants and a reduced number of branches with an increase in plant density of okra. This may well be explained that as plant spacing increases, there is ample space and reduced competition for resources resulting in each plant having enhanced lateral vegetative growth of the crop. This also indicated the plasticity response of plants to various plant spacing, that is to say increase in plant population is associated with a progressive decline in number of branches up to a certain limit beyond which plants become mono-culms whereas, plants at lower density produce higher number of branches in order to compensate the dry matter per unit area of higher densities.

2.9 Harvesting Interval Effect on Leaf Yield

Leaf harvesting entails manual picking of all young but fully expanded trifoliate leaves. These leaves are usually smoother, pale green and looks shiner than the mature leaves, Most African indigenous vegetables, slender leaf included are harvested this way for vegetable use (Nduhiu, 2017). The effect of defoliation on plants depends on the intensity, frequency and timing of foliage removal (Dada & Oworu, 2010). The green portion of plants constitutes the plants' photosynthetic mechanism and especially leaves. When leaves are removed from the plant, the photosynthetic surface area is reduced resulting in a decline in photo-assimilates which are necessary for the growth of the plant. The decline of photo assimilates is more critical with the removal of tender leaves if tender leaves since they are the key manufacturing locates and are the sources of photosynthates in plants. The leaf surface area determines the amount of incident radiation intercepted for energy supply in photosynthesis (Egea et al., 2011).

Observations made by Aminifard (2012) who found out that frequent leaf harvesting lead to the formation of more vegetative growth in cow peas. This could have been as a result of redistribution of auxins at the point where the leaves were plucked causing the stimulation of the growth of more buds that later developed into branches and leaves resulting to increase in plant height, canopy span and branches per plant (Aminifard, 2012). This is contrary to findings made by Amaglo (2007), which showed significantly higher number of leaves, fresh and dry leaf yields from wholesome harvested plants than piecemeal harvested plants, Similar results finding where made in amaranth plant whereby frequent leaf harvesting reduced fresh leaf yield (Amaglo, 2007). Similar observation have been made in sweet potato, pumpkin, cassava, cowpea and clover (Evers & Parsons, 2010) .It has also been observed that root development of cassava in

Democratic Republic of Congo (DRC) is negatively affected by the harvesting of excess leaves for commercialization.

In white clover leaf removal has been observed to reduce the area for subsequent emerging of new leaves as they open fully. Some compensatory expansion occurs after but, the length of the petiole reduces substantially (Evers & Parsons, 2010). The greatest reduction in leaf size is exhibited by the young plants due to excessive defoliation. Defoliation has slight influence on the rate of subsequent leaves development. The seedlings of white clover have huge ability to recover from leaf removal, particularly if only old leaves are removed. But the removal of petioles and lamina causes a great growth reduction.

Sink- source relationship can be altered by defoliation. The sink strength of the remaining developing leaves can be increased by leaf removal. Defoliation causes a shortage of carbohydrates to plants and plants generally responds to this shortage by presenting an increase in resource allocation to shoot growth while a decreased resource allocation to the growth of fruit together with the growth of roots (Dada & Oworu, 2010). Buleti et al. (2015) observed that photosynthesis is altered by defoliation directly through sink-source relationship effects. Then photosynthates are focused towards formation of new leaves instead for grain or fruit production. They are also translocated to the root system for root and nodule growth following leaf harvesting.

2.10 Effect of Harvesting Interval and Plant Spacing on Pod Formation

According to Maurya, Bailey and Chandler (2013), optimum okra fruit yields can be due to suitable plant spacing while low yields and poor-quality fruits could be caused by wrong planting spacing. Another important index in crop yield and vegetative growth of vegetables is harvesting interval. Harvesting interval influenced the growth of okra due to the fact that it is a fast-growing crop (Maurya et al., 2013). Depressed yield was obtained in frequent harvesting interval but delayed harvesting interval depressed marketable yield because the over aged fruits becomes fibrous and will not be desirable for marketing. With increased harvesting interval the yield of okra gradually decreases while the highest number of pods is attained at. The highest pod yield is attained when harvesting interval is lowest (Maurya et al., 2013). The differences arose due to the fact that frequent defoliation encouraged the production of higher number of fruits per plant while prolonged defoliation leads to increased fruit size and weight and leading to the highest yields of fruits per plant and eventually per hectare.

2.11 Effect of Harvesting Interval and Plant Spacing on Seed Yield

Low yield was attained in frequent harvesting interval but on the other hand, delayed harvesting interval depressed marketable yield because the fruits are over grown and are fibrous and will not be appropriate for marketing. With Okra, the increased harvesting interval leads to decreased yield while at lowest harvesting interval the pod yield is high. The differences arose because regular defoliation stimulated the plant to produce a higher number of fruits per plant. When the harvesting interval is prolonged, there is increased fruit size and weight (Maurya et al., 2013). Schobesberger and Kaul reported some significant differences due to harvesting of leaves among amaranth genotypes (2013). There was a reduction of grain yield as a result of leaf harvest. When the leaves of amaranth are removed completely from the plant, the grain yield and number of seed per plant reduced by about 64.3 % and 63.7% respectively (Schobesberger & Kaul, 2013).

2.12 Challenges and Opportunities in the production of Slenderleaf Vegetable in Kenya

The production of African Indigenous vegetables, slenderleaf, has several challenges. Some of the challenges include low yields per unit area, this could be due to low plant population, poor harvesting practices and others poor agronomical factors. Poor quality seeds is also another challenge. Most of the farmers in Kisii use the seed from the previous crop which may end up not giving a good yield.

Slenderleaf production lacks technical packages for its optimum yields. Slenderleaf production in Kenya relies on rain fed agriculture which is a common practice with most of agricultural production activities.

Huge losses of AIV is experienced due to disease and pests infestation. According to Angeles et al. (1993), slenderleaf is not attacked much by diseases and pests. However the whole crop may be damaged by blight just before flowering during wet seasons.

A lot of wastage of AIV is realized due to poor roads in the rural areas which are deteriorated during rainy seasons.

Most farmers are faced with the challenges of poor infrastructure, high production costs, low uptake of technology, poor access to markets and being exploited by middlemen (FAO, 2015; WBG, 2015). Opportunities exists in addressing these challenges by carrying out the necessary interventions in order to increase productivity and production of AIV. Once the production increases it will benefit the Kisii population by improving food and nutrition security, increasing the people’s income, reducing poverty levels and raising the County’s economy. Opportunities in slenderleaf production present themselves mainly on the area of plant population for maximum space utilization, harvesting interval, plant breeding and seed selection.

Slenderleaf vegetable can be used for medicinal purposes as reported by Woomer (2000) that slenderleaf is favorable in treating malaria and stomach-related illnesses. It can also be used to improve fertility to soils through atmospheric nitrogen fixation. Slenderleaf can also be used to suppress weeds in arear where it is difficult to cultivate (Polhill, 1982). This important advantage presents an opportunity of improving the slenderleaf production and other the yields of other crops which maybe intercropped with it. This will in turn contribute to food and nutrition security and also to restoration of the environment.

2.13 Contribution to livelihood and Food and Nutrition Security

Health and Nutrition Improvement

It has been known and reported that a greater number of AIVs contain health beneficial properties and uses, most of them being used for preventive and healing purposes by the rural populations. These characteristics of AIVs is clearly related to their nutritious and non – nutritious biologically active properties. The nutritional intake of vitamins and mineral of the local communities have for years been considerably contributed by the AIVs. They are richer in several vitamins, minerals and crude fiber while they also contain good amounts of proteins, fats and oils and they aid in the palatability as well as the digestibility of foods in the human gut (Adebooye & Opabode, 2004). When consumed, they can boost the immune system of the body and thus can slow the advancement of some diseases like Acquired immune deficiency syndrome (AIDS). When consumed with staple foods the AIVs has the ability of increasing the bioavailability of micronutrients. And since they are easily accessible by the rural poor communities then they act as the major source of nutrients.

Source of income generating and food security

African indigenous vegetables (AIVs) are grown by most farmers for consumption and the surplus for income generation. The production of AIVs can be carried out with least starting capital therefore offering a great opportunity for the resource poor people to earn a living. It also provides an opportunity for making a living for those who are in the informal sector. With the current land pressure in Kisii County, AIVs, slenderleaf included, is ideal to be grown for income generation since it does not require a big area of land. Moreover there exist other technologies like hanging gardens, use of used tins and cement bags and multistory gardens where very little or no land is required to produce the vegetables. One can generate some income even with very little available space and most of these vegetables, over 70 percent is traded in the rural areas making it a cash income earner to the farmers (Schippers, 2000; Abakutsa - Onyango, 2003).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Site Description

Location

The field experiment was conducted at Kisii Agricultural Training centre during the short rains to determine plant population effect and fresh leaf harvesting interval on the yield of slender leaf (*Crotalaria brevidens*). The study site was located in Nyaribari Chache Sub County, Kiogoro ward, within Kisii Municipality, Kisii County, Kenya. It is 400 km from Nairobi. It boarders KALRO Kisii to the East, Jogoo estate to the North, CRF substation to the south and Kisii national polytechnic (KNP) to the west. KATC has 32.9 ha of land. It lies 1^0 South and longitude 34^0 East at a height of 1,722 meters above sea level. It lies within Upper Midland Agro Ecological zone (AEZ) ranging from 1140 - 2211 m above sea level with average humid temperature of 21- 30^0C.

Rainfall

The rainfall is high and also reliable, averaging 1,200 – 2,100 mm per annum. The County experiences a highland equatorial climate; with two rainy seasons. The long rains fall between February and June and the short rains are received in the months of September, October and early December. July and January are relatively dry months. The conditions of adequate rainfall and moderate temperatures are suitable for growing most crops which include industrial crops (tea, coffee, and pyrethrum), food crops (maize, beans, finger millet, potatoes, bananas, groundnuts) and vegetables like AIV. Dairy, poultry and fish farming is also practiced (Kisii County Agriculture report, 2013).

Temperature

Maximum temperatures is between 21°C – 30°C and minimum temperatures is between 15°C – 20°C.

Soil Types

Kisii soils has seventy five percent volcanic soils (nitosols), which are well drained, very deep in organic matter. The rest is poorly drained clay soils (phaezems), red loams and sandy soils. Black cotton soils (verisols) and organic peats soils (phanosols) (Kisii, CIDP, 2018 - 2022). The Soils at the study site are moderately acidic with a pH of 5, moderate in organic compounds and adequate Manganese levels. They are low in Nitrogen, phosphorus and potassium. This is revealed in the soil analysis report by Kisii Agricultural Research Institute (KALRO) Kisii in Appendixes 4 & 5. The recommended rates for phosphorus and potassium were applied in the treatment plots.

3.2 Experimental Procedure

The experiment involved growing Slenderleaf vegetable (*Crotalaria brevidens)* under three different plant spacing and four different harvesting intervals. The farming tools mainly used included ordinary and fork jembes, farm inputs, measuring tape, weighing scale and brown A4 envelopes for putting in the harvested leaves.

The experiment was carried out in the short rains of September to December 2018 at Kisii Farmers Training Centre. The research experiment used a Randomized complete block design

(RCBD) with three replications. The treatment combinations were assigned once per block randomly and six (6) plants per plot were also selected randomly for data collection.

Land preparation

Before the setting up of the experiment a complete top soil sampling was done. The sample, of 0-30 cm depth, was taken to KALRO Kisii for the initial nutrient level analysis (Appendix 4). First and second ploughing was done and harrowing using a tractor. This was done after the second week of September due to the delayed rains. Plot demarcation and layout was done with proper labeling and marking to provide ease of identification. The plot demarcation is shown in the Plate 3.1.

Plate 3.1

Plot Demarcation, Layout, Marking and Labeling

The plots were demarcated, marked and labelled before planting as shown in plate 3.1

Planting

Slender leaf seeds for planting was sourced from Kisii KALRO. During planting uniform amount of Di ammonium phosphate (DAP) was applied in all plots at 60 Kilogram per hectare. To avoid direct contact with seed, the fertilizer is mixed well with the soil. Planting of the seeds was done at the onset of rains in rows at spacing of 30cm x 30 cm, 30 cm x 20 cm and 30 cm x 15 cm), five seeds per hill and later at fourteen days after emergence thinned to one plant for every hill, as shown in Plate 3.2.

Plate 3.2

Planting of Slenderleaf

Planting of the treatment plots after demarcation was done as indicated in plate3.2

Weed Control

The experimental plots were kept weed free by hand weeding using hoes and fork jembes to reduce competition for space, moisture, nutrients and light. When weeding was done it was accomplished the same day for all treatments. Plate 3.3.

Plate 3.3

Weed Free Plots

The plots were weeded and kept free of weeds throughout the experiment period as shown in plate 3.3

Pests and Disease Control

Observations were done on weekly basis during the experiment period. Regular control measures of pest and diseases by chemicals application to prevent any attacks to plants was carried out.

Harvesting

- The defoliation of slenderleaf was carried out at specific intervals (7days, 28 days, and at 49 days) per plot according to the treatments.

