EFFECT OF DIFFERENT SPACING INTERVALS ON GROWTH AND YIELD OF COWPEA VARIETIES IN KILIFI COUNTY, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN AGRICULTURAL AND RURAL DEVELOPMENT OF KENYA METHODIST UNIVERSITY

AUGUST 2020

DECLARATION AND RECOMMENDATION

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

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DEDICATION

This Thesis is dedicated to my wife Rose, my son David and my daughter Esther for their encouragement and support.

ACKNOWLEDGEMENT

First and foremost, I wish to express my most sincere gratitude to the almighty God for the gift of life. Great and marvellous are your deeds O, Lord God Almighty.

I am greatly indebted to my supervisors Professor Peter A. Kamau and Professor Ellis M. Njoka of Kenya Methodist University for their advice, guidance and support during this study.

Special thanks go to the Kenya Agricultural productivity and Agribusiness Project (KAPAP) National Coordinator, Mr Francis Muthami as well as the County service Coordinator, Mr Anthony Chibudu for their support and encouragement.

I also wish to thank Mrs. Jane Kanamu, Officer in charge, Mtwapa Agricultural Training Centre (ATC) for allowing me to use the institution's demonstration farm.

The support of Mr Milton Munialo, Mr Zachary Mwangi, Pastor & Mrs Victor Miriti Nderi, Mr Francis Njogu, Mr Wycliffe Kombo and Mr Stanslous Mwagambo is gratefully acknowledged.

God bless you.

ABSTRACT

Cowpea (Vigna unguiculata [L.] walp) is an ancient leguminous plant that is indigenous to Africa. Cowpea is commonly cultivated in the Middle East region, South United States, Asia, Africa, and throughout the sub-tropics and tropics. In Kenya, cowpea is the most important grain legume after common beans and pigeon peas. In Kilifi County and the entire Coastal Kenya, cowpea crop is considered as the most crucial African leafy vegetable (ALV), being the main source of dietary protein, especially for the urban and rural poor. The major constraints facing cowpea production in Coastal Kenya include unavailability of quality seed, lack of technical packages, low plant population and general lack of awareness of the potential the crop holds in mitigating poverty and malnutrition challenges in the community. A field experiment was carried out at Mtwapa Agricultural Training Centre-(ATC) demonstration farm to determine the effect of different spacing intervals on growth and yield of cowpea varieties. The experiment was laid out as a randomized complete block design (RCBD), with 12 treatment combinations consisting of 4 (four) cowpea varieties namely Ken kunde, Katumani 80 (K80), KVU 27-1 and Machakos 66 (M66) and 3 (three) spacing intervals, 40x20 cm, 50x20 cm (Control) and 60x20 cm. It was replicated three times. The specific objectives of the study were to assess the effect of different plant population on growth and yield of cowpea, to evaluate growth and yield of different cowpea varieties and to determine the interaction effect between cowpea varieties and plant population density. The yield parameters investigated were pod length, number of seeds per pod, number of pods per plant, 100 seed weight, seed weight per plant, total seed weight per plot and harvest index. Plant height, number of branches and above ground biomass were the growth parameters investigated. The results revealed significant differences ($P < 0.05$) between the treatment means for pod length, 100 seed weight, above ground biomass, total seed weight per plot and harvest index. There were no significant differences ($P > 0.05$) between treatment means for height of plant, number of branches, number of pods per plant, number of seeds per pod and weight of seeds per plant. Different responses were noted as a result of spacing variations. The mean number of branches, mean number of pods per plant, mean number of seeds per pod, mean seed weight per plant and the mean above ground biomass increased with variation of spacing intervals from 40x20 cm to 60x20 cm. The mean plant height and mean total seed weight per plot decreased with variation of spacing intervals from 40x20 cm to 60x20 cm. KVU 27-1 had the highest mean pod length, mean 100 seed weight and highest grain yield of 2,310 kg/ha. The yields of Machakos 66, Katumani 80 and Ken Kunde were 2,120 kg/ha, 1,860 kg/ha and 1,050 kg/ha respectively. Machakos 66 had the highest mean above ground biomass. The highest mean pod length was realized at the spacing interval of 40x20 cm whereas the highest mean above ground biomass was at the spacing interval of 60x20 cm. For agricultural practitioners with cowpea maximum biomass yield as the motive, the spacing interval of 60x20 cm is recommended. Cowpea variety KVU 27-1 and spacing interval 40 x 20 cm are recommended for maximum cowpea grain yield in Kilifi County.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ALV	African Leafy Vegetables
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Land
A.S.L	Above Sea Level
ATC	Agricultural Training Centre
BT	Bacillus Thuringiensis
CL_3	Coastal Lowland 3
CNSL	Cashew Nut Shell Liquid
CPMOV	Cowpea Mottle Virus
CPMV	Cowpea Mosaic Virus
CYMV	Cowpea Yellow Mosaic Virus
EC	Emulsifiable Concentrate
FAO	Food and Agricultural Organization of United Nations
HI	Harvest index
IITA	International Institute of Tropical Agriculture
ISRA	Institut Senegalais de Recherches Agricoles
IWM	Integrated Weed Management
K-80	Katumani 80
M66	Machakos 66
MOALF	Ministry of Agriculture, Livestock & Fisheries
NARL	National Agricultural Research Laboratories

Ppm	Parts per million
PSB	Pod Sucking Bug
SSR	Simple Sequence Repeat
UCR	University of California, Riverside
USDA	United States Department of Agriculture
WUE	water utilization efficiency

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Cowpea which goes by the scientific name (*Vigna unguiculata*) is considered to be an important grain legume crop that is made up of different species totalling over 100. The crop belongs to the genus *Vigna* and has wide distribution within the tropical and sub-tropical regions. Cowpea has been found to exhibit great diversity in terms of ecology and morphology (Oyewale & Bamaiyi, 2013). The alternate Common names of Cowpea (*Vigna unguiculata* (L) Walp are caupi, southern pea, crowder pea, black eyed pea, yardlong bean, field pea, catjang. The alternate scientific name is *Vigna sinensis* (L.) Savi (Sheahan, 2012). Cowpea is an ancient crop, with the origin and first point of domestication assumed to be Africa but is adapted to different environmental conditions thus grown worldwide (Agbicodo et al., 2009).

The estimated area in hectares of cowpeas cultivated world-wide was 14 million in the year 2000 (Hall, 2012). In the year 2010, the UN-Food & Agricultural Organization (FAO) approximated the world-wide production of dry cowpea grains at more than 5.2 million metric tonnes (Oyewale & Bamaiyi, 2013). Globally, 92% of cowpeas are produced in Africa, where it is consumed on a daily basis by approximately 200 million people (Okeyo-Ikawa et al., 2016). The main cowpea production areas in Africa are the Sudan Savanna region in North Nigeria as well as the Sahel region (Central Mali, South Niger, Senegal and Sudan). Additionally, significant production has been recorded in the regions of North Eastern Brazil, East and Southern part of Africa and South East Asia (Hall, 2012). Nigeria is the world leader in cowpea production and consumption, with an estimated 2.4 million tons produced annually on 5 million hectares (Okeyo-Ikawa et al., 2016). Table 1.1 shows twenty (20) leading cowpea producing countries globally (2014)

Table 1.1

Twenty (20) leading cowpea producing countries globally (2014)

Rank	Country	Production in tons	Area in ha	Yield in kg/ha
	Nigeria	2,137,900	3,701,500	578
2	**Niger**	1,593,166	5,325,168	299
3	**Burkina Faso**	573,048	1,205,162	475
4	**Tanzania**	190,500	197,323	965
5	**Cameroon**	174,251	209,019	834
6	**Mali**	149,248	353,382	422
7	**Kenya**	138,673	281,877	492
8	**Myanmar**	115,200	132,000	873
9	**Mozambique**	103,837	377,900	275
10	**Sudan**	80,000	260,000	308
11	**Congo**	70,042	159,945	438
12	**Senegal**	64,088	153,142	418
13	**Malawi**	35,903	81,753	439
14	**Haiti**	29,895	41,525	720
15	**USA**	21,591	12,060	1,790
16	**Peru**	17,588	12,779	1,376
17	**Serbia**	16,189	4,777	3,389
18	**Sri Lanka**	15,281	11,519	1,327
19	**China**	13,500	13,000	1,038

20	**Uganda**	10,100	25,000	404

Source: FAOSTAT, 2017

Economically, Cowpea is an important and most versatile indigenous legume crop in the continent of Africa, often being referred to as a "hungry-season crop" due to its fast maturity rate and the fact that cowpea harvesting used to precede that of cereal crops. Besides being a good source of nutrition for human beings and their livestock, Cowpea has the ability to improve soil fertility through its ability to fix Nitrogen. Consequently, it contributes to increase in cereal crops yields and helps to sustain cropping systems when it is grown in rotation. Cowpea is grown on small scale basis by millions of African farmers, majority of who are women (Agbicodo et al., 2009).

In the Kenyan grain legume sub-sector, cowpea occupies the third position in terms of importance, after pigeon peas and common beans. Cowpea production and consumption is widely practised in Kenya within the Semi-Arid parts of Eastern, with the area under its cultivation estimated at about 85% mostly in Machakos, Kitui, Makueni, Tharaka Nithi and Embu. Low rainfall of between 100 and 900 mm per year that is erratic and poorly distributed characterizes the semi-Arid lands, usually leading to poor yields (Kurum et al., 2019). The remaining 15% of the cowpea growing area is in Coast, Western and Central Provinces (Kimiti et al., 2009). Cowpea in Eastern Kenya is intercropped with maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.), and sorghum (*Sorghum bicolor L.*) *Moench*), pearl millet (*Pennisetum glaucum*), dolichos (*Lablab purpures* L.) and finger millet (*Eleusine corcana (L.) Gaertn*). Kilifi, one of the counties in Coastal Kenya is ranked as one of the poorest in the Country, with average poverty and food insecurity levels averaging at between 70 and 90% (Kimiti, 2011).

In Kilifi County and in the entire Kenyan coast region, cowpea is considered as one of the prime African leafy vegetable (ALV), being the main source of dietary fibre and protein, especially for the urban and rural poor. Lack of technical packages along the entire value chain, unavailability of quality seeds, and the general lack of awareness of the potential of cowpea to mitigate poverty and malnutrition challenges in the community are the major impediments limiting cowpea production in the Coastal Kenya. Cowpea has not received adequate attention in a strongly patriarchal system where the rural communities still view most of the ALVs, cowpea included, as a 'woman's' crop. More attention is now being focussed on support for African leafy vegetables (ALVs) research unlike in the past when it was largely neglected, having been singled out as a key pillar for food and nutrition security strategy and income generation alternative among smallholder farmers in Kenya (Hutchinson et al., 2016).

1.2 Statement of the Problem

Globally, the yield potential for cowpea is high averaging at between 1,500 and 6,000 kg /ha depending on the genotype (Lemma et al., 2009). Similarly, the most improved Kenyan cowpea cultivars have a grain yield potential ranging from 1,170 to 1,800 kg /ha in stands that are pure (Kimiti, 2011). However, the actual yields of cowpea in Kenya are very low averaging at between 150 - 500 kg /ha (Wamalwa et al., 2016). In Mtepeni ward, Kilifi County, low cowpea grain yields of between 350 - 450 kg/ha are realised as opposed to the area potential of average 1,400 kg /ha in pure stands (Mtwapa Agricultural Office report, 2014). This is attributed to poor crop management practises like inappropriate cowpea plant density as a result of poor spacing and use of poor, low yielding Cowpea varieties such as Kiringongo and Kaemakoko. The practice usually leads to under-utilization of the available production space and subsequently low cowpea yields, especially among the small holder farmers in Kilifi County and by extension the entire sub-Sahara Africa.