3.3 Experimental Research Design

- The experiment design of 3 x 4 factorial experiment arrangement in RCBD replicated three times was used with twelve combination namely three plant spacing combined with four leaf harvesting intervals. The spacing was 30 cm x 30 cm, 30 cm x 20 cm and 30 cm x 15 cm with the leaf harvesting interval of 7days, 28 days, and 49 days and at physiological maturity (98 days). This formed twelve treatments. Plot size used was 3 m x 2 m. Data was collected on the following variables: germination percentage, stem height, branch numbers, Fresh leaf yield, dry leaf yield, number of pods as well as the yield of dry seed.

Plate 3.4

Data Collection on Stem Height and Branch numbers

The data collection on stem height was done as indicated in plate 3.4

3.4 Treatment and Treatment Combination

Treatments

There were seven different treatments containing three spacings and four harvesting intervals.

There were a total of twelve combinations.

i) Spacing:

30 cm x 30 cm (S1): Giving 110,000 plant/hectare population

30 cm x 20 cm (S3): Giving 166,666 plants/hectare population

30 cm x 15 cm (S2): Giving 221,666 plants/hectare population

ii) Harvesting Interval:

7 days (H1),

28 days (H2),

49, days (H3),

At Maturity (H4)

b) Treatment Combination

There were twelve combinations in three blocks replication (Table 3.1)

Table 3.1

Treatment Combinations

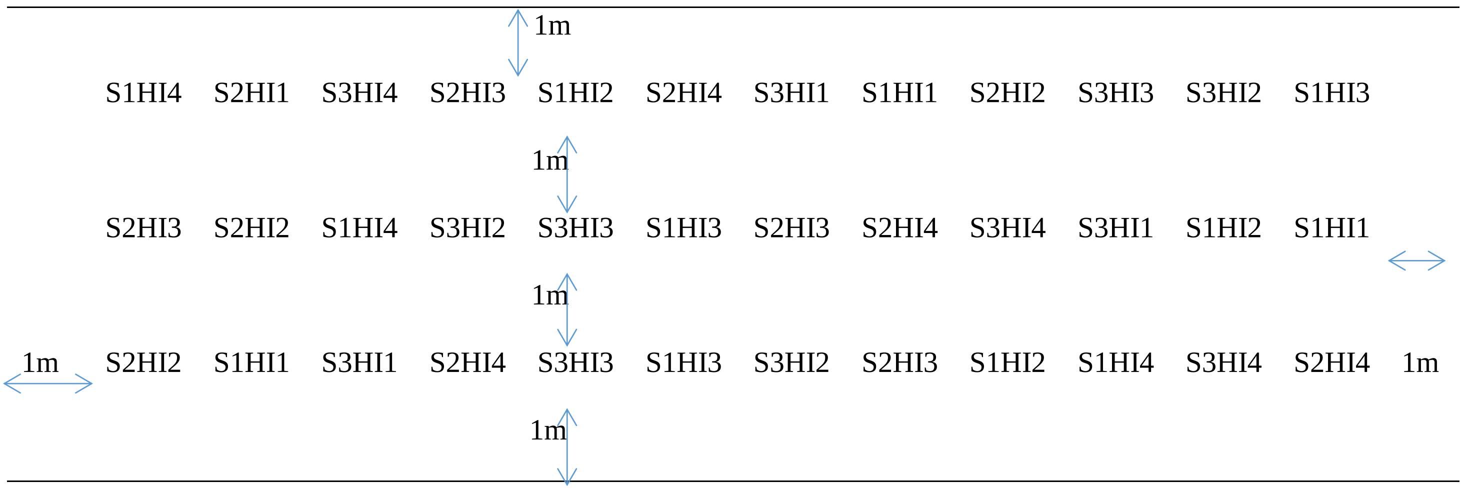
		Harvesting Interval			
Plant		H1	H2	H3	H4
Spacing	S1	S1H1	S1H2	S1H3	S1H4
	S2	S2H1	S2H2	S2H3	S2H4
	S3	S3H1	S3H2	S3H3	S3H4

3.5. Plot Layout

The research experiment was laid out using Randomized Complete Block Design (RCBD) with twelve treatment combinations replicated thrice as shown in figure 3.1.With 3 m x 2 m experiment plot size of and 0.5 m footpath separating the adjacent plots and 1m separating the adjacent blocks.

Figure 3.1

Plot Layout



3.6. Data Collection Procedure

Plant Sampling

Six plants from each of the trial plots were randomly sampled and tagged avoiding the boarder rows using the computer generated random numbers. These plants were used to measure various parameters progressively throughout the experiment period. The parameters measured were; stem height, branch numbers, yields for both fresh and dry leaf, number of pods plus weight of seed. These parameters are discussed below.

Plant Height

The stem height of the plant above the soil level from the plant base to the tip of the terminal shoot was measured in centimeters using a tape measure to establish the growth of the plant. The measurements were taken as indicated below:

- Initial at 7 days after emergence,
- Then at 21 days after emergence,
- At 42 days after emergence,
- At maturity (84 days).

The mean heights for each treatment plot were computed and recorded for statistical analysis.

Branch Numbers

The branch numbers for every plant per treatment plot were counted physically as follows;

- Initial at 7 days after emergence,
- Then at 21 days after emergence,
- At 42 days after emergence,
- At maturity(98 days)

The mean of branch numbers per plant for each plot was computed then recorded for statistical analysis.

Fresh Leaf Yield

The plant's fresh leaves were harvested after every 7 days, 28 days and 49 days for different plots according to the treatment after observation for readiness for harvesting and consumption (21 DAE). The leaves were weighed in Kilograms using an electronic weighing balance. The mean weights from each treatment plot was computed and recorded for statistical analysis.

Dry Leaf Yield

After the fresh leaves had been weighed, they were placed on an oven pan and dried in an electric oven at 125^0F for six hours. This was done uniformly for all the fresh leaves harvested.

After drying the leaves were weighed in Kilograms using an electronic weighing balance. The mean weights from each treatment plot was computed and recorded for statistical analysis.

Number of Pods

The number of pods from the six (6) sampled plants from each treatment plot were collected after the plant had attained maturity stage (98 days after Emergency). The mean number of pods for each treatment plot was computed and recorded for statistical analysis.

Weight of Seed

The weight of seed for each treatment plot was taken when the plants had attained full maturity (98 days after Emergence). The seeds were dried under a shade and weighed with an electronic weighing scale. The total seed weight per treatment plot was recorded for statistical analysis.

3.7. Data Analysis

Collected data was entered and processed in a Ms Excel spread sheet then using SPSS version 21.0 the data is subjected to analysis of variance (ANOVA). Post hoc test was done using Least Significant Difference (LSD) when the ANOVA indicated a significant differences ($P \leq 0.05$) between the treatments.

CHAPTER FOUR

RESULTS AND DISCUSSION

This section discusses both the growth and yield parameters that were indicated for research. For the purpose of this research, the growth parameters measured, recorded and interpreted were; plant height and number of branches. The yield parameters taken were; fresh and dry leaf weights, number of pods per plant and seed yield per plot. In the discussions, comparisons are made between the harvesting interval and spacing effects on all the plant growth and yield parameters.

4.1 Establishment Rate

The crops germination/ establishment rate was observed between 10^{th} to 14^{th} days after planting. The number of seedlings that have germinated for each treatment plot was counted on the 14^{th} day for each block. Then the germination mean percentage for each treatment plot was computed. The establishment percentage of slenderleaf was recorded as shown in table 4.1.

Table 4.1

Percentage Establishment of Crop at 14th Day

Treatment	**Treatment Combination**	**% Establishment**
1	S1HI1	98
2	S1HI2	95
3	S1HI3	99
4	S1HI4	98
5	S2HI1	97
6	S2HI2	98
7	S2HI3	95
8	S2HI4	97
9	S3HI1	95
10	S3HI2	98
11	S3HI3	97
12	S3HI4	98

The crop establishment percentage for all treatments was above 97% giving an ideal crop population to be used in the treatments' experimental evaluation.

4.2 Plant Height

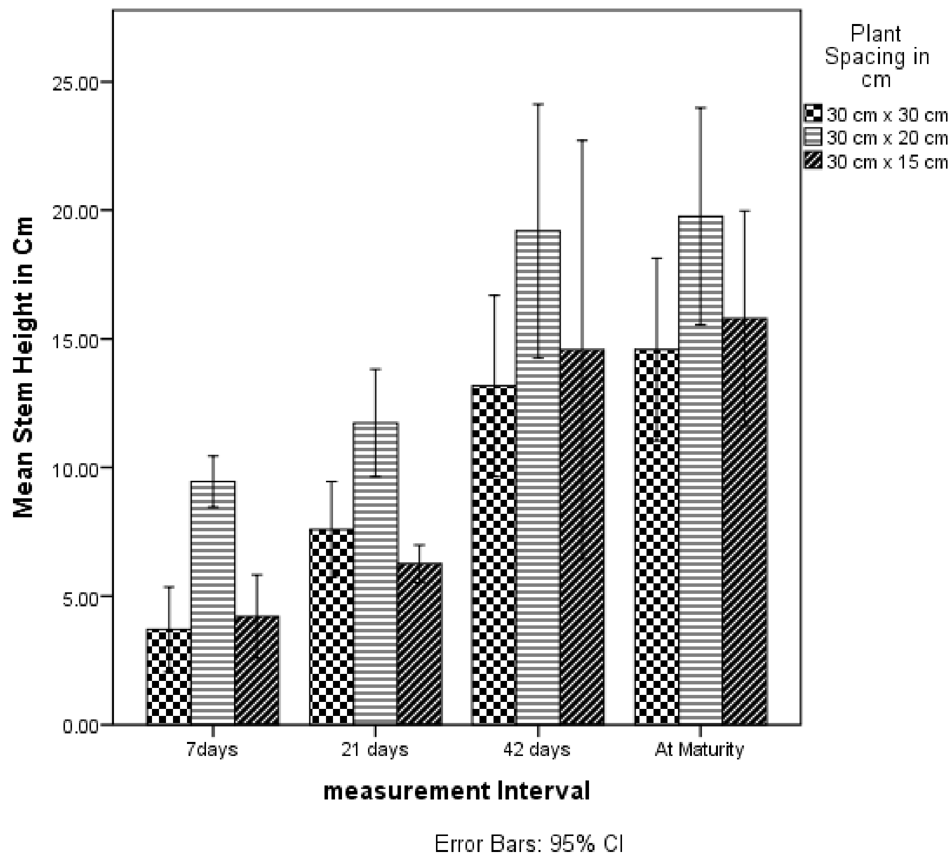
The plant's stem height above the soil level was measured in centimeters, using a metal tape measure. Measurements taken from the plant base to the terminal shoot tip for all the six randomly sampled plants per plot. The measuring intervals were as follows:

- Initial at 7 days after emergence,
- Then at 21 days after emergence,
- At 42 days after emergence,
- At maturity.

The mean heights for each treatment plot were recorded for statistical analysis and analyzed using SPSS Version 21.0 and the results are as here below. Plant height was used as a proxy measure to determine the growth rate according to the treatments. The mean stem Height of the slender leaf against stem height measurements interval is as shown in figures 4.1.

Figure 4.1

Effect of Measuring Interval and Plant Spacing on Stem Height



The results represented in figure 4.1 indicated that there were noted differences in slenderleaf plant height at different stem height measurement intervals and spacing. Plant heights at 30 cm x 20 cm spacing were consistently fairly tall in all the measuring intervals. The increased plant height at closer spacing implies that plants were competing for light, nutrients, space and moisture. The plants at maturity recorded the highest mean stem height (19.76 cm) followed by the 42 day measurement interval which recorded a height of 19.19 cm.

The differences in plant heights as exhibited in figure 4.1` were further subjected to ANOVA to determine where there were significant differences. Post Hoc (LSD) test was conducted at P≤0.05 to separate the differences between the mean heights as shown in tables 4.2 and 4.3.

Table 4.2

Univariate Analysis of Variance on Effect of Measurement Interval on stem Height

Tests of Between-Subjects Effects

Dependent Variable: Stem Height in Cm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Stem height measurement interval	771.621	3	257.207	30.836	.000
Error	266.912	32	8.341		
Total	1038.533	35			

* The mean difference is significant at the p ≤0.05 level.

The results (table 4.2) showed that there was significant difference in stem height under different measuring intervals. There was need to carry out a post hoc test for the dependent variable stem height to determine the difference between the mean of the four measuring intervals..

Table 4.3

LSD Summary of Measuring Interval against Plant Height

	7 days	21 days	42 days	At Maturity
7 days		-2.7344	-9.8589*	-10.9233*
21 days			-7.1244*	-8.1889*
42 days				-1.0644

* The mean difference is significant at the 0.05 level.

LSD results (table 4.3) indicated that increased days of measuring interval (DAE) in slenderleaf production statistically increased the plant height. The mean stem height increased with time, starting to show significant differences ($P<0.05$) from the 42nd DAE. It shows that the maximum elongation stage of the vegetable is at 42 days after emergence.

Table 4.4

Univariate Analysis of Variance on Effect of Plant Spacing on Stem Height

Tests of Between-Subjects Effects

Dependent Variable: Stem Height in Cm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	205.132	2	102.566	4.061	.026
Error	833.401	33	25.255		
Total	1038.533	35			

* The mean difference is significant at the p≤ 0.05 level.

The ANOVA results showed that there was significant difference (P=0.026) in stem height under different plant spacing (table 4.4).

A post hoc test was done among the dependent variables stem to determine the difference between the means of the three plant spacing.

Table 4.5

LSD Summary of Plant Spacing against Plant Height

	30 cm x 30 cm	30 cm x 20 cm	30 cm x 15 cm
30 cm x 30 cm		-5.2708*	-.4433
30 cm x 20 cm			4.8275*
30 cm x 15 cm			

* The mean difference is significant at the $p \leq 0.05$ level.

LSD results (table 4.5) indicated that there was a significant difference ($p<0.05$) between the different plant spacing on plant height. There was a significant difference between spacing 30 cm x 30 cm and 30 cm x 20 cm and also between 30 cm x 20 cm and 30 cm x 15 cm. There was no significant difference between spacing 30 cm x 30 cm and 30 cm x 15 cm.

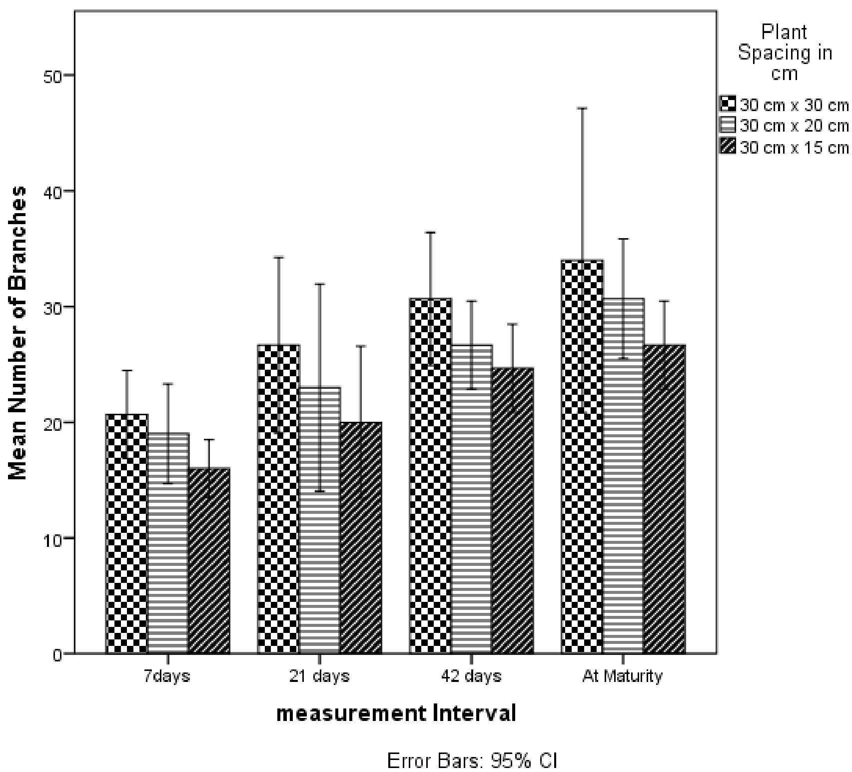
In figure 4.1, it showed that closer spacing (30 cm x 20 cm and 30 cm x 15 cm) showed the highest increase in stem height whereas lower stem height increase was shown in the wider spacing (30 cm x 30 cm). It agrees to what Amaglo, (2007) found while working with Moringa (*Moringa oleifera*) that closer spacing showed the highest plant height increase whereas the wider spacing showing relatively lower plant height increase. According to Lyons, (1968), the rate of plant growth is enhanced by increasing plant density therefore increased heights in closer spacing. This could be due to the competition of the necessary plant growth requirements (light, nutrients, Space and moisture) by the higher plant population which in turn makes the stem to grow taller.

4.3 Branch Numbers

The branch numbers for each plant was counted at an interval of 7, 21, and 42 days after emergency and at maturity. The means of branch numbers for each plant were computed then recorded for statistical analysis. The mean branch numbers of the slender leaf (*Crotalaria brevidens*) plants under different treatments is as shown in figure 4.2.

Figure 4.2

Effect of Measuring Interval and Plant Spacing on Number of Branches



The results (figure 4.2) showed that there were observed differences in the number of branches between different treatment combinations. The 30 cm x 30 cm plant spacing and at maturity exhibited the uppermost number of branches. The lowest number of branches was exhibited by treatment 30 cm x 15 cm spacing at 7 days measurement interval. Plant spacing 30 cm x 30 cm exhibited the highest number of branches in all the measurement intervals. This agrees with the observation made by Tripathi *et al*., 2013 who observed that wider spacing in *Crotalaria juncea* L yielded the highest number of primary and secondary branches.

Table 4.6

Univariate Analysis of Variance on Effect of Measuring Interval on Branch Numbers

Tests of Between-Subjects Effects					
Dependent Variable: Number of Branches					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Measurement Interval	636.556	3	212.185	15.693	.000
Error	432.667	32	13.521		
Corrected Total	1069.222	35			

Significant difference ($p \leq 0.05$) was realized in measuring intervals

This observation was confirmed by ANOVA test which showed that there was a significant difference ($p \leq 0.05$) between the measuring intervals. There was need to carry out a post hoc test for the dependent variable number of branches to establish the different means among the four measuring intervals.

To separate yield difference between the measuring intervals, LSD multiple comparisons at $P \leq 0.05$ was conducted and the results are as indicated in tables 4.7.

Table 4.7

LSD Summary of Number of Branches (α≤0.05) under Different Measurement Intervals

	7 days	21 days	42 days	At Maturity
7 days		-5.44*	-7.56*	-11.67*
21 days			-2.11	-6.22*
42 days				-4.11*

* The mean difference is significant at the 0.05 level.

The LSD results indicated that the number of branches is considerably influenced by the number of days after emergence. There were significant difference on number of branches between all the measuring intervals except 21 days and 42 days where there were no significant difference.. Branch numbers counted at 7 days interval and 21 days interval was statistically different between them and among the other measurement intervals. The 21 day interval and the 42 day interval number of branches counted were not very different. There results showed the presence of significant differences ($p \leq 0.05$) between measuring intervals. Measuring interval of 7 days also at maturity had the greatest significant difference. This could be because at 7 days after emergence the plant is still very young and the formation of most primary and secondary branches had not taken place while at 21 and 42 days most of them had formed and at maturity all the secondary branches had been established by the plant.

Table 4.8

Univariate Analysis of Variance on Effect of Plant Spacing on Branch Numbers

Tests of Between-Subjects Effects

Dependent Variable: Number of Branches

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	228.222	2	114.111	4.244	.023
Error	887.333	33	26.889		
Corrected Total	1115.556	35			

The ANOVA results indicated a significant difference ($p \leq 0.05$) amongst the plant spacing means on number of branches. Therefore, there was need to conduct a post hoc test for the dependent variables number of branches to establish which of the difference among the three plant spacing means..

Table 4.9

LSD Summary of Number of Branches (α≤0.05) under Different Plant Spacing

	30 cm x 30 cm	30 cm x 20 cm	30 cm x 15 cm
30 cm x 30 cm		3.17	6.17*
30 cm x 20 cm			3.00
30 cm x 15 cm			

* The mean difference is significant at the 0.05 level

From the LSD summary (table 4.9), it was proven that the spacing of 30 cm x 30 cm and 30 cm x 15 cm were significantly different. There was however no difference observed in spacing of 30 cm x 20 cm. This shows that as the population density increases the branch numbers per plant reduces. This may well be explained by the fact that as plant spacing increases, there is ample space and reduced competition for resources resulting in each plant having enhanced lateral vegetative growth of the crop. Plants at lower plant density produce higher number of branches in order to compensate the dry matter per unit of higher density. The same outcomes were reported by Lyon et al. (2010) presenting that more numbers of branches were recorded due to wider spacing and lesser plant density in Okra. This is contrary to what was found by Mabapa et al (2017) who reported that closer plant spacing of sunflower produced more branches per plant than those of wider plant spacing.

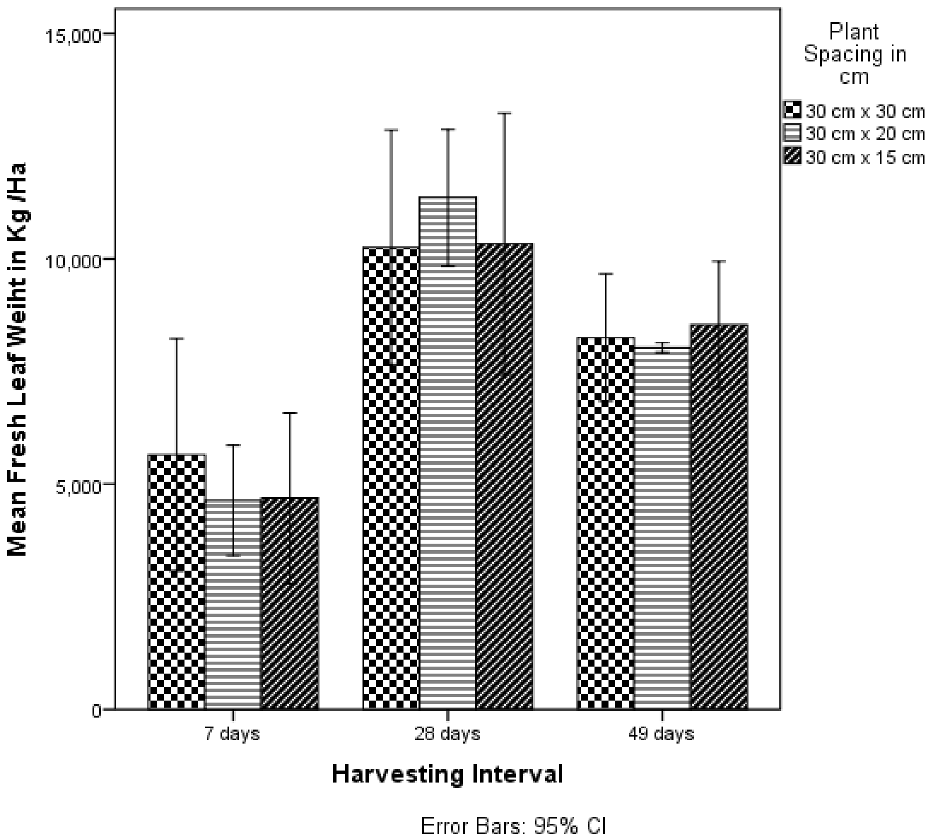
4.4 Fresh Leaf Yield

Influence of harvesting interval on fresh leaf yields in kgs/ha

Harvesting of fresh leaves was done after every 7 days, 28 days, and 49 days. The leaves at the maturity stage were not harvested because the leaves were too hard and had passed the consumable stage. At this stage I was interested with the seed which most farmers in Kisii sell to other farmers to be used for planting the next crop. The leaves were weighed in Kilograms using an electronic weighing balance. The mean weights from each treatment plot was computed and recorded for statistical analysis. The SPSS outputs of the fresh leaf yield data are as presented in figure 4.3.

Figure 4.3

Effect of Harvesting Interval and Spacing on Fresh Leaf Yield in kgs/ha



The results (figure 4.3) showed that the fresh leaf weight was highest generally at 28 days harvesting interval as compared to the other measurement intervals at spacing 30 cm x 20 cm. Under treatment 30 cm x 20 cm and 28 days interval gave the highest fresh leaf weight followed by 30 cm x 15 cm and 28 days and 30 cm x 30 cm and 28 days with the same amount of fresh leaf weight. Fresh leaf weight was lowest in 7 days harvesting interval (frequent harvesting) with treatment 30 cm x 20 cm and 7 days being the lowest.

The data was further subject into univaraiate analysis of variance and post hoc test using SPSS version 21.0 and the results are as presented in tables 4.14 and 4.15.

Table 4.10

Univariate Analysis of Variance on Effect of Harvesting Interval on Fresh Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Fresh Leaf Weight in Kg /Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	145279484.519	2	72639742.259	113.275	.000
Error	15390389.333	24	641266.222		
Total	160669873.852	26			

The mean difference is significant at ($p \leq 0.05$) level.

The tests (table 4.10) indicated that there was significant differences ($p \leq 0.05$) between the harvesting intervals on fresh leaf weight. The results were subjected to Post Hoc test to see the difference between the harvesting intervals means.

Table 4.11

LSD Summary of Fresh Leaf Weight in Kg/Ha for Different Harvesting Intervals

	7 Days	28 Days	49 Days
7 Days		-5657.78*	-3282.11*
28 Days			2375.67*
49 Days			

* The mean difference is significant at the 0.05 level.*

It is observed from the LSD summary that all harvesting intervals had an influence on fresh leaf yield. The lowest fresh leaf weight at 7 days harvesting interval could have resulted from the fact that the green parts of the plants, leaves included, form the plants' photosynthetic mechanism. When tender leaves are removed it increases the rate of reduction of photo assimilates. Therefore when leaves are harvested at 7 days interval there is a great loss of the photosynthetic sites and thus the growth of the plant is reduced. Mabapa et al (2017) reported that frequent leaf harvesting reduced fresh leaf yield in Moringa (Moringa oleifera). Similar result finding where made by Amaglo (2007) who showed significantly higher number of leaves, fresh and dry leaf yields from wholesome harvested plants than piecemeal harvested plants also with Moringa (Moringa *oleifera Lam*),

This is contrary to the finding made by Maurya et al. (2013) who reported that frequent leaf harvesting initiated the formation of more vegetative growth in cowpeas.