1.3 Justification of the Study

Fewer studies have been conducted to develop appropriate agronomic/ production packages such as plant density for improved and high yielding cowpea varieties like KVU 27-1, Ken kunde, M66 and K-80 (Hutchinson et al., 2016). Cowpea yield levels are subject to the level of agronomic practises employed and key among these are planting density and row spacing which happen to be powerful management tools. It was necessary to carry out this study to determine the optimum cowpea plant densities for the different varieties as well as establish the most appropriate cowpea variety. The study was significant in that the findings will be used by Agricultural practitioners to cut down on land wastage, enhance production per unit area, and contribute to food security and improved income.

1.4 General Objective

To evaluate the effect of plant population and different varieties on growth and yield of cowpea in Mtepeni Ward, Kilifi County

1.4.1 Specific Objectives

i. To assess the effect of different plant population on growth and yield of cowpea

ii. To evaluate growth and yield of different cowpea varieties

iii. To determine the interaction effect between cowpea varieties and plant population density.

1.5 Research Hypothesis

i. There are significant differences in growth and yield of cowpea due to plant population

ii. There are significant differences in growth and yield of cowpea due to different varieties

iii. There are significant differences due to interaction effect between cowpea varieties and plant population density.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution of Cowpea

Cowpea (*Vigna unguiculata [L.] walp*) is an ancient leguminous plant that is indigenous to Africa. It was domesticated in Sub-Sahara Africa, probably the West African region and happens to be one of the main components of the traditional systems of cropping within the tropics, especially in the drier parts. Cowpea is an important food crop that is known to have multiple uses (Kimiti, 2011). The wild cowpea progenitors are thought to have originated from Swaziland due to the existence of higher species diversity, a position supported by some cowpea genetic studies in the African continent. Extensive cultivation of cowpeas is done in the continent of Africa and Asia as well as in the Caribbean, Brazil, India Australia and the US, the centre of origin notwithstanding. The Western and Central regions of Africa which include Burkina Faso, Cameroon, Democratic Republic of Congo, Mali, Niger, Nigeria and Senegal constitute up to 89% of the entire area utilized for global cowpea production. Modest cowpea amounts also emanate from Kenya, Mozambique, Somalia, Sudan, Tanzania and Uganda. Other notable producers are Egypt, Haiti, Myanmar, Serbia and Sri Lanka (Oyewale & Bamaiyi, 2013).

2.2 Plant Description

Cowpea exhibits diverse characteristics of growth. Some varieties are bushy and short, tall, or prostrate and vine-like attaining a canopy height of up to 60–90 cm. Some cowpea varieties have upright hollow and hairless stems whereas the twining varieties have much thinner stems. Cowpea leaves are hairless, egg-shaped and three-parted measuring about 10 cm in length and 8 cm in terms of width. The small pores on the surface of its leaves and stems of leaves act as floral nectaries that secrete nectar to attract beneficial insects. Stemmed flowers purple or white in colour, and approximately 2.5 cm in length are usually produced along the main axis by the branchless inflorescence. The lower most leave whorl has the shape of a bell. The lobes of the flower are fused and lateral petals appear to be shorter than upper petals. Two-valved pods measuring about 8–15 cm emerge from the leaf axils and are either coiled, round, crescent or linear in shape. About 6–13 seeds are borne in each pod and are usually embedded within the spongy tissue (Sheahan, 2012).

Oyewale and Bamaiyi (2013) noted that most cowpea cultivars take a long duration to produce flowers and subsequently seed and hence are classified as indeterminate in nature. Other cultivars produce flowers and seed within a season hence referred to as determinate. Abadassi (2015) indicated that size of cowpea seeds ranges from small size to big size with the most common seed coat colours being black, white, red, brown, cream, green and buff. The distinguished seed coat textures are smooth, rough, wrinkle and loose. Sheahan (2012) concludes that the other two types of cultivated cowpea, namely the sub-species *V. sesquipedalis* and *V. catjang* are different from *V. unguiculata* in terms of pod length and shape as well as characteristics of seed. However, there are variations in characteristics which are often difficult to isolate since the plants can readily cross fertilize and produce hybrids that are fertile.

2.3 The Genetics of Cowpea

Cowpea is considered to have a narrow genetic base since it is a crop that is primarily self-pollinating. Variations in qualitative or phenotypic traits like habit of growth, colour of flower or traits associated with agronomy such as stress tolerance and potential of yield that does not indicate actual relationships in genetics are used to estimate diversity in cowpea (Wamalwa et al., 2016). In genetics of cowpea improvement, the most desirable traits are desirable quality of seed, resistance to insects, resistance to lodging, early maturity, high potential of grain yield, erect growth habit, efficiency in phosphorous use, virus and bacteria resistance, day length insensitivity among others (Boukar et al., 2018).

Development of pest resistant and early maturing cultivars is being spearheaded by Institut Senegalais de Recherches Agricoles **(**ISRA) and International Institute of Tropical Agriculture - IITA. Cultivars of cowpea that are adapted to areas with low amount of rain especially in drought conditions have been developed through selection for early flower formation, maturity as well as yield testing (Agbicodo et al., 2009). Needs and preferences of Cowpea end users are varied. In Cowpea improvement breeding, acceptability and adoption can greatly be enhanced through proper understanding of the knowledge of farmers concerning preferences of varieties (Kurum et al., 2019).

Since early 2000s, several international Organizations have been involved in the preservation of the major cowpea germplasm collections. A collection of about 600 accessions consisting of African and Mediterranean landraces was preserved in Bari, Italy by the Istituto di Genetica Vegetale, 8,000 accessions by the US Department of Agriculture-USDA (Hall, 2012). The IITA is maintaining in its gene bank a cumulative number of 15,003 cultivated varieties of Cowpeas derived from 89 Countries. IITA has so far released over eighty (80) cowpea varieties to more than sixty (60) Countries (Boukar et al., 2018). Farmers in the African continent have widely adopted varieties of cowpea that are terminal drought escaping and early maturing since they were released. However, further enhancement to drought tolerance, early, midterm and terminal season drought stresses is being undertaken through breeding (Agbicodo et al., 2009).

2.4 Cowpeas Cropping Systems

Cowpea is an important component in multiple cropping systems. The systems can be classified as mono-cropping, relay cropping and mixed intercropping (Oyewale & Bamaiyi, 2013). Cowpea ability to tolerate shade makes it suitable as an intercrop with sorghum, millet, maize as well as with several other plantation crops. Although cowpea mono crop is profitable, many small- scale farmers in Asia and Africa prefer to plant cowpea in various intercropping systems in order to maximize on production in their small farms. Cowpea usually serves as an ideal security crop in cases where there is failure of the main crop when incorporated into such a system (Saidi et al., 2010). Cowpea is usually intercropped with sugarcane, cotton, various cereals, or planted in relay with rice within Asia. However, it is intercropped with maize or sorghum in Africa.The intercrop combinations are mostly Cassava\Yam\Maize, Sorghum\Groundnut \Millet, Cowpea\Okra\Millet, Maize\Yam\Cowpea, Cowpea/Cassava\Maize, Sorghum\ Millet\ Cowpea, Cassava\Melon\ Vegetable etc (Oyewale & Bamaiyi, 2013).

Two common cowpea production systems are used. The entire cowpea plant is uprooted at the three - five true leaf stage just before the leaves over mature and become fibrous in instances where it is grown purely for vegetable production. In dual-purpose production, leaves are harvested sequentially during the vegetative stage culminating with seed harvesting when the season comes to an end. Most growers who intercrop prefer the latter system (Saidi et al., 2010). The practice of intercropping cowpea with other crops and the harvesting of tender leaves for use as vegetables remains prevalent in many vegetable growing areas that are rural, peri-urban and urban within Africa (Sebetha et al., 2010).

2.5 General Uses of Cowpeas

Cowpea is commonly cultivated in Africa, Asia, the Middle East, Southern United States, and throughout the tropics and subtropics as a highly palatable and nutritious food source (Sheahan, 2012). Cowpea can be utilized at various stages of its growth cycle (Sebetha et al., 2010). It can be used as a source of income, fodder as well as food. The young cowpea pods, tender leaves and grains are utilized as food (Kimiti et al., 2009).

2.5.1 Use of cowpeas as a food source

Cowpeas is known to be a source of dietary fibre and also contains several crucial health promoting components like phyto-chemicals, vitamins and minerals, which include phenolic compounds that are antioxidants with ability to prevent cancer and heart diseases. It also contains proteins, carbohydrates and amino acids. Use of legumes as partial replacement of animal foods has led to improved nutritional status given that plant foods have lower cholesterol levels. Animal protein nutritive value is however higher than that of cowpea. Increased fibre intake from plant food diets lead to reduced incidences of bowel diseases like Cancer and Osteoporosis. Several conventional food formulations as well as textured foods can be formulated from cowpea protein concentrates and isolates **(**Khalid & Elhardallou, 2016).

Cowpea is a concentrated protein source that is cheaper than dairy products, meat, fish, or even poultry especially in areas where subsistence farming is practiced. Cowpea grain can be combined with cereal grain in the ratio of 1:3 to provide a near-complete food. Full sized cowpea pods are sometimes harvested before they dry out and their shelled grains prepared for consumption as fresh "southern peas." This is practiced in the South Eastern United States and in the Sahel region of Africa which is semi-arid especially in Senegal. The main reason is that southern peas is available in months of August and September, the "hungry period" that precedes the major harvest of peanuts, sorghum, pearl millet and dry cowpea grains from traditional varieties, which usually begin in the month of October. Consumption of fresh immature cowpea pods was reported in Southeast Asia (yard-long beans), Kenya (the African green beans) and the bodie beans in Trinidad (Hall, 2012).

According to Sebetha et al. (2010), it is a common practice in many parts of Africa for young cowpea leaves to be harvested and used as vegetables. Some studies have shown that removal of the oldest cowpea leaves enhances grain yield whereas removal of too many young leaves has the effect of impairing grain yield. Partial defoliation of cowpea plants can severely decrease the number of seeds and pods in each plant and the total grain yield hence the need to stop leaf harvesting just before the pods begin to expand for cases where cowpea is grown for grains. Oyewale and Bamaiyi (2013) noted that in Sudan and Ethiopia, roots are eaten. In the country of Nigeria, cowpea is utilized as a source of fibre especially the stems and peduncles. Table 2.1 shows the levels of various nutrients in 100g dried cowpea seeds and raw leaves.

Table 2.1

Nutritional value of 100 g of dried cowpea seeds and raw leaves

Nutrients	Dried raw seeds	Raw leaves
Energy (Kcal)	313	30
Calcium (mg)	112	188
Zinc (mg)	3.37	1
Carbohydrates (g)	43.3	0.7
Fat (g)	1.1	0.4
Fiber (g)	14.3	4.9
Niacin (mg)	2.4	1.6
Phosphorous (mg)	276	17
Proteins (g)	25.3	3.4

Riboflavin (mcg)	0.15	0.37
Thiamine (mcg)	0.90	0.49
ß-Carotene (mcg)	19	0
Water (ml)	12.4	88.7
Iron (mg)	5.97	2.7
Potassium (mg)	1380	485
Sodium (mg)	22	31

Source: FAO/Government of Kenya. 2018.