Table 4.12

Univariate Analysis of Variance on Effect of Plant Spacing on Fresh Leaf Weight

Tests of Between-Subjects Effects					
Dependent Variable: Fresh Leaf Weight in Kg /Ha					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	196659.852	2	98329.926	.015	.985
Error	160473214.000	24	6686383.917		
Corrected Total	160669873.852	26			

It is observed from the ANOVA (table 4.12) that plant spacing has no statistically significant differences between treatments. This means that spacing had no influence on the fresh leaf yield of slender leaf.

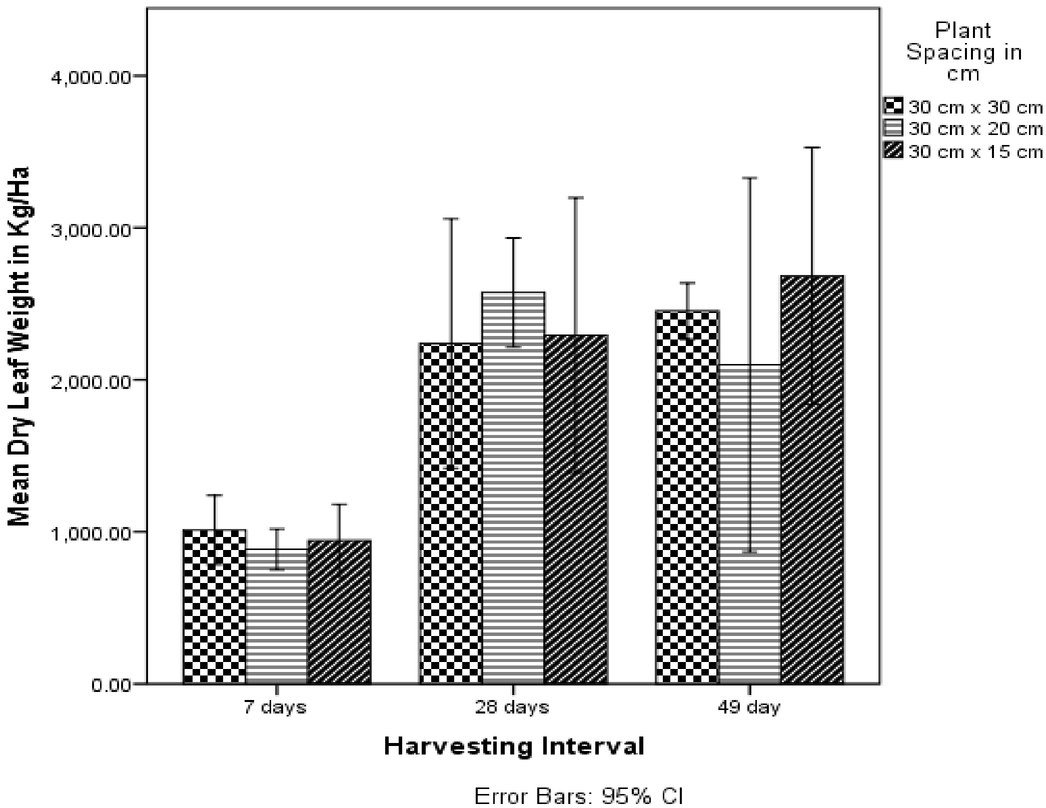
4.5 Dry Leaf Yield

After the fresh leaves had been weighed they were rapidly dried in an open pan and using an electric oven at 125^0F for six hours. This was done uniformly for all the fresh leaves harvested. After drying the leaves were weighed in Kilograms using an electronic weighing balance. The mean weights from each treatment plot was computed and recorded for statistical analysis.

The mean yields for dried leaf weight of the slender leaf **(***Crotalaria brevidens***)** in kgs/ha are shown in figure 4.4.

Figure 4.4

The Effect of Harvesting Interval and Spacing on Dried Leaf Yield in kgs/ha



Observations from figure4.4 indicated that the leaf dry weight was highest in 49 days harvesting interval for spacing intervals 30 cm x 15 cm and followed by 28 days at spacing 30 cm x 20 cm. The lowest dry leaf weight was exhibited at harvesting interval of 7 days with 30 cm x 20 cm and 7 days giving the lowest dry leaf weight. This could be due to great reduction of weight due to higher percentage of water loss after drying the leaves harvested at 28 day harvesting interval as compared to the 49 days harvesting interval. The dry leaf yield was almost directly proportional to the fresh leaf weight.

The differences in dry leaf yield as exhibited in figure 4.4 above were further subjected to ANOVA and the differences were significant. Post Hoc (LSD) test was conducted at p=0.05 to separate the differences between the mean yields are as shown in table 4.10 below.

The data was further subject into univaraiate analysis of variance and were further subjected to ANOVA and the differences were significant. Post Hoc (LSD) test was conducted at p=0.05 to separate the differences between the mean yields are as shown in table 4.18 below.

Table 4.13

Univariate Analysis of Variance on Effect of Harvesting Interval on Dry Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Dry Leaf Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	12506625.988	2	6253312.994	73.647	.000
Error	2037835.833	24	84909.826		
Total	14544461.821	26			

The ANOVA results (table 4.13) pointed out that there was a significant ($p \leq 0.05$) of harvesting interval on dry seed weight. Therefore a post hoc test was done for the dependent variable dry leaf weight to find out if there was any differences between the means of the four harvesting intervals.

Table 4.14

LSD Comparison of Dry Leaf Yields (p≤0.05) Under Different Harvesting Intervals

	7 days	28 days	49 days
7 days		-1422.2222*	-1464.3711*
28 days			-42.1489

It is observed from the LSD summary that as the harvesting frequency decreases the dry leaf yield increases being highest at 49 days harvesting interval.

Table 4.15

Univariate Analysis of Variance on Effect of Plant Spacing on Dry Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Dry Leaf Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	21125.397	2	10562.698	.019	.981
Error	14790136.266	27	547782.825		
Total	14811261.662	29			

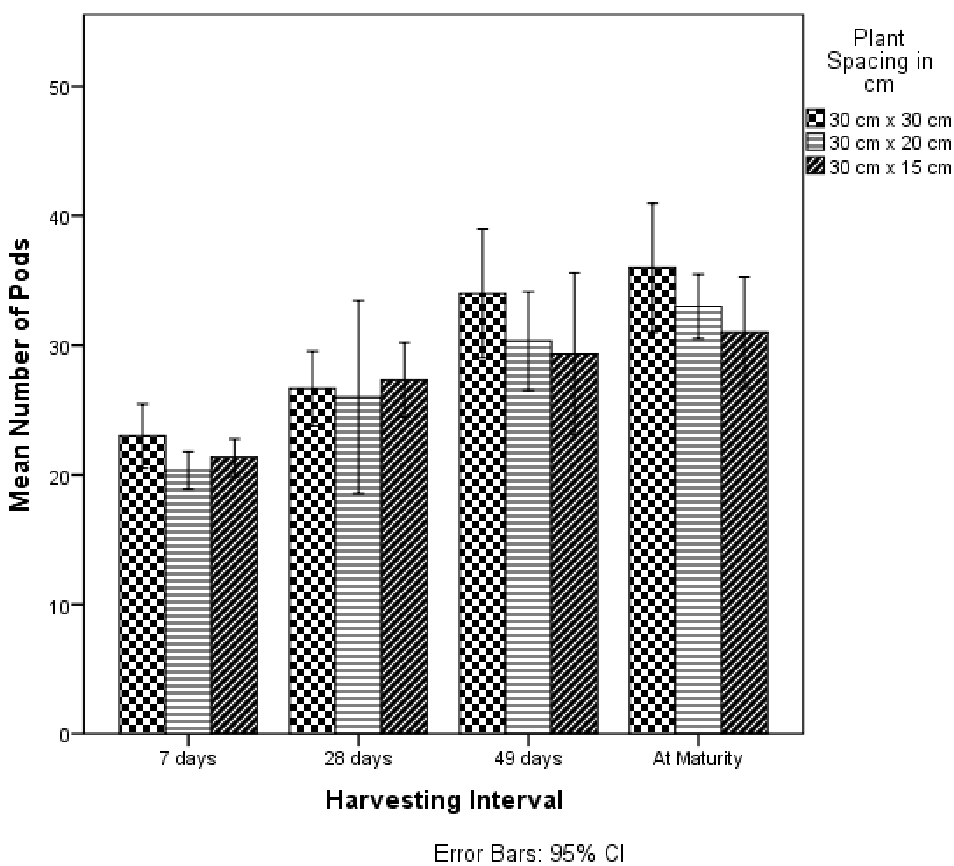
The results indicated that plant spacing had no significant difference on dry leaf weight

4.6 Number of Pods

When the plant had attained physiological maturity stage the collection of number of pods per plant per plot was carried out. The mean of number of pods per plant for each treatment plot was computed and recorded for statistical analysis. Results are as shown in figure 4.5.

Figure 4.5

The Effect of Harvesting Interval and Spacing on Number of Pods per Plant



The observation (figure4.5) showed that the highest number of pods was exhibited at maturity under treatment 30 cm x 30 cm. The lowest amount of pods was exhibited by 7 days harvesting interval under treatment 30 cm x 20 cm and 7 days harvesting interval. Overall, spacing 30 cm x 30 cm exhibited the highest amount of pods per plant under harvesting intervals 7days, 28days. 49 days and at maturity indicating that the longer the duration of harvesting interval, the higher the amount of pods per plant or the less the harvesting frequency the more the pods.. The data was further subjected into univaraiate analysis of variance and a post hoc test was done to separate the means among different treatments and the results are shown in tables 4.22 and 4.23.

Table 4.16

Univariate Analysis of Variance on Effect of Harvesting Interval on Number of Pods

Tests of Between-Subjects Effects

Dependent Variable: Number of Pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	288.667	2	144.333	15.745	.000
Error	220.000	24	9.167		
Total	508.667	26			

The mean difference is significant at the 0.05 level

A post hoc test was carried for the dependent variables number of pods in order to find out if there was any differences between the means of the four harvesting intervals.

Table 4.17

LSD Summary of Number of Pods (p≤0.05) Under Different Harvesting Interval

	7 days	28 days	49 days	At Maturity
7 days		-5.11*	-9.67*	-11.78*
28 days			-3.67*	-6.67*
49 days				-2.11*

As per the LSD results (table 4.17) the number of pods per plant increased with reduced harvesting frequency being highest at maturity where there was no leaf harvesting done. There was a wider variance between 7 days interval and at maturity. The results showed that the highest number of pods is attained at lowest harvesting interval. This is in line with (Maurya et al. (2013) who reported that Okra (Abelmoschus esculentus L) yielded highest number of pods at lowest harvesting interval. This could be due to the fact that with the lowest harvesting interval the plants had enough leaves to aid in the formation of pods through better-quality photosynthesis.

Table 4.18

Univariate Analysis of Variance on Effect of Plant Spacing against Number of Pods

Tests of Between-Subjects Effects

Dependent Variable: Number of Pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	53.556	2	26.778	7.859	.002
Error	102.222	30	3.407		
Total	893.639	35			

The results indicated that there was significant ($p \leq 0.05$) difference between the plant spacing on number of pods.

A post hoc test was carried for the dependent variables number of pods in order to find out if there was any differences between the means of the three plant spacings.

Table 4.19

LSD Summary of Number of Pods (p≤0.05) Under Different Plant Spacing

	30 cm x 30 cm	30 cm x 20 cm	30 cm x 15 cm
30 cm x 30 cm		2.50^{*}	2.67^{*}
30 cm x 20 cm			.17
30 cm x 15 cm			

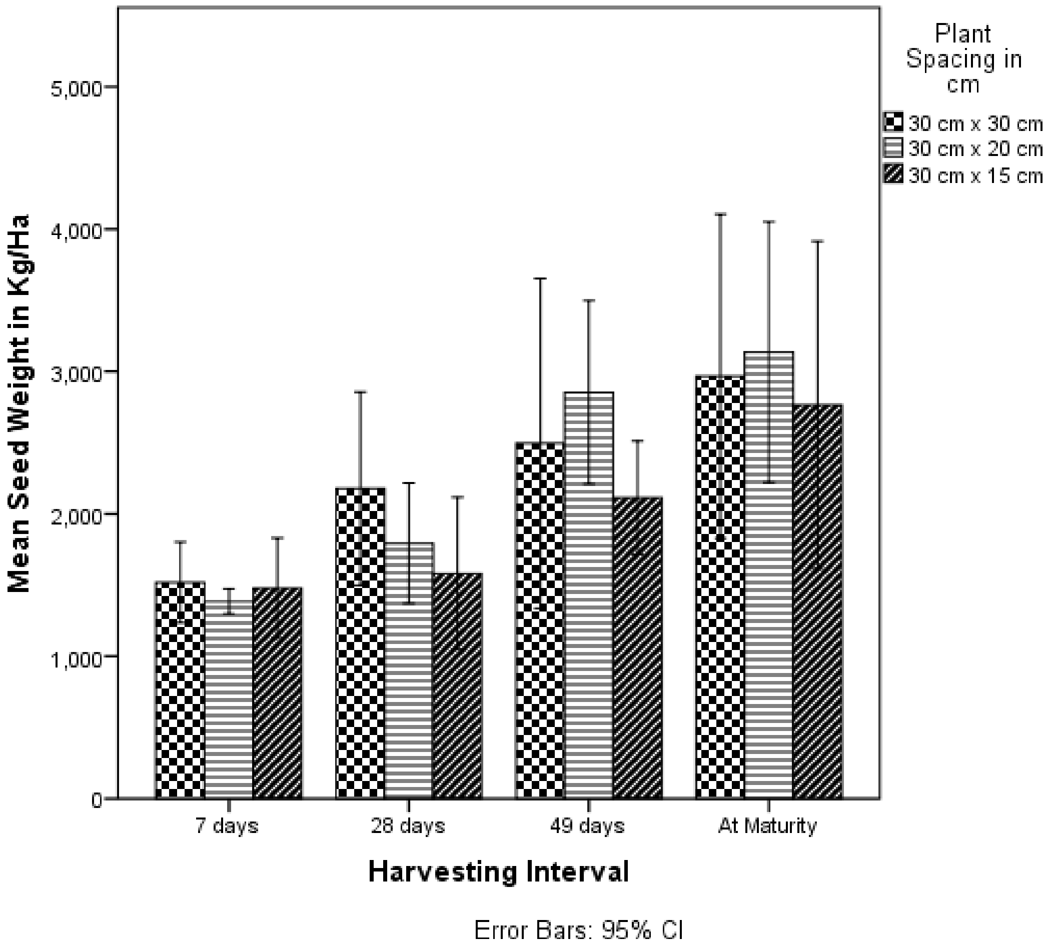
The pod density had significant difference between spacing 30 cm x 30 cm and 30 cm x 20 cm and between 30 cm x 30 cm and 30 cm x 15 cm. There was no significant difference between spacing 30cm x 20 cm and 30 cm x 15 cm.

4.7 1000 – Seed weight

The seeds (1000 seeds) from each treatment plot were harvested when the plants had attained full maturity (98 days after Emergence). The seeds were sun dried and weighed by the use of an electronic weighing scale. Total seed weight for each treatment plot in kilograms per hectare was recorded for statistical analysis. The seed weights were analyzed and the results are as shown in figure 4.6.

Figure 4.6

The Effect of Harvesting Interval and Spacing on Dry Seed Weight in kgs//ha



The results (figure 4.6) showed that the highest seed weight was exhibited at maturity under spacing 30 cm x 20 cm. The seed yield tended to be high where harvesting was conducted once. The greatest reduction of seed yield was at harvesting interval of 7 days where the plants were subjected to frequent harvesting. The results showed that with increased harvesting interval there was gradual decrease of slender leaf seed yield. Similar results were reported by Maurya et al. (2013) showing that Okra yield decreased gradually with increased harvesting interval.

The data was further subject into univaraiate analysis of variance and a post hoc test was done to separate the means among different treatments and results are shown in tables 4.20, 4.21, and 4.22.

Table 4.20

Univariate Analysis of Variance on Effect of Harvesting Interval on Dry Seed Weight in kgs//ha

Tests of Between-Subjects Effects

Dependent Variable: Seed Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	5286956.963	2	2643478.481	15.514	.000
Error	4089412.444	24	170392.185		
Total	9376369.407	26			

The mean difference is significant at the 0.05 level

There was need for a post hoc test to be conducted to establish which of the four harvesting intervals means were different.

Table 4.21

LSD Summary of Dry Grain Yield (α≤0.05) Under Different Harvesting Interval

	7 days	28 days	49 days	At Maturity
7 days		-390.3333	-1070.89*	-1494.56*
28 days			-680.56*	-1104.22*
49 days				-423.67*

***. The mean difference is significant at the 0.05 level**

The LSD results (table 4.21) indicated that harvesting the seed at maturity, with least frequency of leaf removal; was quite different from the other three and recorded the highest seed grain weight. At maturity no harvest of leaves took place thus the photosynthetic material was not interfered with. The same outcomes were reported by (Schobesberger & Kaul, 2013) who stated that grain yield of amaranth was reduced by 64.7% due to leaf harvest.

Table 4.22

Univariate Analysis of Variance on Plant Spacing on Dry Seed Weight in kgs//ha

Tests of Between-Subjects Effects

Dependent Variable: Seed Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	1057536.889	2	528768.444	1.058	.359
Error	16497602.333	33	499927.343		
Total	17555139.222	35			

There is no significant difference between plant spacing on seed weight.

There was no difference in seed weights under different plant spacing. This means that plant spacing had no influence on seed weight of slenderleaf.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The present study has revealed that fresh leaf yield is depended upon the spacing and harvesting interval. Closer spacing gives taller plants , fewer branches due to competition of resources, sunlight, air and nutrients, while more branches were realized in wider spacing and plant were shorter and with vigor where all the resources are adequately available. The treatment 30 cm x 20 cm and with 28 days leaf harvesting interval gave the highest fresh leaf weight of an 11,358 kg/ha. A higher dry seed weight was realized with least harvesting interval, at maturity, and at a medium spacing of 30 cm x 20 cm giving a weight of 2,896 Kg/ha as opposed to extensive harvesting ,7 days interval under wider spacing ,30 cm x 30 cm with a weight of 1,478 Kg/ha. At medium spacing and average harvesting interval of 28 days both fresh leaf weight and dry seed weight were moderately high.

5.2 Recommendation

The spacing of 30 cm x 20 cm and harvesting interval of 28 days yielded the highest fresh leaf yield and therefore recommended to be used for higher growth and yield of slenderleaf in Kisii County. Harvesting at spacing 30 cm x 20 cm and at maturity yields the highest quantity of seed. Further research recommended to establish the most efficient and profitable spacing and harvesting interval giving higher foliage, higher and best quality seed as the target products.

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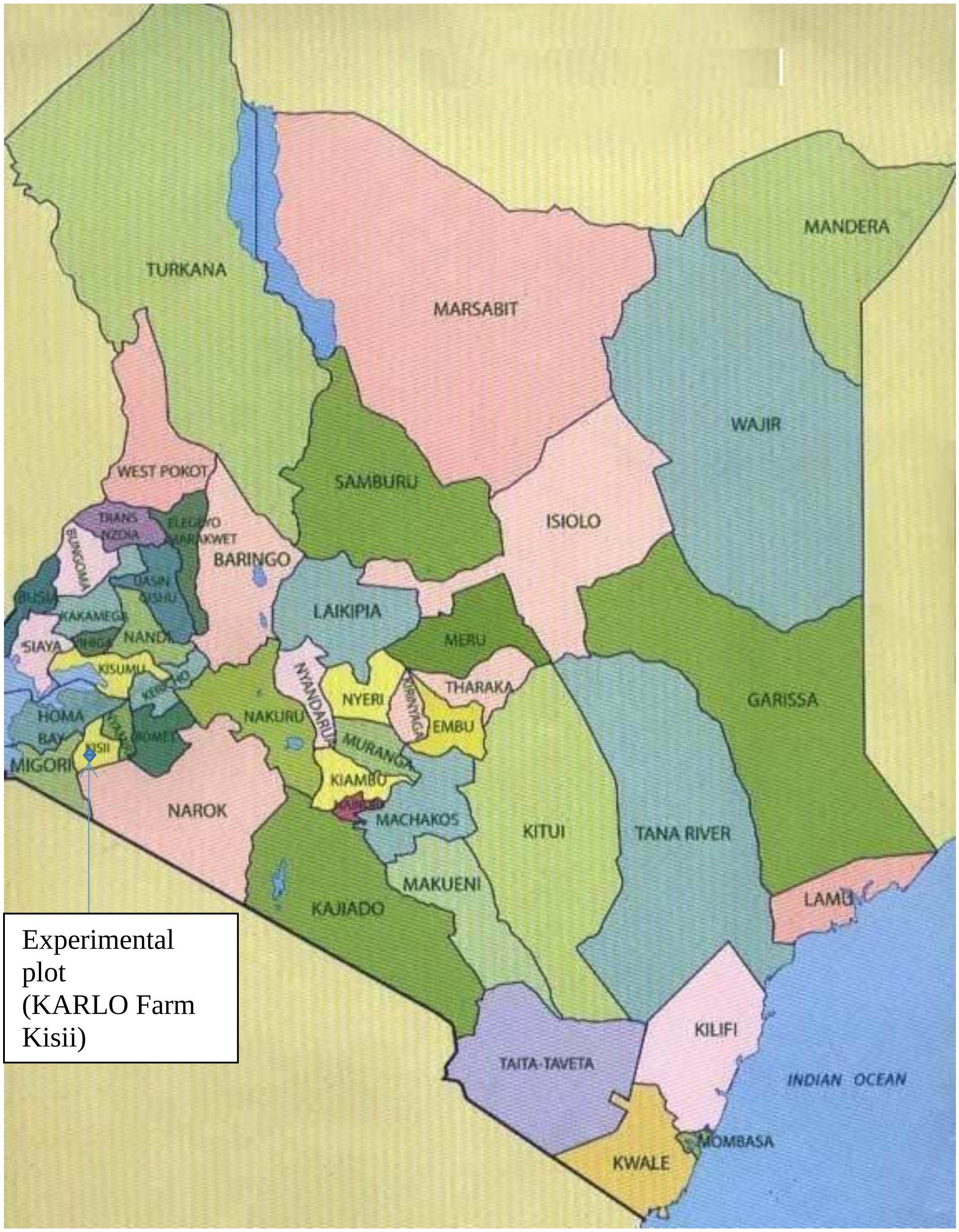
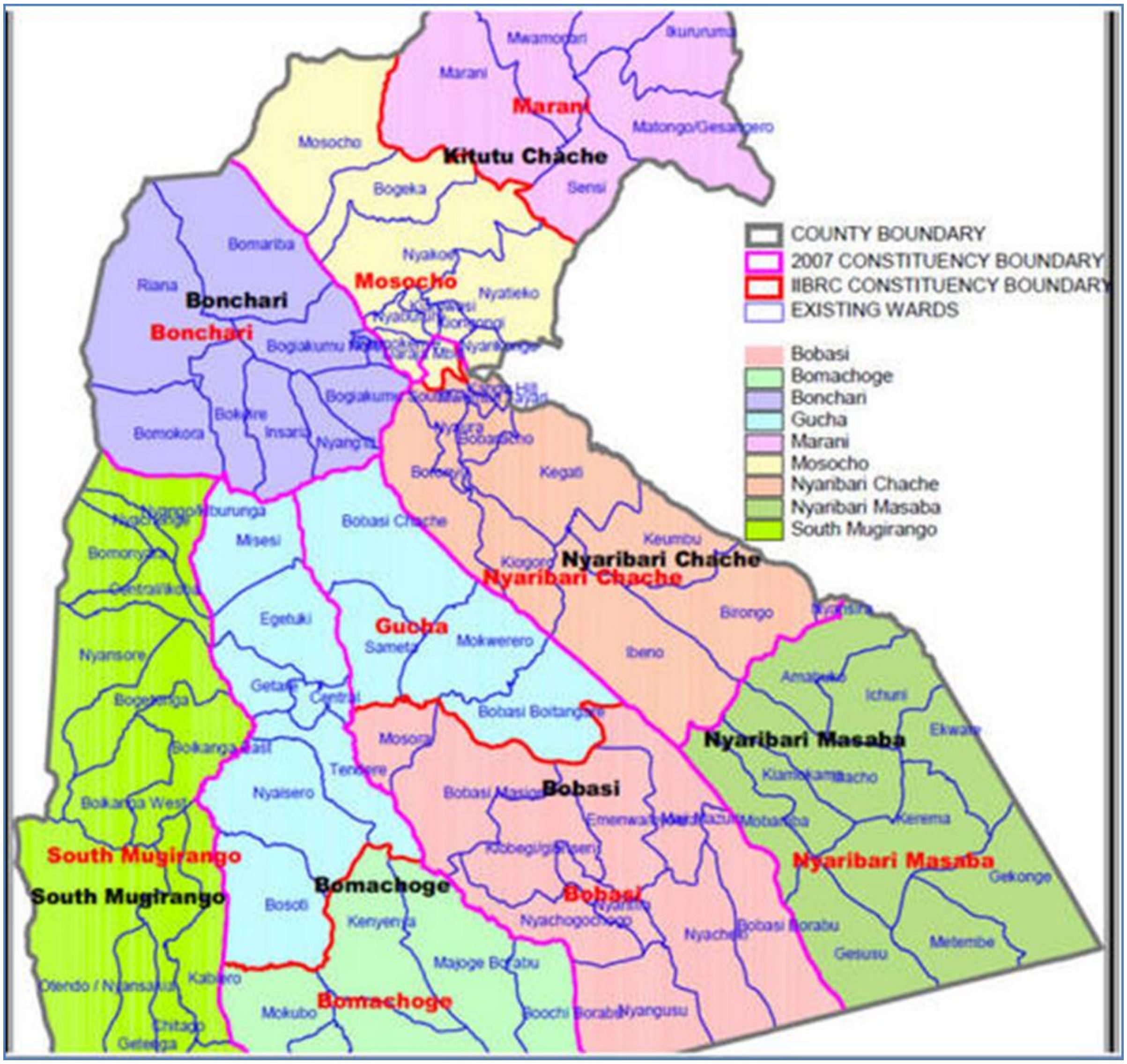
APPENDICES

APPENDIX 1: Location 0f Kisii County In Kenya



Source: Kisii County Integrated Development Plan (2013-2017)

APPENDIX 2: Kisii County Map



Source: Kisii County Integrated Development Plan (2013-2017)

APPENDIX 3: Research License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 351356

Date of Issue: 07/January/2020

RESEARCH LICENSE

This is to Certify that Ms.. GRANDUEL MOMANYI of Kenya Methodist University, has been licensed to conduct research in Kisii on the topic: EFFECT ON PLANT POPULATION AND HARVESTING INTERVAL ON THE GROWTH AND YIELD OF SLENDER LEAF (crotalaria brevident) IN KISII COUNTY, KENYA. for the period ending : 07/January/2021.