According to some studies, older cowpea leaves have been found to contain higher carbohydrate concentration with the protein content in such leaves being comparable to that which is found in seeds (Sebetha et al., 2010).

2.5.2 Use of cowpeas as livestock feed

Cowpea can be utilized as hay, silage and forage. In instances where it is to be utilized as forage, grazing should be done lightly after flowering. The plant has got the ability to regenerate if several buds are spared after defoliation. Cowpea blends well with maize, molasses or sorghum in provision of fermentation sugar when used as silage. Seeds are eaten by some variety of birds, including wild turkey. Quails use it for cover (Sheahan, 2012). After pod harvesting, especially during the prolonged dry season in the African Sahelian zone, cowpea is used as hay for maintenance of draft animals. It is also used for fattening goats and rams in readiness for various events or festivals (Hall, 2012).

2.5.3 Use of cowpeas as a source of income

Besides the use as food, young cowpea pods, leaves and grains are sold to generate cash for farmers (Kimiti et al., 2009). According to Hall (2012), the cash needed during the dispensation commonly referred to as the hungry period is generated through sale of fresh southern peas, a task undertaken mainly by women. Estimates on sale of fresh southern peas made between 1994 and 1996 in Senegal indicated that the peas fetched double the price of dried grains in terms of per seed basis.

2.5.4 Use of certain cowpeas lines to suppress weeds and pests

Suicidal germination of *Striga hermonthica* which is parasitic to maize, pearl sorghum and millet can be induced by use of certain cowpea lines. Other lines have been known to suppress Nematode (*Scutellonema cavenessi),* which is the main pest affecting peanut, sorghum and pearl millet in the Sahelian zone (Hall, 2012). Sheahan (2012) concludes that weed suppression by cowpea is as a result of the existence of allelopathic compounds.

2.5.5 Use of cowpeas as a cover crop

Cowpea is a quick growing cover crop. The wide and vegetative spread coupled with a long tap root makes cowpea an ideal crop for weed suppression and erosion prevention. It has been successfully used as groundcover in orchards (Sheahan, 2012).

2.5.6 Use of cowpeas to improve soil fertility

Cowpea is deemed to be an important rotational crop with cereals (Hall, 2012). Its contribution to the soil nitrogen status is one of the most important beneficial attribute.

This is realised through symbiotic Nitrogen fixation, which in effect enhances soil fertility thus reducing the need for N-fertilizer application (Ndema et al., 2010). Under field conditions, cowpeas are nodulated. Little or no response of cowpeas to Nitrogen soil fertilization has been observed in California and Senegal. This could possibly be attributed to its ability to substantially fix nitrogen biologically (Hall, 2012).

2.6 Cowpeas Establishment and Weed Management

2.6.1 Establishment of Cowpeas

Cowpea is usually cultivated in an intercrop (binary culture) on marginal soils as a companion crop with various cereals. Few farmers plant it as a sole crop (Sebetha et al., 2010). The period starting from late May through mid-June is the most ideal planting time. Sowing involves seed placement 2 to 4 cm deep. Cowpea seeds germinate readily and the young plants are vigorous, with the crop having the potential to reseed from the previous crop. Cowpea flowers in roughly 48 days and pod production occurs in roughly 60 days in earlier varieties (Sheahan, 2012).

2.6.2 Weed management in Cowpeas

Cowpea is less successful at suppression of perennial grasses despite the fact that it is a quick-growing weed-fighter. Row cultivation is recommended as a measure to control weeds when cowpea is grown for the purpose of dry seed (Sheahan, 2012). In tropical zone, a number of weeds are known to cause significant damages to cowpea plants and can result to yield losses of up to 86%. *Cyperaceae* like *Cyperus sp*., *Scrofulariaceae* like the parasite *Striga gesnerioides*, *Gramineae* such as *Digitaria* velutina, *Panicum* *maximum* or *Imperata cylindrical* and *Euphorbiaceae* such as *Euphorbia hirta* or *Euphorbia heterophylla* are some of the examples (Abadassi, 2015).

Weed density, weed species and weed dry biomass determine the extent of cowpea yield reduction. A density of 2 to 100 plants m^{-2} of *Solanum nigrum* plant can decrease cowpea yield by between 13 and 77%. Reduction of yield loss due to weeds require different management practices, integrated weed management (IWM) being one of them. Combinations of practises are involved in (IWM). These are cultural, chemical, physical and biological methods for effective and efficient or economical control. Compatible mixtures are recommended in order to widen the weed suppression spectrum in the management of mixed weed population at the same time avoiding herbicide resistance that may emanate from continuous use of a single herbicide. Good control at dozes considerably below those normally applied in a single application can be achieved with herbicide combinations (Mekonnen et al., 2016).

2.7 Cowpea Climatic Requirements

2.7.1 Moisture

Cowpea can grow under wide and extreme moisture conditions. However, it is usually grown under agriculture that is rain fed in areas with at least 600 mm annual rainfall (Ndiso et al., 2016). Areas receiving 750 to 1500 mm annual rainfall are considered most ideal for cowpea production (Oyewale & Bamaiyi, 2013). Cowpea cannot withstand flooded conditions (Sheahan, 2012). Water stress affects cowpea yields in various ways depending on the severity. Flowering period is cut short and the seeds mature earlier under water deficit conditions which are evident in the semi-arid zones. There is delay in formation of new floral nodes and flowers, thus leading to low productivity. Under mild water stress, cowpea yield reduction ranges from 9.5% to 47.2%, 42.6% to 65.8% under moderate water stress and 63% to 98.4% under severe water stress (Ndiso et al., 2016).

2.7.2 Temperature

Generally, cowpea is better adapted to extreme temperatures, drought and other types of biotic stresses than most other crops (Ndiso et al., 2016). The most ideal temperature for cowpea growing is 26.7°C during the daytime and a steady soil temperature averaging at 18.3°C (Sheahan, 2012).

2.7.3 Soils

Cowpea growth is supported by different types of soils, including those of low fertility but well-drained, highly acid to neutral soils are more preferable (Sheahan 2012). Cowpea does best on fertile, well-drained, sandy-loam soils (Oyewale & Bamaiyi, 2013). A pH range of between 5.5 and 6.5 is the best for cowpea (Ndiso et al., 2016).

2.8 Fertility Management

2.8.1 Nitrogen

Cowpea uses its root nodules to fix its own Nitrogen from the air and therefore does not require a lot of Nitrogenous fertilizers (Karikari et al., 2015). The crop provides a fixed Nitrogen deposit of up to 60 - 70 kg ha–1 in the soil besides providing a high proportion of its own requirement (Singh et al., 2011). A starter dose for a good crop of about 15 kg of Nitrogen is necessary in areas with Nitrogen poor soils. Cowpea requires more

Phosphorus than Nitrogen in the form of Single Super Phosphate (Karikari et al., 2015). According to Hall (2012), biological fixation of cowpeas is more drought sensitive than the process of photosynthesis. The kind of limitation observed, however, is insignificant to warrant intensive program of breeding to increase the contributions of cowpeas to the process of biological fixation of Nitrogen under drought exposure.

2.8.2 Phosphorus

Cowpea is sensitive to soil Phosphorus levels. Low soil Phosphorus leads to retarded growth (Kimiti, 2011). In many tropical soils, Phosphorus happens to be among the most crucial elements that are necessary for crop production but P and Nitrogen are inherently deficient in those soils. Phosphorus is important in many processes of the plant such as initiation of nodule formation, nitrogen fixation, enzyme regulation, energy metabolism, photosynthesis, respiration, influence efficiency of rhizobium legume symbiosis, synthesis of nucleic acids and membranes, increase of metabolism and promotion of rapid cell division in young plant cells such as root tips and shoot, aiding in flower initiation, seed and fruit development as well as the protein synthesis physiological processes and energy transfer in plants. Phosphorus has a tendency to decrease cowpea grain Zinc concentration, thereby affecting its quality in terms of nutrition**.** Cowpea yields have been reported to improve with application of Phosphorus (Karikari et al., 2015). Organic matter added in form of animal or plant residual matter, inorganic fertilizers and Phosphate-rich rocks like Mijingu Phosphate rocks or Busumbu can replenish soil P. Inorganic Phosphorus added at rates of between 13 and 25 Kgha-1 in form of Di-ammonium Phosphate (DAP) or in form of Triple Super Phosphate can improve cowpea growth (Kimiti, 2011).

2.9 Pests and Diseases of Cowpea and their Management

Cowpea harbours a number of insect pests that attack vegetables and is susceptible to various diseases that affect legumes, with most locations having between 2 and 4 species being key pests (Oyewale & Bamaiyi, 2013). Cowpea suffers heavily from field pests as well as storage pests with yield reductions of up to 95%, depending on location, year and cultivar. Aphids have been identified as the main field pests and bruchids as the main storage pests (Ilesanmi & Gungula, 2010). Fungal diseases and insect pests pose a major threat in stored cowpea resulting in various losses such as discoloration, change in taste, heating and mustiness and poor germinability. Harvested field-infested pods, seeds or remnants from an initial infestation are the major source of store infestation. In the absence of insect pest control measures in stored cowpea, losses of up to 30-70% have been recorded (Bawa et al., 2012).

2.9.1 Pests of Cowpea

The main insect pests of cowpea capable of causing major economic losses incude; cowpea pests include; aphids (*Aphis craccivora*), leafhoppers (*Empoasca sp*.), thrips (*Megalurothrips sp*.), Stinkbugs infestation also occurs if the cowpea is allowed to form pods (Tiroesele et al., 2015). Other pests are legume pod borer, *Maruca vitrata* Fab. (*Lepidoptera: Pyralidae*), flower bud thrips, *Megalurothrips sjostedti* Tryb. (*Thysanoptera: Thripidae*) and a group of bugs which specialize in sucking such as

Anoplocnemis sp., *Aspavia sp.,Clavigralla sp*. and *Riptortus sp*.which are known to be the most damaging. Birds and rodents feed on the seeds in the establishment phase and routine monitoring is crucial (Oyewale & Bamaiyi, 2013). .

2.9.2 Diseases of Cowpea

Cowpea diseases can be classified into several groups such as Bacterial, Viral, Fungal and Nematodal. Several cowpea diseases whose causative agent is fungi do exist. One such disease is Damping off caused mainly by a fungus species known as *Pythium*. It affects plants which are congested and exposed to conditions that are moist especially seedlings, stem rot (*Fusarium sp*.), Root rot (*Verticillium sp*.), powdery mildew (*Erysiphe polyqoni*) especially under humid conditions, charcoal rot by fungus species *Sclerotium*, anthracnose (*Colletotrichum lindemuthianum*), and Fusarium wilt by the fungus species Fusarium (Oyewale & Bamaiyi, 2013).

Diseases caused by viruses pause a major challenge in areas where cowpea is cultivated. They affect production and subsequently the yield. Over twenty (20) virus types are known to affect production of cowpea globally and can cause losses in yields of up to 90% or in some cases cause total failure of the crop (Mbeyagala et al., 2014). Cowpeas diseases caused by virus are: Cowpeas mottle virus (CPMOV), Aphid borne mosaic virus, Blackeye mosaic virus and Cowpeas mosaic virus (CPMV) belonging to the genus known as *comovirus*. Cowpea diseases caused by Nematodes are: Dagger nematodes (*Xiphinema sp*.), Root lesion nematodes whose causal agent is (*Pratylenchus sp*.) and

Root knot nematodes (*Meloidogyne sp*.). Cowpeas diseases caused by Bacterial agents are: Cowpeas bacterial pustule (*Xanthomonas sp. pv. Vigna unguiculata*) and Cowpeas blight -*Xanthomonas sp. pv. Vignicola* (Oyewale & Bamaiyi, 2013).

Aspergillus fumigatus and *Aspergillus flavus* are the cause of fungal diseases on stored cowpea. Field fungi and storage fungi are responsible for infestation of stored foods and agricultural commodities with most of the storage fungi being in the category of moulds, whose flora is mostly acquired in the field and after harvest. The moulds usually remain inactive until they are exposed to environmental conditions that favour their growth hence poor storage conditions predispose grains to fungal spoilage, this being exacerbated by insect damage (Bawa et al., 2012). Climatic conditions in the tropical countries are often favourable for high mould growth. Microorganisms can raise temperature of stored grain by between 70 and 75°C as a result of spontaneous heating and associated increase in respiration. Invasion of the embryo by storage fungi has effect on seed germinability. Insect pests have a devastating effect on almost every stage of cowpea development (Oyewale & Bamaiyi, 2013).

2.9.3 Management of Cowpea pests and diseases

a) Use of synthetic insecticides

Pest and disease control by use of synthetic based chemicals has been deemed necessary and effective method to achieve meaningful yield of cowpea grains. Occasionally, negative consequences are realised from excessive and unwise application (Egho et al., 2012). Four main classes under which most insecticidal compounds fall are: Carbamates, organophosphates, pyrethroids and organochlorines. Yield increase of several folds is realized with insecticide application and virtually no yields for some improved varieties without any application. However, eight to ten applications are sometimes made during the growing season. About $ 8.1 billion a year is the estimated cost in terms of finances, attributed to damage incurred by the social economy as well as the environment. A number of synthetic chemicals are available in the market (Oyewale & Bamaiyi, 2013).

Actellic 2% dust, Phostoxin (Aluminium phosphide) tablet and Actellic 25 E.C are some of the insecticides recommended for cowpea in storage with Actellic 25 E.C. being recommended where there is bulk storage over a long period (Bawa et al., 2012). Where grain is to be stored on short-term basis, dusts and gaseous forms of insecticides are highly recommended (Ilesanmi & Gungula, 2010). Actellic 25 E.C is used at a rate of 10-20 ml in 1-2 litres of water per 100 kg cowpea meant for storage, and it is essential to make the store air-tight for the chemical's fumigant action to be effective on all stages of insect pests present. Actellic 2% dust is applied at a rate of 25-50 g to a 50-100 kg layer of unthreshed cowpea and a rate of about 10-12 ppm to threshed cowpea as recommended by FAO. The treatment is repeated 2-3 months after the initial treatment. Phostoxin (Aluminium phosphide) is used at a dose of 1 tablet for every 100 kg of cowpea in a container that is air-tight or 1 to 3 tablets for every ton with treatment being repeated 4-6 months after. To prevent re- infestation, fumigated grains ought to be maintained in insect proof containers (Bawa et al., 2012).

In Africa, many cowpea growers do not use insecticides due to affordability issues, non-availability of some as well as lack of proper equipment and training on their use. Phostoxin gas and Actellic (2%) though helpful are expensive and not readily available. Insecticides are polluting, expensive and potentially dangerous to the users. Phostoxin fumigant is dangerous. It can kill both humans and animals (Ilesanmi & Gungula, 2010). Care should be exercised when handling all types of fumigants due to their hazards to man if inhaled. To control cowpea bruchids, dusts have to work at higher dosages eventually making the grains unsafe for human consumption. Chemical applications should always be made away from domestic animals and living houses (Bawa et al., 2012).

b) Use of botanical insecticides

Increased awareness on the perils associated with prolonged chemical use has led to calls to cut down on their use to a bare minimum, while exploring other viable means of control that are more cost effective and less harmful (Egho et al., 2012). Green plants are a source of pesticides that are innocuous which are not only non-toxic to mammals but also biodegradable easily compared to synthetic chemicals (Ilesanmi & Gungula, 2010). Botanical insecticides are derived from plant extracts and easily break down in the soil with no evidence of storage in animal or plant tissue. Botanical insecticides have several advantages over synthetic ones. They have no long lasting effect, are biodegradable hence harmless to the environment, are target specific with little or no harm to organisms that are non-targets, with pest resistance to them less likely. Only a few plants have been scientifically evaluated though over 2000 species have been known to possess insecticidal activities. Low concentration of Cashew Nut Shell Liquid (CNSL) which contains active Phenolic compounds, Cardol and Anacardic acid that have corrosive and abrasive properties has proved effective in management of *Callosobruchus maculatus* (Oyewale & Bamaiyi, 2013).

Insect pests on stored cowpea can be controlled by applying Neem kernel powder at a rate of 5-10 g per 100 g seed, powders of guava, Eucalyptus, lemon grass leaves as well as grape and orange peels applied at similar rates. Capsicum frutescens (L.) Ocimum basilicum, Sesamum indicum, ash, groundnut oil at 5 to 10 mls per kg, palm kernel oil, castor oil at 6 ml per kg cowpea seed and palm oil have also proved effective in control of stored cowpea insect pests. Mode of action by most plant materials is through anti-feedant properties, insecticidal action, repellant action and disruption of normal pest activities thus inhibiting their multiplication. The plant materials are easily available, cheap and easy to use (Bawa et al., 2012).

c) Use of cowpea varieties resistant to insects

The IITA adopted the use of cowpea varieties that are resistant to leaf hoppers and which do not necessarily require any application of insecticides against the hoppers. The varieties are Tvu123, VITA-3, Tvu59 and VITA -1. Bacillus thuringiensis, commonly abbreviated as *Bt* is a soil bacterium that is common in the world with the ability to produce *Bt* protein and *Bt* gene. *Bt* proteins have the ability to kill selectively certain types of insects without endangering other living organisms (Oyewale & Bamaiyi, 2013).

Cowpeas that shows resistance to pod borers has also been developed from *Bt* gene according to study from laboratories, with great potential for improved yields and enhancement of economic and nutrition status among farmers that are small-holders (Mohammed et al., 2014) *Bt* crops don't require sprays with the ordinary pesticides to deal with specific *Bt* protein controlled pests. Maruca-resistant cowpeas (*cry1Ab*) was developed by use of *Bt* gene that is utilized in a number of *Bt* maize activities. Though several institutions have made concerted efforts in the development of cowpea varieties which have resistance to a wide range of insect pests, farmers have not received those varieties (Oyewale & Bamaiyi, 2013).

2.10 Cowpea Yield Potential

Cowpea has a high yield potential averaging at between 1,500 and 6,000 kg /ha depending on the genotype but the actual yields realized are the lowest globally compared to other pulses, averaging at 300 kg/ha and with the annual total production being ranked 8^{th} among ten pulse crops (Lemma et al., 2009). In Sub-Saharan part of Africa, yields of cowpea rank as the lowest among all food legume crops averaging at 450 kg/ha (Hutchinson et al., 2016). The most improved Kenyan cowpea cultivars have a yield potential of between 1,170 and 1,800 kg /ha in pure stands (Kimiti, 2011). In Kenya, cowpea yields remain extremely low, ranging from 150 - 500 kg/ha (Wamalwa et al., 2016). Genotype variations among cowpea seeds could be attributed to seed development, inherent genotypic differences during crop growth, and maturation, as well as capacity to utilize reserve food material (Kumar et al., 2015).

Cowpea yields consist of several components namely: number of seeds per pod, number of pods per plant, 100 seeds weight, weight of seeds per pod, length of pods per plant, and weight of pods per plant. Most components of cowpea yields are significantly affected by plant density or population. Increased spacing was found to increase number of pods per plant and number of seeds per pod. Increased yield was noted at lower spacing i.e. when row spacing was decreased (Jakusko et al., 2013). Pod numbers and grain yields depend on the type of cropping systems at different locations. Higher number of pods and subsequently higher grain yields are realized in sole cowpea production system due to less competition for the available nutrients, which include nitrogen and possibly the reduced effect of shading (Sebetha et al., 2010). Different optimum densities are necessary for cowpea varieties with different plant morphology to fully express their full seed yield potential (Jakusko et al., 2013). High cowpea plant population increases competition for nutrients, carbon dioxide, light and soil moisture (El Naim & Jabereldar, 2010). However, light interception increases with high plant density as well as dry matter and yield components such as pods and seeds (Kamara et al., 2018).

Low cowpea yields (less than 1,000 kg/ha) in many producing areas can be attributed to a number of constraints such as biological constraints (diseases, weeds, pests, rodents, birds), climatic constraints (inadequate and poorly distributed rainfall), technical constraints (poor farming techniques, low soil fertility, deficiencies of the varieties) and socio-economic constraints such as lack of credit and/or labour (Abadassi, 2015). In the sub-Saharan part of Africa, low population of cowpea in a unit area of production is reported to be the main factor which accounts for depressed cowpea yields realised by small scale farmers ((Jakusko et al., 2013). Lemma et al., (2009) concluded that yield levels are subject to the level of agronomic practises employed and key among these are planting density and row spacing which happen to be powerful management tools. Harvesting of cowpea is done at various stages of growth; at pod stage when young, green and tender, when green and mature, and finally when they have dried (Oyewale & Bamaiyi, 2013). Pods are ready for harvesting when all have turned brown and are drooping (Karanja et al., 2008). Table 2.2 shows area, production and yield of cowpea during the period 2010 -14.

Table 2.2

National Production trend of Cowpeas in Kenya from 2010 to 2014

Year	**2010**	**2011**	**2012**	**2013**	**2014**
Area (ha)	168,273	197,980	212,730	250,798	281,877
Production 90 kg bag	532,810	668,361	1,254,976	1,486,180	1,540,813
tons	47,953	60,152	112,948	133,756	138,673
Yield (90 kg/ha)	3.2	3.4	5.9	5.9	5.5

Source: Republic of Kenya, MOALF, Economic Review of Agriculture, 2015

2.11 Cowpea drying and Storage

Cowpea for storage needs to be dried properly to moisture content of 13% and below since excessive moisture level exposes it to deterioration and infestation by fungi and insect pests. Properly dried grains are less susceptible to insect and fungi attack. Avoid storage of cowpea on bare floor to stem moisture migration to the cowpea. Broken, damaged and unhealthy cowpea will encourage infestation (Bawa et al., 2012).

2.11.1 Cowpeas storage structures

Cowpea can be stored both in threshed and unthreshed form in structures such as Polythene bags, Earth wave-pit method, Earth wave type of Granary (Rumbus), Tins or Drums made of steel and Silos. Cowpea that is not threshed can be stored in hermetic storage. Tins and drums made of steel and polythene bags are ideal for storing cowpea that is threshed. Structures recommended for bulk storage of threshed cowpea include Silos Butyl rubbers or aluminium silos. This form of storage where fumigation is necessary at three- month intervals commencing 2-3 weeks after storage, is recommended for large organizations like co-operatives, companies and companies. Storage of threshed cowpea in areas with low annual rainfall can also be done in polythene or mat lined pits measuring 4x4x2 m. To prevent moisture from entering the pit, the floor is cemented. However, it is not rodent-free and the wall lining is prone to destruction by termites. Maintenance cost depends on availability of material and the locality (Bawa et al., 2012).