License No: NACOSTI/P/20/3312

351356

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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APPENDIX 4: Soil Analysis Report Before the Experiment

Kenya Agricultural & Livestock Research Organization
FOOD CROPS RESEARCH INSTITUTE
KISII CENTRE

P.O. Box 523-40200,
Tel. 0202122762 (Wireless)
Email:kari.kisii@kari.or
Website:

SOIL TEST REPORT

Name Gladwell Momanyi
Address P.O.BOX 2727, KISII
Telephone 0722241137
Location of farm, town or village, county: KISII ATC, KISII COUNTY
Crop(s) to be grown Crotalaria (Mito)
Field size or green house
Date sample received 15/02/2019
Date sample reported 21/02/2019
Reporting officer (through Director KALRO KISII) Jacob Ademba

	Soil Analytical Data	
Field or plot	Gladwell Momanyi	
Lab. No/2019	11/19	
Soil depth /cm	Top	
Fertility results	Value	Class
Soil pH	5.0	moderately acidic
Elect. Cond. µs/cm	0.08	moderate
Org. Carbon %	2.6	moderate
Phosphorus ppm	15	low
Total Nitrogen %	0.12	low
Potassium mg/Kg	50	low
Manganese me %	1.4	adequate

Interpretation and fertilizer recommendation
The soil reaction (pH) is moderately acidic. The phosphorus and nitrogen content is low. Organic matter content is adequate but should be maintained by the below treatments.

CROTALARIA (Sun hemp, Mitoo)
Soils: high organic matter content, good drainage, pH 5.5 – 6.8.

Temperatures: 20^{o}c – 30^{o}C

Sowing

Sow directly to seedbed in rows 30cm apart

For even seed distribution, mix seeds with sand or dry soil at a ratio of 1:10.

Germination takes place in 3-4 days.

Thin 2 weeks after sowing to a spacing of 30x30cm.

Fertilizer and manure application

Apply 20t/ha (2 Kg manure per metre) of manure

Compound fertilizer 20-20-20 is then applied at the rate of two tablespoonful in one metre.

Pests and their control
Slender leaf does not suffer much from diseases and even less from pests.
Under very wet conditions control blight just before flowering by use of fungicides.
Aphids and thrips maybe observed but are not a serious problem.
Seed production

Harvest seeds when mature but before drying up and shattering.

Dry, thresh, winnow and store in airtight containers at room temperature.

NOTE: Test results are based on customer sampled sample(s)

APPENDIX 5: Soil Analysis After Before the Experiment

Kenya Agricultural & Livestock Research Organization
FOOD CROPS RESEARCH INSTITUTE
KISII CENTRE

P.O. Box 523-40200,
Tel. 0202122762 (Wireless)
Email:kari.kisii@kari.or
Website:

SOIL TEST REPORT

Name Gladwell Momanyi
Address P.O.BOX 2727, KISII
Telephone 0722241137
Location of farm, town or village, county: KISII ATC, KISII COUNTY
Crop(s) to be grown Crotalaria (Mito)
Field size or green house
Date sample received 06/09/2018
Date sample reported 12/09/2018
Reporting officer (through Director KALRO KISII) Jacob Ademba

	Soil Analytical Data	
Field or plot	Gladwell Momanyi	
Lab. No/2018	89/18	
Soil depth /cm	Top	
Fertility results	Value	Class
Soil pH	5.0	moderately acidic
Elect. Cond. µs/cm	0.09	moderate
Org. Carbon %	2.6	moderate
Phosphorus ppm	15	low
Total Nitrogen %	0.12	low
Potassium mg/Kg	50	low
Manganese me %	1.4	adequate

Interpretation and fertilizer recommendation
The soil reaction (pH) is moderately acidic. The phosphorus and nitrogen content is low. Organic matter content is adequate but should be maintained by the below treatments.

CROTALARIA (Slender leaf, Mitoo)
Soils: high organic matter content, good drainage, pH 5.5 – 6.8.

Temperatures: 20^{o}c – 30^{o}C

Sowing

Sow directly to seedbed in rows 30cm apart

For even seed distribution, mix seeds with sand or dry soil at a ratio of 1:10.

Germination takes place in 3-4 days.

Thin 2 weeks after sowing to a spacing of 30x30cm.

Fertilizer and manure application

Apply 20t/ha (2 Kg manure per metre) of manure

Compound fertilizer 20-20-20 is then applied at the rate of two tablespoonfuls in one metre.

Pests and their control
Slender leaf does not suffer much from diseases and even less from pests.
Under very wet conditions control blight just before flowering by use of fungicides.
Aphids and thrips maybe observed but are not a serious problem.
Seed production

Harvest seeds when mature but before drying up and shattering.

Dry, thresh, winnow and store in airtight containers at room temperature.

NOTE: Test results are based on customer sampled sample(s)

APPENDIX 6: Raw Research Data

Block	Plant Spacing	Harvesting Interval	Measurment Interval	Fresh Leaf Weight in Kg/Ha	Dry Leaf Weight in Kg/Ha	Stem Height in Cm	No of Branches	No of Pods	Seed Weight in Kg/Ha
1	1	1	1	5293	1046.67	3.49	19	23	1387
1	1	2	2	9087	1993.33	7.45	26	28	2390
1	1	3	3	7633	2366.67	11.9	32	36	2975
1	1	4	4	-	-	15.46	28	34	2535
1	2	1	1	4480	893.33	9.75	18	21	1420
1	2	2	2	10886	2480	11.41	27	29	1990
1	2	3	3	8070	2413.33	18.96	27	30	3025
1	2	4	4	-	-	20.26	29	33	2765
1	3	1	1	5020	980	4.7	15	21	1630
1	3	2	2	9713	2100	6.1	21	28	1775
1	3	3	3	8133	3073	14.27	25	29	2275
1	3	4	4	-	-	13.89	28	32	3296
2	1	1	1	4840	906.67	3.17	21	24	1585
2	1	2	2	10567	2106.67	6.92	24	26	2275
2	1	3	3	8753	2506.67	12.92	28	34	1745
2	1	4	4	-	-	15.36	36	36	2915
2	2	1	1	5187	933.33	9.62	18	20	1385
2	2	2	2	11140	2500	12.68	20	26	1690
2	2	3	3	7987	2353.33	21.28	28	32	2980
2	2	4	4	-	-	17.87	33	34	3145
2	3	1	1	3813	833.33	3.47	17	21	1350
2	3	2	2	9607	2066.67	6.59	17	26	1620
2	3	3	3	8300	2450	18	26	27	2110
2	3	4	4	-	-	17.11	25	29	2548
3	1	1	1	6820	1080	4.45	22	22	1585
3	1	2	2	11113	2613.33	8.4	30	26	1870
3	1	3	3	8367	2480	12.94	38	38	1350
3	1	4	4	-	-	9	21	20	1700
3	2	1	1	4240	826.67	11.09	22	23	2555
3	2	2	2	12047	2740	17.33	25	29	3500
3	2	3	3	8027	1526.67	21.16	30	32	1455
3	2	4	4	-	-	4.45	16	22	1350
3	3	1	1	5227	1013.33	6.07	22	28	1350
3	3	2	2	11680	2713.33	11.47	23	32	1655
3	3	3	3	12047	2523	16.36	27	32	2450
3	3	4	4	-	-	21.16	30	32	3500

APPENDIX 7: Rainfall Data

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jan	111.2	98.8	100.7	14.9	66.4	60.3	12.6	157	36.0	63.9	24.3
Feb	61.3	99.6	42.5	66.4	75.3	40.7	42.6	53.2	101.1	38.3	23.7
March	237.3	193.5	138.6	153.5	244.2	183.2	82.3	109	114.3	386.9	166.4
April	230.1	230.8	228.7	343.6	448.5	129.8	263.3	322.83	284.2	252.4	223.1
May	279.4	406.3	267.5	256.9	244.5	194.0	268.5	365.1	205.3	296.9	189.4
June	152.3	192.0	91.6	270.7	93.8	185.7	191.9	87.3	178.7	134.6	164.9
July	63.2	73.6	100.5	100.4	94.4	154.3	104.4	32.2	65.8	80.1	83.3
Aug	197.2	188.2	233.6	204.6	131.4	362.4	127.6	143.4	203.2	135.2	151.7
Sept.	201.0	251.6	227.1	238.8	240.4	224.4	298.4	192.2	215.1	84.2	157.2
Oct.	86.2	213.3	183.0	171.7	122.6	198.2	261.2	72.1	254.5	140.4	237.8
Nov.	170.1	108.9	360.6	301.1	207.3	149.9	302.5	142.9	127.8	142.4	228.1
Dec.	305.5	188.5	206.8	131.6	102.2	79.8	244.2	49.2	54.8	174	252.9
Total	**2094.8**	**2245.1**	**2181.2**	**2254.2**	**2254.2**	**1962.7**	**2199.5**	**1726.43**	**1840.8**	**1929.3**	**1902.8**

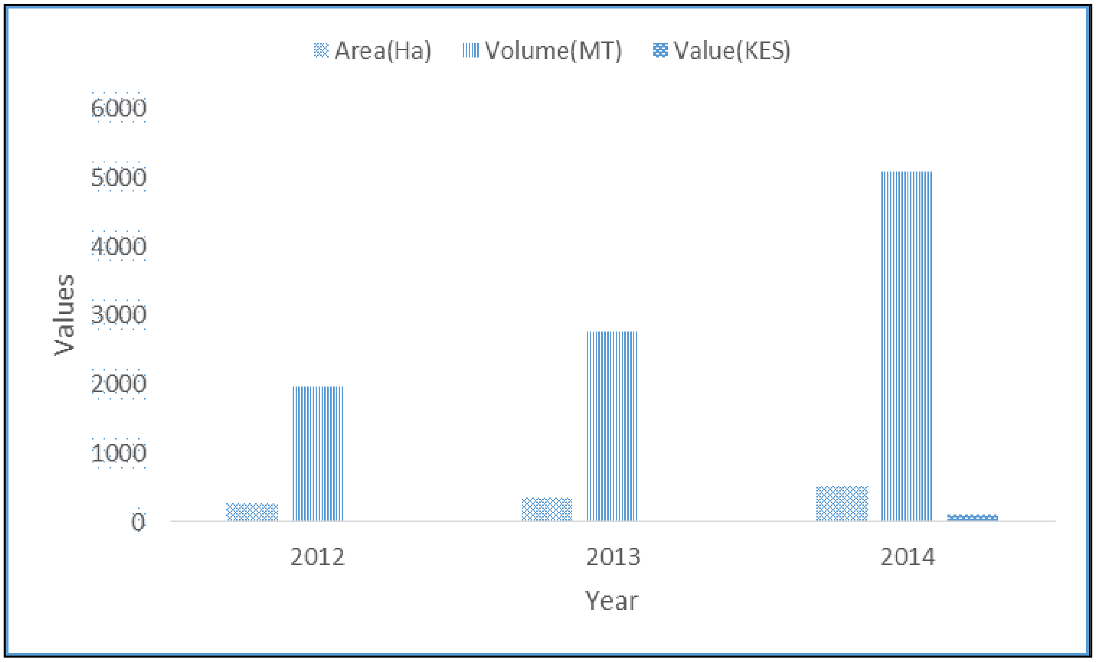
APPENDIX 8: Percentage Establishment of Crop at 14th Day

Treatment	Treatment Combination	% Establishment
1	S1H1	98
2	S1H2	95
3	S1H3	99
4	S1H4	98
5	S2H1	97
6	S2H2	98
7	S2H3	95
8	S2H4	97
9	S3H1	95
10	S3H2	98
11	S3H3	97
12	S3H4	98

APPENDIX 9: Production of Slender Leaf in Selected Counties, Horticulture Validation Report, HCDA