2.12 Cowpea Drought Adaptation Mechanisms

Climate change, water scarcity, environmental degradation and population pressure have put agriculture at a crossroad. Production of Cowpea is subject to a wide range of constraints namely biotic and abiotic with drought being the major abiotic constraint. The dry savanna and Sahel where cowpea is mainly grown have irregular rainfall with no irrigation facilities. Cowpea plants are usually weakened by drought conditions exposing them to insect pest attacks and disease infestations (Agbicodo et al., 2009). The reproductive development stage of many cowpea cultivars is sensitive to high temperatures and drought (Ndiso et al., 2016). Drought tolerance is the ability of a plant to live, grow, and satisfactorily yield even when there is limited supply of water in the soil or under intermittent water supply. To cope with drought stress, plants use mechanisms such as drought avoidance, drought escape and drought tolerance. In Africa, early maturing cultivars reach maturity within 60 to 70 days in many of the cowpea producing areas. Besides drought escape, the cultivars that are early maturing also escape some infestations by insects. Although varieties of cowpea that are early maturing escape terminal drought, moisture stress exposure during the time of vegetative growth causes them to perform very poorly. To unravel cowpea drought coping mechanisms and come up with varieties that can adapt to climate change in Sub-saharan Africa, studies on physiology, biochemistry and genetics are being undertaken (Agbicodo et al., 2009).

Cowpea exhibits minimal changes in water potential of the leaf when exposed to drought situation and minimal osmotic adjustment. Their stomata partially close before any variations in water potential of the leaf are sensed due to sensitivity to soil drying. Cowpea leaves track the sun by orienting more vertically when exposed to drought situation in the field, a strategy that helps to minimize solar radiation interception. Through these mechanisms, cowpea is able to withstand extreme droughts during the vegetative stage that kills most of the other crop plants except if there is presence of ashy stem blight (*Macrophomina sp*.) causing organism in the field. Presence of the lesser cornstalk borer larva also has the same effect especially to young cowpea plants which are attacked and killed (Hall, 2012). Although cowpea drought avoidance, escape, and tolerance mechanisms have been documented, the pathways to drought response connected to these identified mechanisms are yet to be clearly comprehended and the extent to which these adaptations operate either separately or jointly to allow the crop to withstand drought conditions still need to be established (Agbicodo et al., 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description

Location of study

The experiment was carried out at Mtwapa Agricultural Training Centre (ATC) demonstration farm, Mtepeni Ward, Kilifi County between June, 2015 and December, 2015. Mtwapa Agricultural Training Centre is situated about 3 km towards the western side of Mtwapa Town and is about 48 km from Kilifi Town, which is the County headquarter. The area of study lies within an altitude of 30 m above sea level (A.S.L).

Climate

The study area is in the coastal lowland agro-ecological zone 3 (CL_3) characterized by semi-humid conditions with high relative humidity of more than 80%. The rainfall in Mtepeni ward is bimodal in nature with the long rains commencing in the month of April/May and extending to August and the short rains starting in the month of October and extending to December. Average annual rainfall received in the area ranges from 1,050 to 1,230 mm with 66% reliability. Annual temperatures within the study area range between 24.4 – 30°C.

Soils

The soils within the area of study are medium sand to loamy medium sand and which are loose to very friable. They are somewhat excessively drained to well drained and very deep (80 – 120 cm thick). The soil colour is yellowish red to yellowish brown. Soil samples drawn from the study area were analysed at National agriculture research laboratories (NARL), Nairobi, Kenya prior to experimentation. Details of the analysis are as shown in Appendix 1

3.2 Experimental Procedure

The experiment was laid out as a randomized complete block design (RCBD), with 12 treatment combinations consisting of 4 (four) cowpea varieties and 3 (three) spacing intervals, and replicated three times. The four cowpea varieties used in the experiment were Ken kunde, Katumani 80 (K80), KVU 27-1 and Machakos 66 (M66), designated as V_1, V_2, V_3 and V_4 respectively. The 3 (three) spacing intervals used were 40x20 cm, 50x20 cm (Control) and 60x20 cm, labelled as S_1, S_2 and S_3 respectively. The land was first cleared and ploughed to medium tilth both by tractor and by hand. Three blocks, each measuring 3 m wide and 50 m long with 2 m paths between them were laid out using a tape measure, pegs and sisal twine. Each of the three blocks was divided into 12 plots measuring 3 m by 3 m with a 1 m path separating each plot from the other, achieving a total of 36 plots. The separation between the plots and blocks was done to avoid inter-block and inter-plot plant competition.

The Four (4) cowpea varieties were planted at a depth of 4-5 cm as per the treatment combinations stated in table 3.2. TSP fertilizer was applied according to the agronomic recommendation of 20 kg of P_2O_5 $ha^{-1}$and continuous weeding done manually to keep the plots (experimental) free from weeds. Five (5) cowpea plants were randomly selected and pre-tagged in each of the plots, excluding the border rows for the purpose of data collection.

3.3 Treatments and Treatment Combinations

i. Treatments

Spacing

40 x 20 cm	S_1
50 x 20 cm	S_2 (Control)
60 x 20 cm	S_3

Cowpea varieties

Ken kunde	V_1
Katumani 80 (K80)	V_2
KVU 27-1	V_3
Machakos 66 (M66)	V_4

Characteristics of the varieties

The characteristics of the cowpea varieties used in the experiment as recorded by Karanja et al. (2008) are as follows:-

a) Katumani 80 (K80)

Katumani 80 is one of the cowpea varieties classified as dual purpose and is suitable for both grain and leaf production. It exhibits semi-spreading growth habit. Leaves are elongated with distinctive silvery mid-rib. The variety has creamy brown grains with purple blue flowers that have corollas with ivory white pigmentation. The Pod is green when immature but at maturity, it turns white brownish with interspersed faint red brown spots. Maturity is between 75 to 85 days. Yield potential ranges from 320 – 720 kg/acre or 800 – 1800 kg/ha. It is aphid resistant; has moderate tolerance to borers of pods, leaf hoppers and thrips. It has moderate tolerance to Mosaic viruses and foliage diseases caused by fungus. The variety is susceptible to cowpea yellow mosaic virus (CYMV).

b) Ken Kunde

Ken Kunde is a dual purpose cowpea variety. Maturity is between 75 to 90 days and best altitude is 0-2000 m ASL. Drought tolerant and performs well in a wide variety of soils

c) KVU 27-1

KVU 27-1 is a cowpea variety that is suitable for production of both leaves and grains and hence dual purpose. Pattern of flowering is indeterminate. It is semi spreading. Leaves are pointed. Flowers are purplish blue. The grain colour is dark reddish. Maturity is between 70 to 90 days. Yield potential ranges from 320 to 720 kg/acre or 800 to 1800 kg/ha. The variety has moderate tolerance to leaf hoppers, aphids, pod borers and thrips. Moderate resistance to Mosaic virus, CYMV and fungal diseases of the foliage.

d) Machakos 66 (M66)

Machakos 66 variety is dual purpose, good for production of both leaves and grains. It is a bushy variety exhibiting semi spreading growth habit. It is creamy brown grains. Dark green leaves and midrib. The flowers are purple with a white corolla. Young pods are green but turn to shiny red during grain-filling stage, then brownish purple when dry. The variety takes 55 – 60 days to flower. Maturity is between 80 - 90 days. Yield potential ranges from 320 – 680 kg/acre or 800 – 1700 kg/ha. It is tolerant to scab and cowpeas yellow mosaic virus-(CYMV) and partly to aphid and thrips damage. Moderately tolerant to powdery mildew and Septoria leaf spot. The general recommendation for improved cowpea varieties by the local research station is 50cmx20cm.

Table 3.2

Spacing and Variety Combinations
Treatment Combinations

	Factor 1 (Variety)			
Factor 2 (Spacing)	**V_1**	**V_2**	**V_3**	**V_4**
S_1	S_1V_1	S_1V_2	S_1V_3	S_1V_4
S_2	S_2V_1	S_2V_2	S_2V_3	S_2V_4
S_3	S_3V_1	S_3V_2	S_3V_3	S_3V_4

3.4 Plot Layout

After the land was cleared and ploughed to medium tilth, three blocks, each measuring 3 m wide and 50 m long with 2 m paths between them were laid out using a tape measure, pegs and sisal twine. Each of the three blocks was divided into 12 plots measuring 3 m by 3 m with a 1 m path separating each plot from the other, achieving a total of 36 plots. The result was as shown in figure 3.1.

Figure 3.1

Plot Layout

Block 1

S_2V_2	S_1V_1	S_3V_3	S_3V_4	S_1V_2	S_3V_1	S_2V_4	S_1V_3	S_2V_3	S_3V_2	S_2V_1	S_1V_4

Block 2

S_2V_3	S_1V_4	S_2V_2	S_3V_3	S_1V_1	S_3V_2	S_1V_3	S_3V_4	S_3V_1	S_2V_4	S_1V_2	S_2V_1

Block 3

S_3V_3	S_1V_2	S_2V_4	S_3V_1	S_2V_2	S_3V_4	S_1V_1	S_2V_3	S_3V_2	S_1V_4	S_2V_1	S_1V_3

3.5 Data Collection

i. Plant height was monitored on a fortnightly basis. Measurements of the primary stem from the base to the highest plant tip were taken for each of the five (5) randomly selected and pre-tagged plants per plot using a tape measure.

ii. No. of existing branches in each plant was obtained through physical count of the main reproductive branches on each of the five (5) randomly selected and pre-tagged plants per plot at maturity.

iii. Number of pods per plant from the five (5) randomly selected and pre-tagged plants per plot was determined through counting at harvest.

iv. Pod length from each of the five (5) randomly selected and pre-tagged plants per plot was determined by measuring with a 30 cm ruler at harvest.

v. No. of seeds in each pod from the five (5) randomly sampled and tagged plants per plot was determined through counting at harvest.

vi. 100-seed weight was determined at harvest through physical count of 100 randomly selected seeds per plot and weighing them by use of an electronic balance.

vii. Seed weight per plant was determined at harvest from each of the five (5) randomly selected and pre-tagged plants per plot using an electronic balance.

viii. The above ground biomass was determined by harvesting each of the five (5) randomly selected and pre-tagged plants per plot at physiological maturity and their dried biomass (from base to the highest tip) determined using an electronic weighing balance.

ix. Seed weight per plot was determined at harvest by seed drying and using an electronic weighing balance. The data collected was extrapolated to obtain yield per hectare.

x. Harvest index-(HI) is defined as ratio of total grain yield to total biomass yield. Harvest index (HI) was determined by dividing the total seed yield per plant by the above ground biomass per plant of each of the five (5) randomly selected and pre-tagged plants per plot. The formula used to compute the *Harvest index* ***(%)*** *is as* follows:-

$$\textit{Harvest index } \mathbf{(\%)} = \frac{\textit{Total seed yield per plant}}{\textit{Above ground biomass per plant}} \times 100$$

All plants at the edge of each plot were considered as border rows and excluded during random selection and pre-tagging for data collection.

3.6 Data Analysis

The data collected was summarized using excel package after which it was analysed using SPSS version 22. Analysis of variance (ANOVA) was carried out at 0.05 significance level to determine whether there were significant differences. Where ANOVA indicated significant differences between the means, then Post-Hoc test was carried out to determine where the differences were.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Effect of spacing on plant height

Plant height was monitored on a fortnightly basis from the date of sowing. Measurements of the primary stem was determined from the base up to the highest plant tip using a tape measure. The results were as shown in Figures 4.1 and 4.2.

Figure 4.1

Mean plant height of varieties in relation to days of sowing

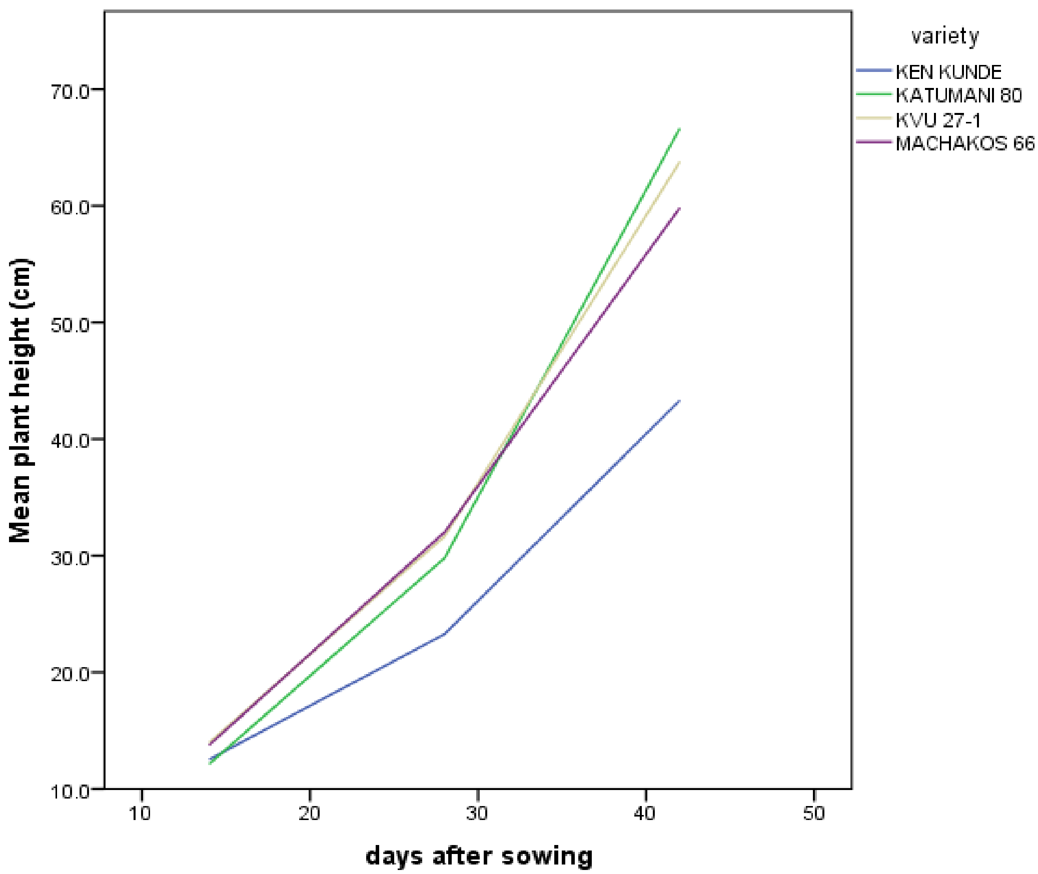
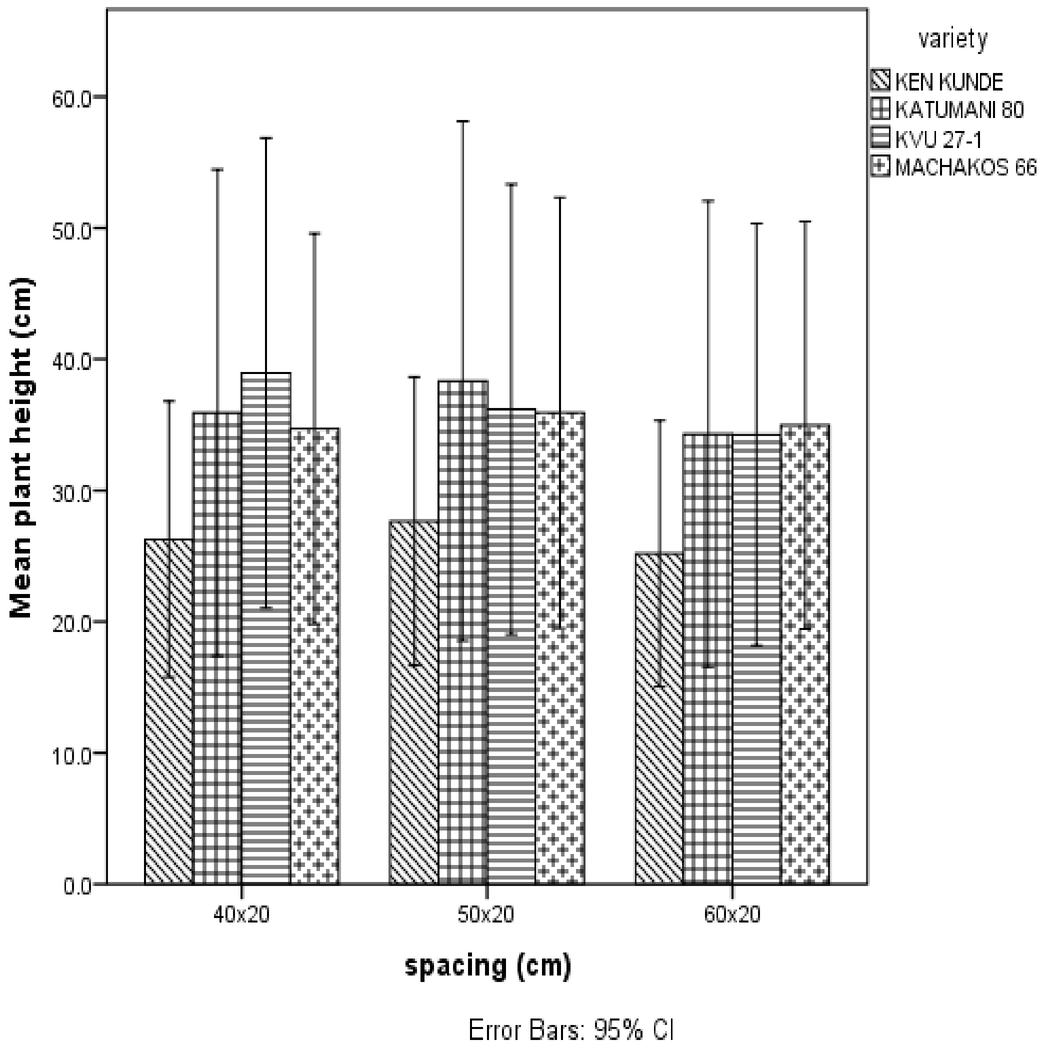


Figure 4.2

Mean plant height of varieties at different spacing intervals



The planting density affected the plant height. There was a general increase in plant height at the narrow intra-row spacing intervals of 40x20 cm and 50x20 cm in comparison to the wider intra-row spacing of 60x20 cm (Figure 4.2). Katumani 80 (K80) attained the highest plant height followed by KVU 27-1and Machakos 6. Ken Kunde, attained the lowest plant height (Figure 4.1). The variance analysis (ANOVA) at $\alpha=0.05$ showed there were no differences that were significant ($p>0.05$) for height of plant between the treatments, hence there was no need for Post hoc test (Table 4.1). The results imply there were no significant interaction effects ($p>0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80, Ken Kunde, and the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm.The results for the analysis of Variance (ANOVA) for plant height were as shown in Table 4.1

Table 4.1

Analysis of Variance (ANOVA) for plant height
Dependent Variable: Plant height (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	15.627	2	7.814	.018	.982
VAR	1880.636	3	626.879	1.456	.232
SP	107.512	2	53.756	.125	.883
VAR * SP	101.171	6	16.862	.039	1.000
Error	40473.064	94	430.565		

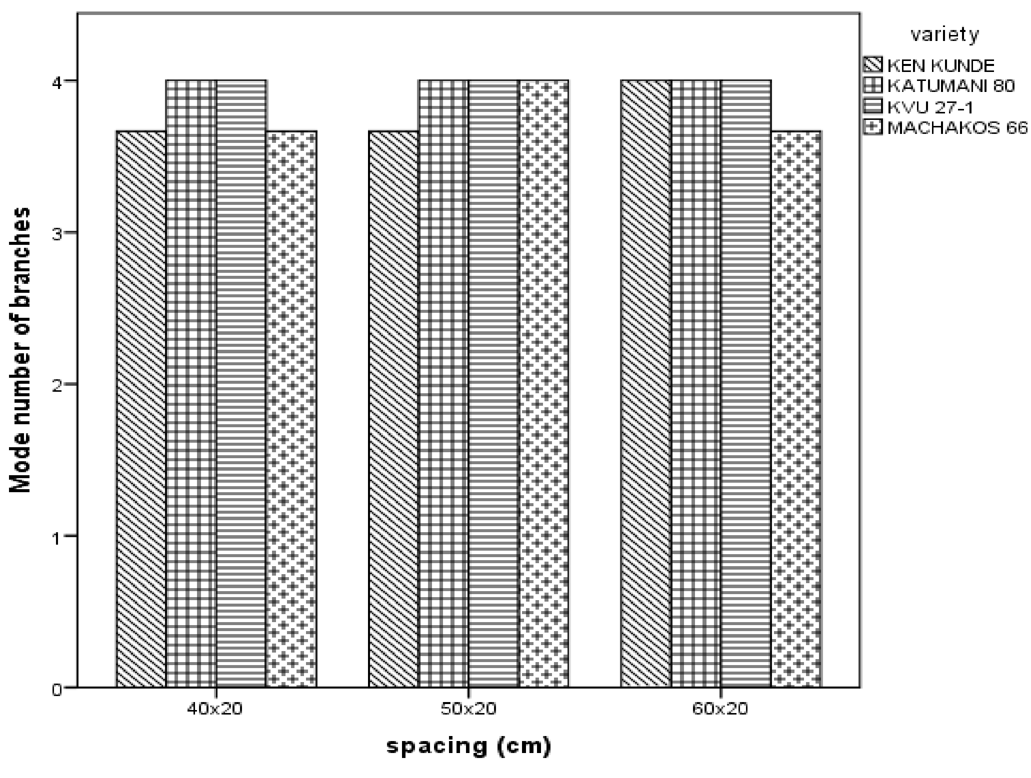
The general increase in plant height at the narrow inter-row spacing intervals could be attributed to competition for light and space. Similar observations were reported in a study by (El Naim & Jabereldar, 2010).They observed that increased plant densities led to increase in plant height.