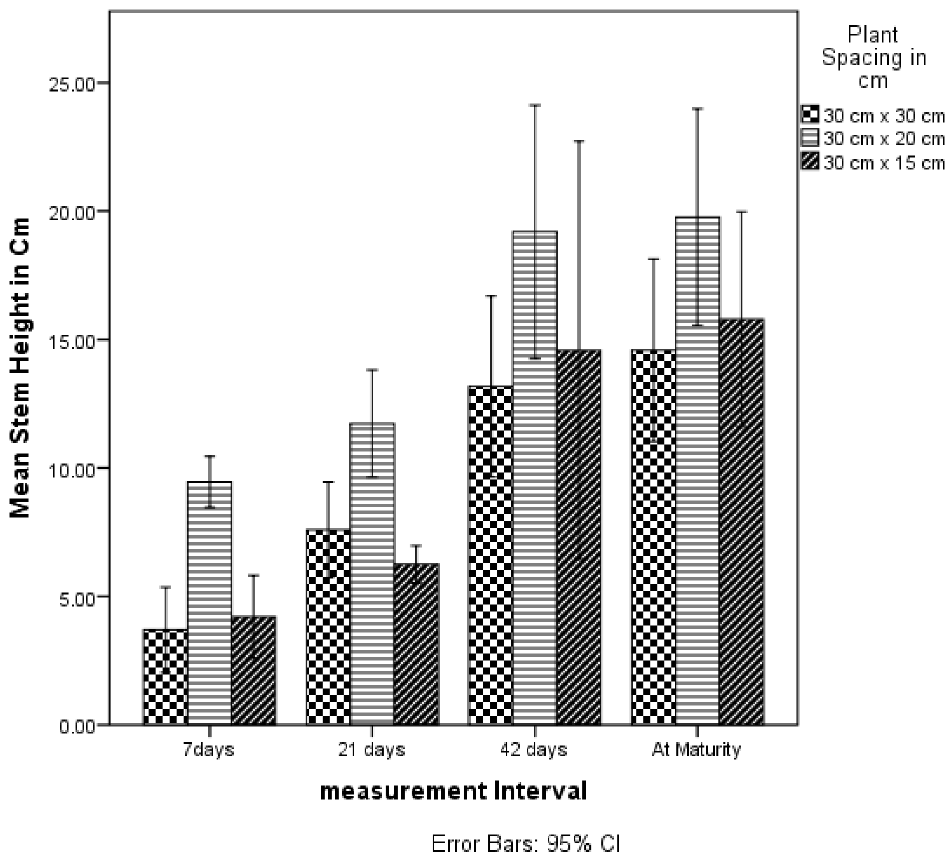
Names Of Counties	2012			2013			2014		
	Area (Ha)	Volume (MT)	Value (Million KES)	Area (Ha)	Volume (MT)	Value (Million KES)	Area (Ha)	Volume (MT)	Value (Million KES)
Siaya	33	257	6.9	71	711	24.0	95	1,084	54.4
T/ Nzoia	28	644	11.9	32	960	9.6	82	2,460	24.6
Migori	18	90	0.9	20	100	3.0	37	170	8.1
H/Bay	42	141	0.9	45	150	1.0	35	141	7.2
T/Taveta	22	403	8.1	20	360	7.2	18	332	6.6
Others	143	449	14.5	182	499	13.4	266	912	18.2
Total	**286**	**1,984**	**43**	**370**	**2,780**	**58**	**533**	**5,100**	**119**

APPENDIX 10: Production of Slender Leaf in Kenya 2012-2014. Horticulture Validation Report, HCDA, (2014)



APPENDIX 11: SPSS Outputs

Effect of Measuring Interval and Plant Spacing on Stem Height



Univariate Analysis of Variance on Effect of Measurement Interval on Plant Height

Tests of Between-Subjects Effects
Dependent Variable: Stem Height in Cm

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Stem height measurement interval	771.621	3	257.207	30.836	.000
Error	266.912	32	8.341		
Total	1038.533	35			

a. R Squared = .743 (Adjusted R Squared = .719)

* The mean difference is significant at the $p < 0.05$ level.

Post Hoc Test: Measuring Interval against Plant Height

(I) measurement Interval	(J) measurement Interval	Mean Difference (I-J)	Sig.
7days	21 days	-2.7344	.053
	42 days	-9.8589*	.000
	At Maturity	-10.9233*	.000
21 days	7days	2.7344	.053
	42 days	-7.1244*	.000
	At Maturity	-8.1889*	.000
42 days	7days	9.8589*	.000
	21 days	7.1244*	.000
	At Maturity	-1.0644	.440
At Maturity	7days	10.9233*	.000
	21 days	8.1889*	.000
	42 days	1.0644	.440

Univariate Analysis of Variance on Effect of Plant Spacing on Plant Height

Tests of Between-Subjects Effects
Dependent Variable: Stem Height in Cm

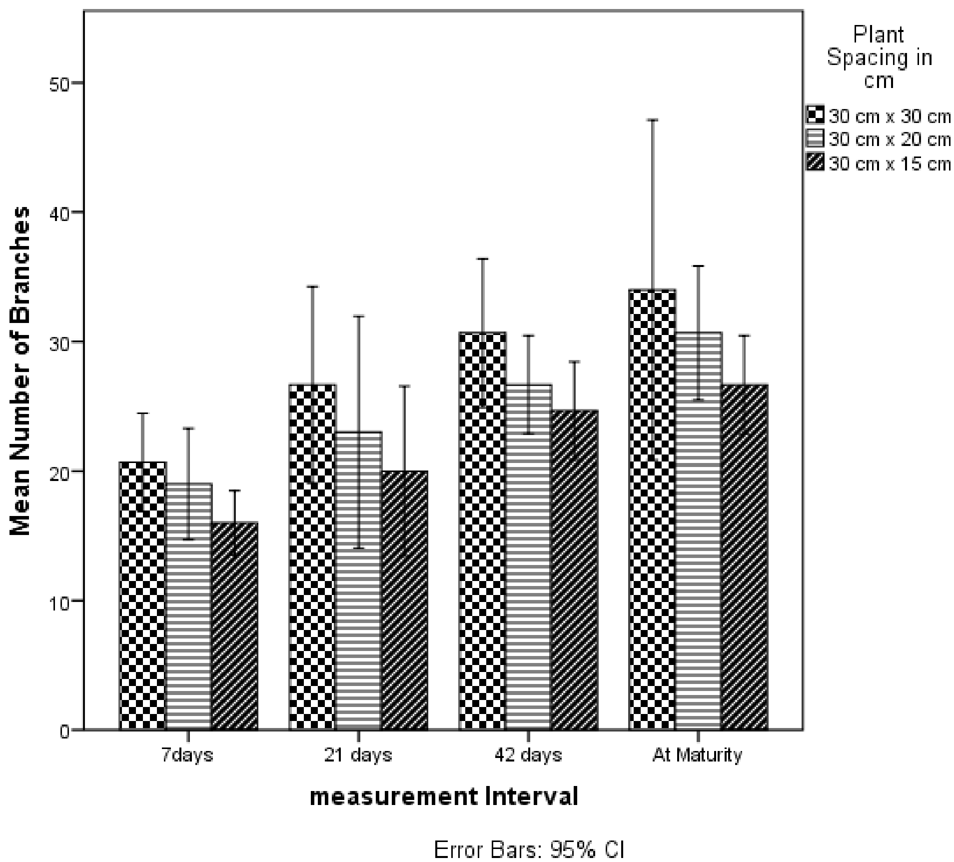
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	205.132	2	102.566	4.061	.026
Error	833.401	33	25.255		
Total	1038.533	35			

a. R Squared = .198 (Adjusted R Squared = .149)

Post Hoc Test: Plant Spacing against Plant Height

(I) Plant Spacing in cm	(J) Plant Spacing in cm	Mean Difference (I-J)	Sig.
30 cm x 30 cm	30 cm x 20 cm	-5.2708*	.015
	30 cm x 15 cm	-.4433	.830
30 cm x 20 cm	30 cm x 30 cm	5.2708*	.015
	30 cm x 15 cm	4.8275*	.025
30 cm x 15 cm	30 cm x 30 cm	.4433	.830
	30 cm x 20 cm	-4.8275*	.025

Effect of Measuring Interval and Plant Spacing on Number of Branches



Univariate Analysis of Variance on Effect of Measuring Interval on Number of Branches

Tests of Between-Subjects Effects
Dependent Variable: Number of Branches

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Measurement Interval	636.556	3	212.185	15.693	.000
Error	432.667	32	13.521		
Corrected Total	1069.222	35			

a. R Squared = .595 (Adjusted R Squared = .557)

LSD Comparison of Number of Branches (α=0.05) under Different Measurement Intervals

(I) measurement Interval	(J) measurement Interval	Mean Difference (I-J)	Sig.
7days	21 days	-5.44*	.004
	42 days	-7.56*	.000
	At Maturity	-11.67*	.000
21 days	7days	5.44*	.004
	42 days	-2.11	.232
	At Maturity	-6.22*	.001
42 days	7days	7.56*	.000
	21 days	2.11	.232
	At Maturity	-4.11*	.024
At Maturity	7days	11.67*	.000
	21 days	6.22*	.001
	42 days	4.11*	.024

Univariate Analysis of Variance on Effect of Plant Spacing on Number of Branches

Tests of Between-Subjects Effects
Dependent Variable: Number of Branches

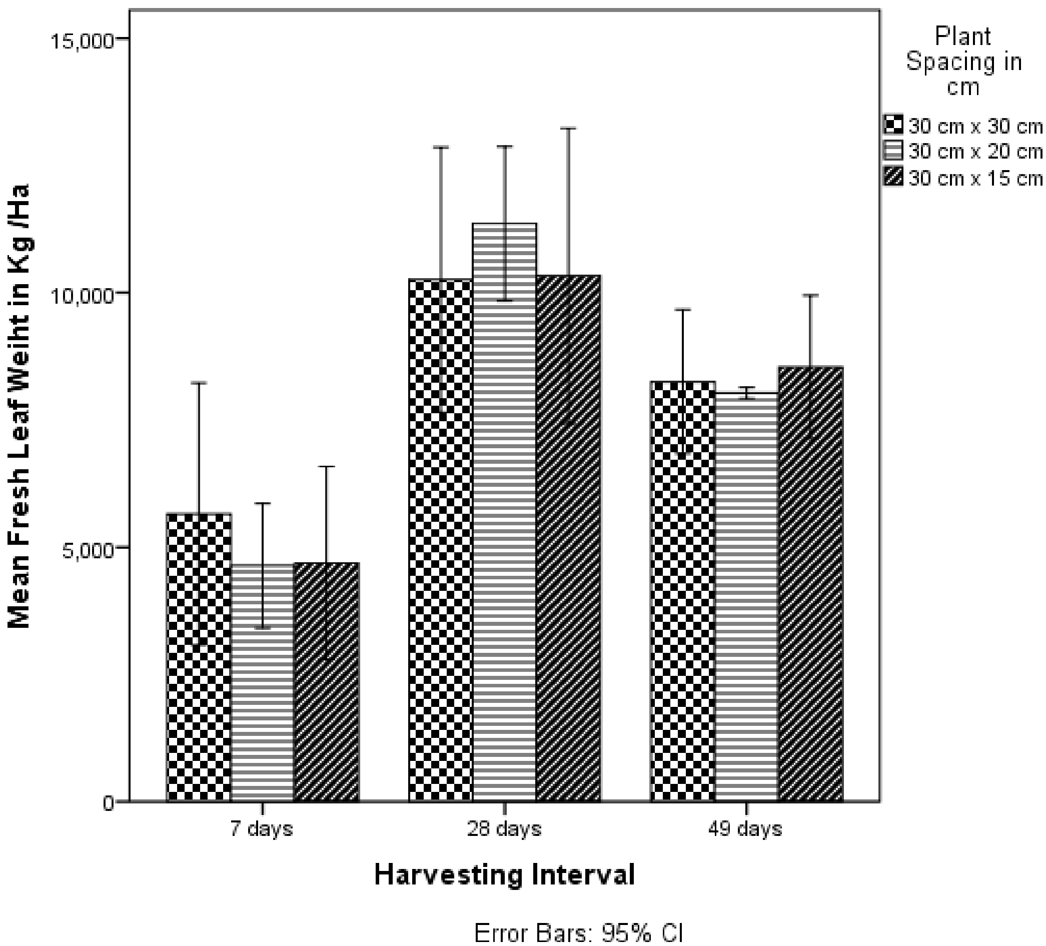
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	228.222	2	114.111	4.244	.023
Error	887.333	33	26.889		
Corrected Total	1115.556	35			

a. R Squared = .205 (Adjusted R Squared = .156)

Post Hoc Test: Plant Spacing against Number of Branches

(I) Plant Spacing in cm	(J) Plant Spacing in cm	Mean Difference (I-J)	Sig.
30 cm x 30 cm	30 cm x 20 cm	3.17	.144
	30 cm x 15 cm	6.17*	.006
30 cm x 20 cm	30 cm x 30 cm	-3.17	.144
	30 cm x 15 cm	3.00	.166
30 cm x 15 cm	30 cm x 30 cm	-6.17*	.006
	30 cm x 20 cm	-3.00	.166

Effect of Harvesting Interval and Spacing on Fresh Leaf Yield in kgs/ha



Univariate Analysis of Variance on Effect of Harvesting Interval on Flesh Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Fresh Leaf Weight in Kg /Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	145279484.519	2	72639742.259	113.275	.000
Total	160669873.852	26			

a. R Squared = .904 (Adjusted R Squared = .896)