4.2 Effect of spacing on number of branches

The number of branches in each plant was obtained at maturity by counting number of primary reproductive branches. The results were as shown in Figure 4.3

Figure 4.3

The mode number of branches at different spacing intervals



Generally, the maximum number of branches was achieved at the wider intra-row spacing of 50x20cm and 60x20cm. At the narrowest intra-row spacing interval

(40x20cm), there was a remarkable decline in the number of branches (Figure 4.3).The variance analysis (ANOVA) at (α=0.05) showed absence of any differences that were significant at ($p>0.05$) for number of branches between the treatments, hence there was no need for Post hoc test (Table 4.2). The results imply there were no significant interaction effects ($p>0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80, Ken Kunde, and the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm.The results for the analysis of Variance (ANOVA) for number of branches were as shown in Table 4.2

Table 4.2

Analysis of Variance (ANOVA) for number of branches

Dependent Variable: Number of Branches

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	.222	2	.111	1.000	.384
VAR	.444	3	.148	1.333	.289
SP	.056	2	.028	.250	.781
VAR * SP	.389	6	.065	.583	.740
Error	2.444	22	.111		

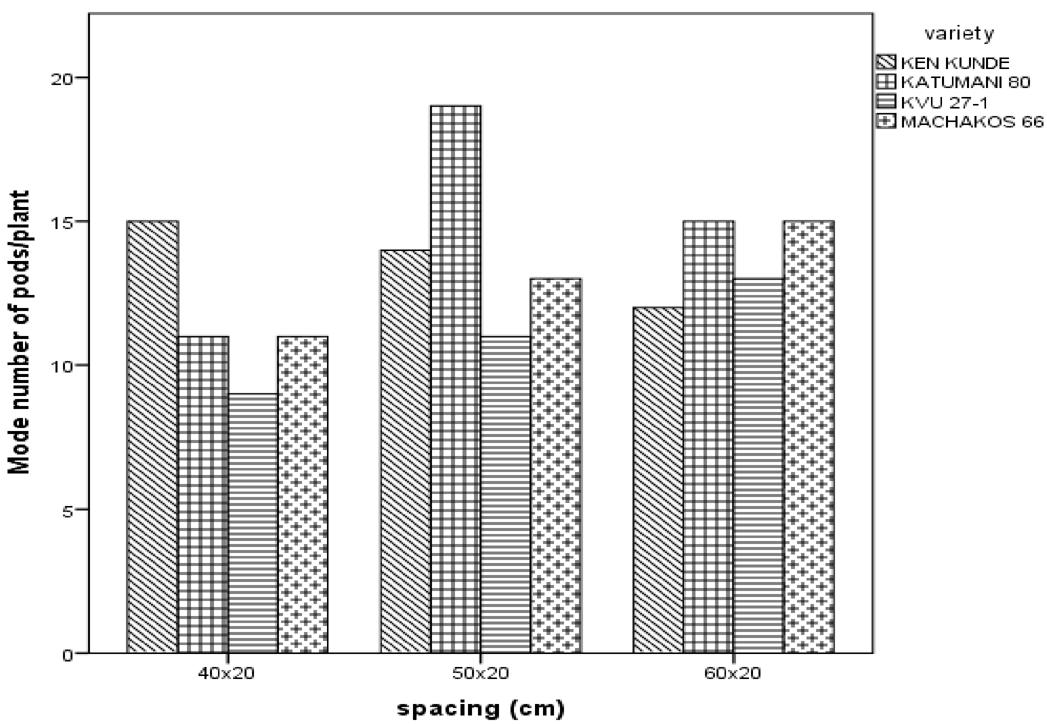
The decline in the number of branches at the narrowest intra-row spacing interval (40x20cm) could be attributed to limitation of space. Similar observations were reported in a study by (El Naim & Jabereldar, 2010).They observed that increased plant densities reduced the number of branches per plant.

4.3 Effect of spacing on number of pods per plant

The number of pods in each plant was determined during the time of harvest through counting. The results were as shown in Figure 4.4

Figure 4.4

The mode number of pods per plant at different spacing intervals



Comparatively, the number of pods per plant was higher at the wider intra-row spacing of 50x20cm and 60x20cm than at the narrow spacing interval of 40x20cm **(**Figure 4.4). The variance analysis (ANOVA) at (α=0.05) showed absence of any differences that were significant at ($p>0.05$) for number of pods in each plant between treatments, hence there was no need for a Post hoc test (Table 4.3). The results imply there were no significant interaction effects ($p>0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80, Ken Kunde, and the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm for pod numbers in each plant. The results for the Variance analysis (ANOVA) for number of pods in each plant were as shown in Table 4.3

Table 4.3

Analysis of Variance (ANOVA) for number of pods per plant

Dependent Variable: number of pods per plant

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
BK	240.500	2	120.250	2.242	.130
VAR	309.444	3	103.148	1.923	.155
SP	272.667	2	136.333	2.541	.102
VAR * SP	142.222	6	23.704	.442	.843
Error	1180.167	22	53.644		

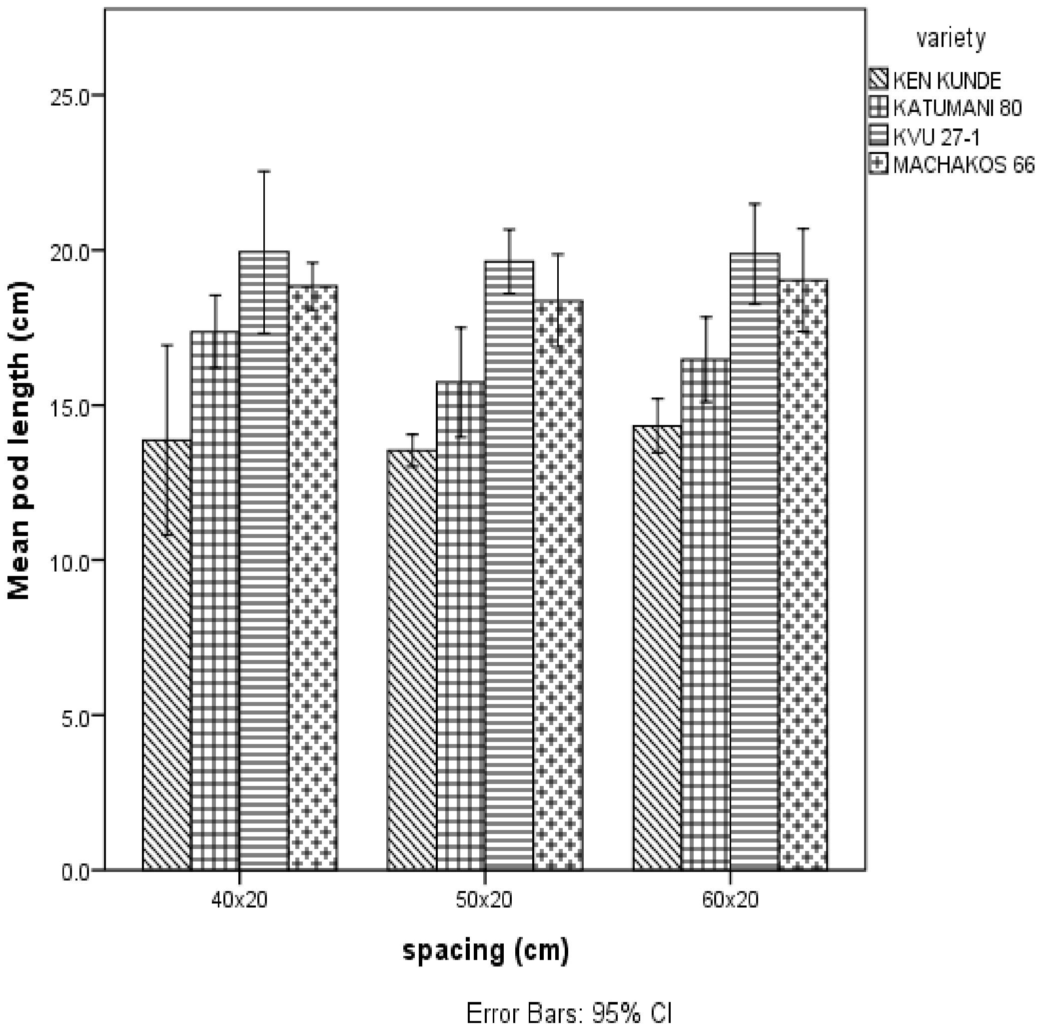
The reduction in number of pods per plant with decrease in plant spacing could be attributed to the interference among branches. Similarly, enhanced mutual shading could have led to increased abortion of reproductive parts in the lower canopy layer in the densely populated plants. This agrees with earlier findings by Jakusko et al. (2013) that increase in spacing significantly increased the number of pods per plant.

4.4 Effect of spacing on pod length

The pod length was determined at harvest by measuring with a 30 cm ruler. The outcome was as shown in Figure 4.5

Figure 4.5

The mean pod length at different spacing intervals



The mean pod length exhibited a similar trend across the spacing intervals. The varieties responded similarly to plant density. The variance analysis (ANOVA) at (α=0.05) showed existence of differences that were significant at ($p<0.05$) in mean pod length for different treatments (Appendix 2). A Post hoc test was done to find out where the differences were and the results are as shown in Table 4.4 for Variety and Table 4.5 for Spacing

Table 4.4

LSD summary for mean Pod length

Variety	Machakos 66	KVU 27-1	Katumani 80	Ken Kunde
Machakos 66		**-1.067***	**2.222***	**4.833***
KVU 27-1			**3.289***	**5.900***
Katumani 80				**2.611***
Ken Kunde				

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.1 at ($p<0.05$), it can be concluded there were significant differences in the mean pod length between variety Machakos 66 and KVU 27-1 , Machakos 66 and Katumani 80 and also between Machakos 66 and Ken Kunde. Significant differences at ($p<0.05$) were also observed between KVU 27-1 and Katumani 80, KVU 27-1 and Ken Kunde and finally at $p<0.05$ between Katumani 80 and Ken Kunde.

The results imply existence of interaction effects that were significant at $p<0.05$ between cowpea varieties KVU 27-1, Machakos 66, Katumani 80 and Ken Kunde for the mean Pod length. The variation among varieties could be attributable to the genotype's genetic potential and their growth habits. In their study, (Nwofia et al., 2014) made observations that were similar. They found that variations among varieties could be due to transferable parental trait differences as well as environmental influence.

Table 4.5

LSD summary for mean Pod length

Spacing	**40x20**	**50x20**	**60x20**
40x20		**.683***	**.075**
50x20			**-.608***
60x20			

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.5 at ($p<0.05$), it can be concluded there were significant differences in the mean pod length between spacing 40 x 20 cm and 50 x 20 cm and also at ($p<0.05$) between 50x20 cm and 60x20 cm. There were no significant differences between 40x20 cm and 60x20 cm.