LSD Comparison of Fresh Leaf Weight (α=0.05) Under Different Harvesting Intervals

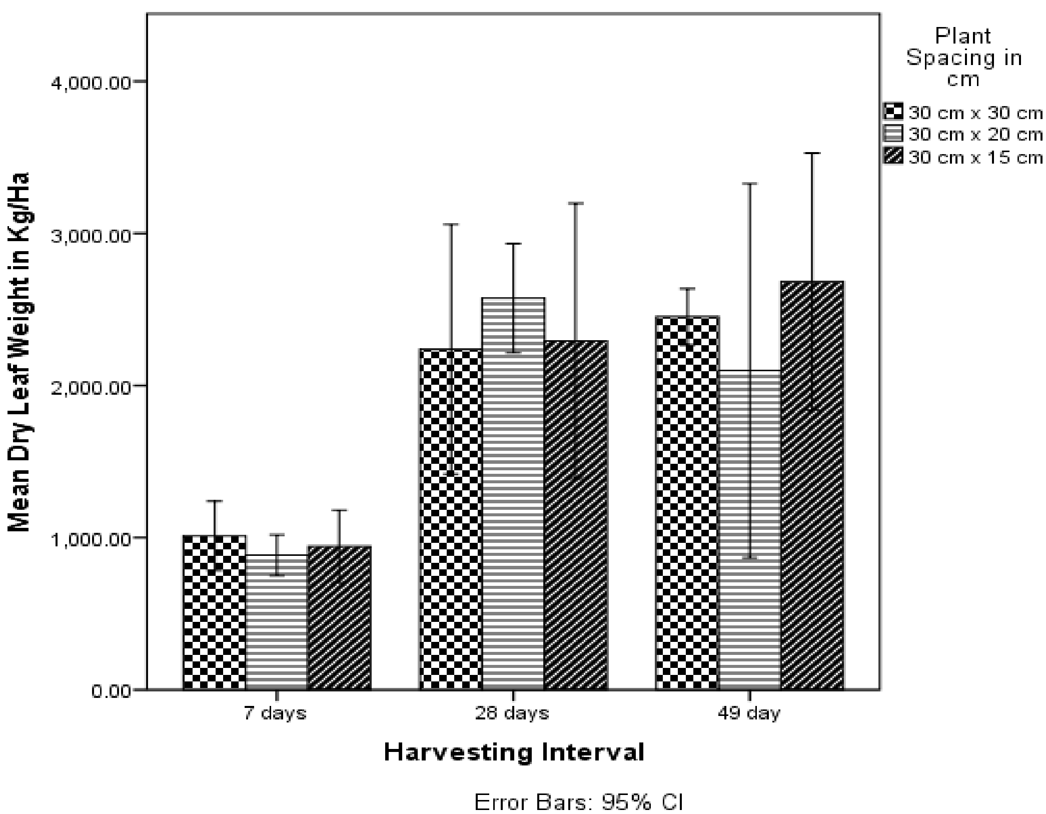
(I) Harvesting Interval	(J) Harvesting Interval	Mean Difference (I-J)	Sig.
7 days	28 days	-5657.78*	.000
	49 days	-3282.11*	.000
28 days	7 days	5657.78*	.000
	49 days	2375.67*	.000
49 days	7 days	3282.11*	.000
	28 days	-2375.67*	.000

Tests of Between-Subjects Effects
Dependent Variable: Fresh Leaf Weiht in Kg /Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	196659.852	2	98329.926	.015	.985
Error	160473214.000	24	6686383.917		
Corrected Total	160669873.852	26			

a. R Squared = .001 (Adjusted R Squared = -.082)

The Effect of Harvesting Interval and Spacing on Dried Leaf Yield in kgs/ha



Univariate Analysis of Variance on Effect of Harvesting Interval on Dry Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Dry Leaf Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	12506625.988	2	6253312.994	73.647	.000
Error	2037835.833	24	84909.826		
Total	14544461.821	26			

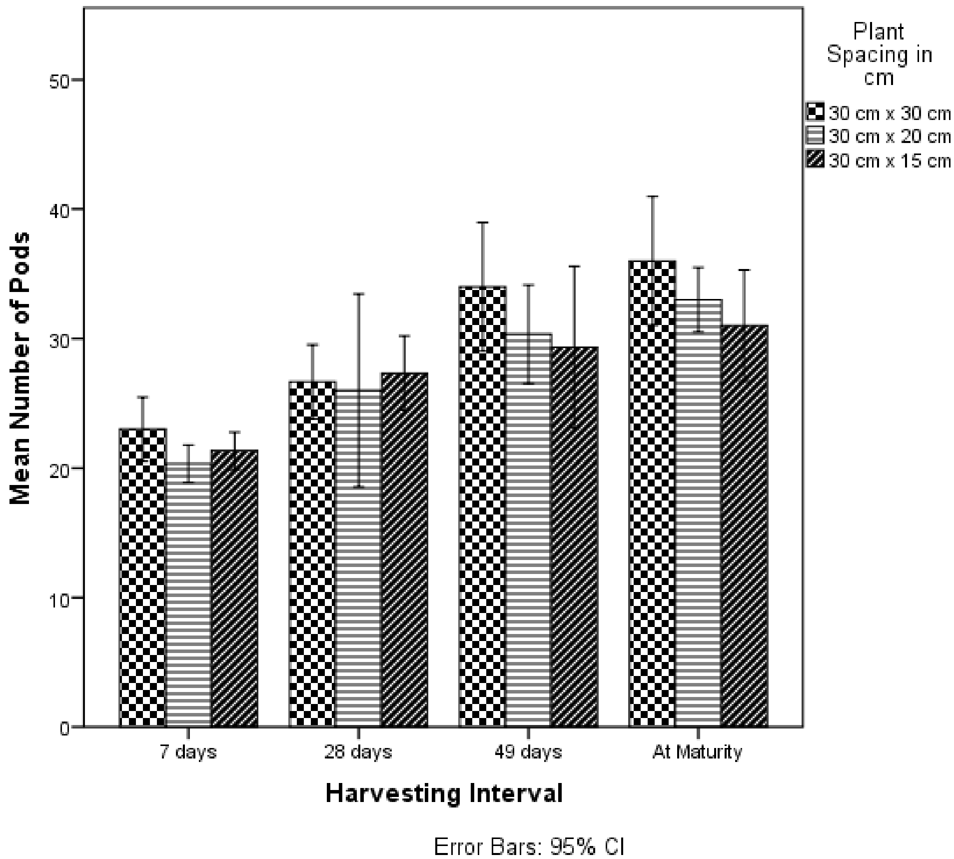
a. R Squared = .860 (Adjusted R Squared = .848)

Univariate Analysis of Variance on Effect of Plant Spacing on Dry Leaf Weight

Tests of Between-Subjects Effects

Dependent Variable: Dry Leaf Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	21125.397	2	10562.698	.019	.981
Error	14790136.266	27	547782.825		
Total	14811261.662	29			



Univariate Analysis of Variance on Effect of Harvesting Interval on Number of Pods

Tests of Between-Subjects Effects

Dependent Variable: Number of Pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	288.667	2	144.333	15.745	.000
Error	220.000	24	9.167		
Total	508.667	26			

a. R Squared = .567 (Adjusted R Squared = .531)

The mean difference is significant at the 0.05 level

Univariate Analysis of Variance on Effect of Plant Spacing against Number of Pods

Tests of Between-Subjects Effects
Dependent Variable: Number of Pods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	30.500	2	15.250	.626	.541
Error	804.250	33	24.371		
Total	834.750	35			

a. R Squared = .037 (Adjusted R Squared = -.022)

LSD Comparison of Slender Leaf Vegetable Number of Pods (p=0.05) Under Different Harvesting Interval

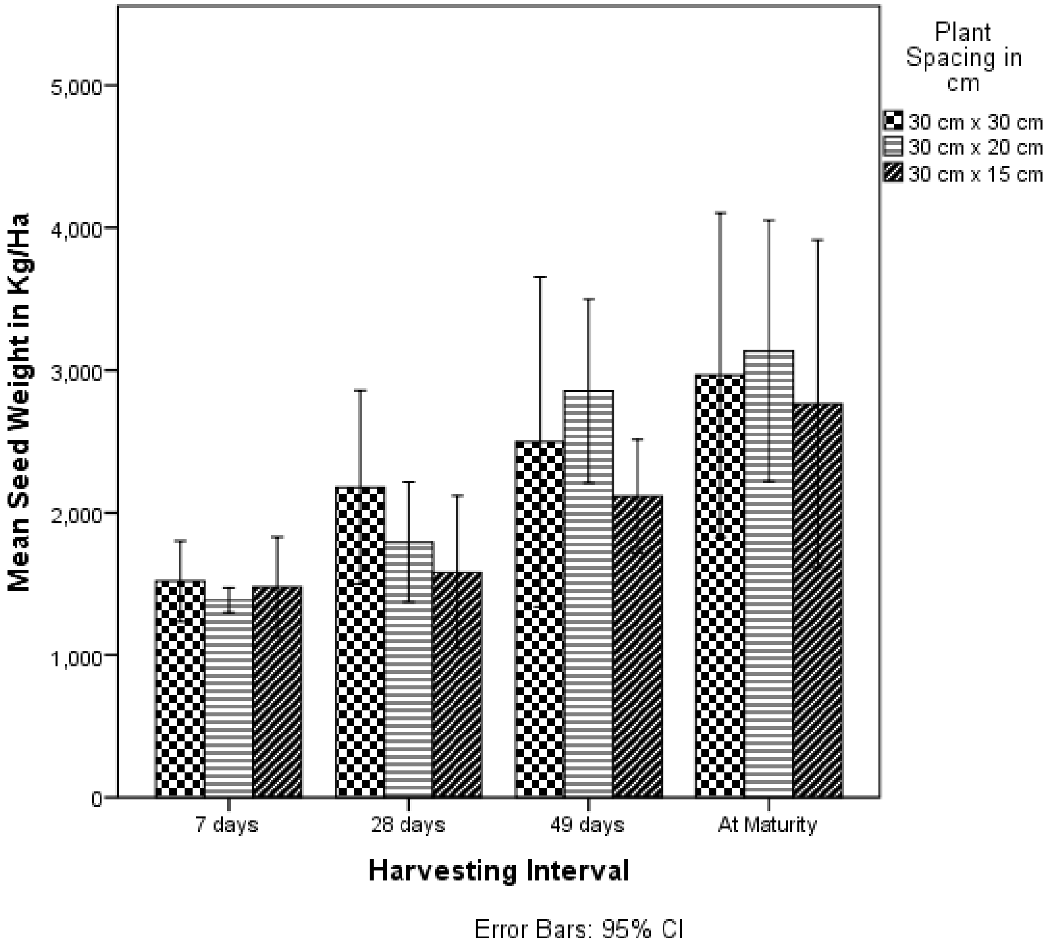
(I) Harvesting Interval	(J) Harvesting Interval	Mean Difference (I-J)	Sig.
7 days	28 days	-4.33*	.006
	49 day	-8.00*	.000
28 days	7 days	4.33*	.006
	49 day	-3.67*	.017
49 day	7 days	8.00*	.000
	28 days	3.67*	.017

Tests of Between-Subjects Effects
Dependent Variable: Number of Pods

Intercept	28617.361	1	28617.361	1124.142	.000
Plant Spacing in cm	53.556	2	26.778	1.052	.361
Error	840.083	33	25.457		
Total	893.639	35			

a. R Squared = .060 (Adjusted R Squared = .003)

The Effect of Harvesting Interval and Spacing on Dry Seed Weight in kgs//ha



Univariate Analysis of Variance on Effect of Harvesting Interval on Dry Seed Weight in kgs//ha
Tests of Between-Subjects Effects
Dependent Variable: Seed Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Harvesting interval	5286956.963	2	2643478.481	15.514	.000
Error	4089412.444	24	170392.185		
Total	9376369.407	26			

a. R Squared = .564 (Adjusted R Squared = .528)
The mean difference is significant at the 0.05 level

Univariate Analysis of Variance on Plant Spacing on Dry Seed Weight in kgs//ha

Tests of Between-Subjects Effects
Dependent Variable: Seed Weight in Kg/Ha

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Plant Spacing in cm	1057536.889	2	528768.444	1.058	.359
Error	16497602.333	33	499927.343		
Total	17555139.222	35			

a. R Squared = .060 (Adjusted R Squared = .003)

There is no significant difference between plant spacing on seed weight.

There was no difference in seed weights under different plant spacing. This means that plant spacing is not statistically significant with seed weight.

LSD Comparison of Dry Grain Yield (α=0.05) Under Different Harvesting Interval

(I) Harvesting Interval	(J) Harvesting Interval	Mean Difference (I-J)	Sig.
7 days	28 days	-390.3333	.056
	49 day	-1070.8889*	.000
28 days	7 days	390.3333	.056
	49 day	-680.5556*	.002
49 day	7 days	1070.8889*	.000
	28 days	680.5556*	.002

***. The mean difference is significant at the 0.05 level**