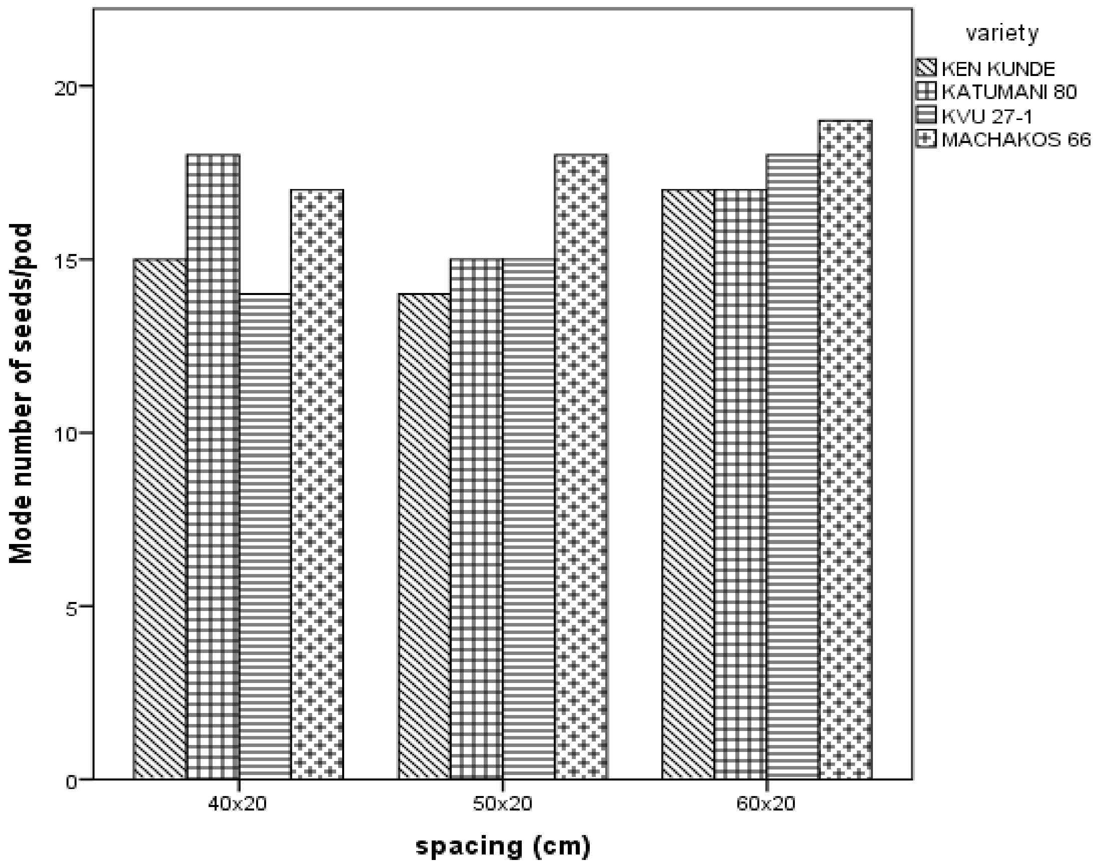
The results imply existence of interaction effects that were significant at ($p<0.05$) between plant population density resulting from varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm for the mean Pod length. The variations observed could attributable to the genotype's genetic potential and their growth habits as well as environmental influence. This is in agreement with previous findings by Nwofia et al. (2014) who observed that differences in pod length could be due to cowpea genetic constituents and planting density variations.

4.5 Effect of spacing on number of seeds per pod

The seed count in each of the pods was determined at harvest time through physical counting.The outcome was as shown in Figure 4.6

Figure 4.6

The mode number of seeds in each pod at different spacing intervals



Generally, the number of seeds per pod was higher at the wider intra-row spacing interval of 60x20cm (Figure 4.6). The variance analysis (ANOVA) at $\alpha=0.05$ showed absence of differences that were significant ($p>0.05$) for mode number of seeds in each pod between the treatments, hence there was no need to carry out a post Hoc test (Table 4.6).

The results imply there were no significant interaction effects ($p>0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80, Ken Kunde, and the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm for no. of seeds in each pod.The results for the analysis of Variance (ANOVA) for number of seeds per pod were as shown in Table 4.6

Table 4.6

Analysis of Variance (ANOVA) for number of seeds per pod
Dependent Variable: number of seeds per pod

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	6.500	2	3.250	1.175	.327
VAR	24.083	3	8.028	2.903	.058
SP	6.500	2	3.250	1.175	.327
VAR * SP	10.833	6	1.806	.653	.688
Error	60.833	22	2.765		

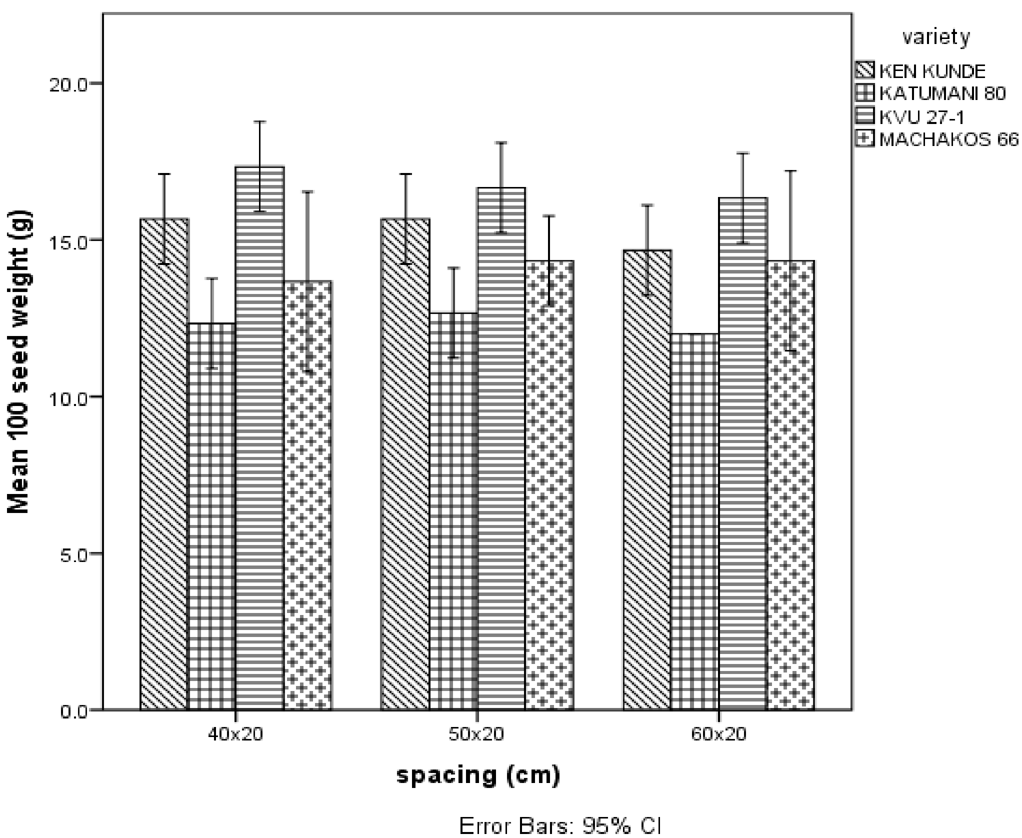
Decrease in plant density (increase in plant spacing) led to increase in the number of seeds per pod. This increase could be due to lower rate of seed abortion as opposed to the case in closely spaced plants. These results are in close conformity with the findings of (El Naim & Jabereldar, 2010).

4.6: Effect of spacing on 100 seed weight

The 100-seed weight was determined at harvest through physical count of 100 randomly selected seeds and weighing them using an electronic balance. The outcome was as shown in Figure 4.7

Figure 4.7

The mean100 seed weight at different spacing intervals



The mean 100 seed weight trend was similar across the spacing intervals. The varieties responded similarly to plant density. The variance analysis (ANOVA) at ($\alpha=0.05$) showed existence of differences that were significant at ($p<0.05$) in the mean 100 seed weight for different treatments (Appendix 3). A Post hoc test was done to find out where the differences were and the outcome was as shown in Table 4.7 for Variety.

Table 4.7

LSD summary for mean 100 Seed Weight

Variety	Machakos 66	KVU 27-1	Katumani 80	Ken Kunde
Machakos 66		**-2.667***	**1.778***	**-1.222***
KVU 27-1			**4.444***	**1.444***
Katumani 80				**-3.000***
Ken Kunde				

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

From the LSD summary, Table 4.7 at ($p<0.05$), it can be concluded there were significant differences in the mean 100 seed weight between variety Machakos 66 and KVU 27-1 , Machakos 66 and Katumani 80 and also between Machakos 66 and Ken Kunde. Existence of differences that were significant was also noted at ($p<0.05$) between KVU 27-1 and Katumani 80, KVU 27-1 and Ken Kunde and finally ($p<0.05$) between Katumani 80 and Ken Kunde**.**

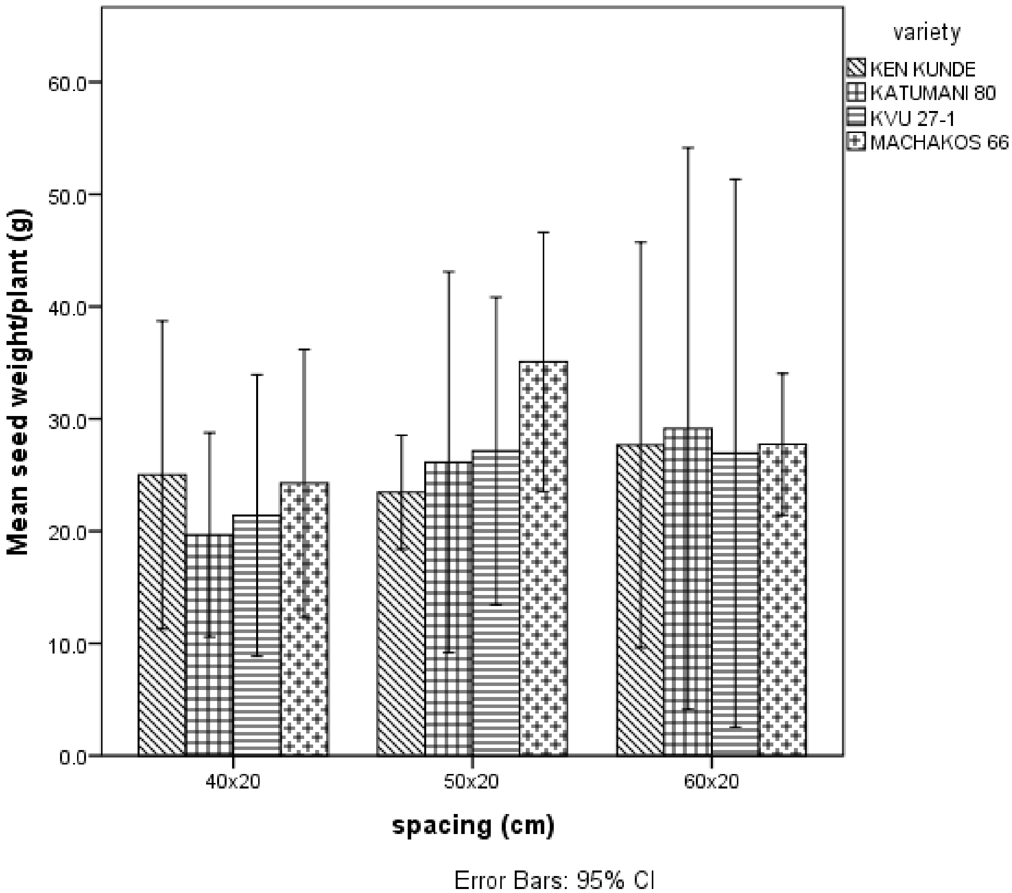
The results imply existence of interaction effects that were significant at ($p<0.05$) between cowpea varieties namely KVU 27-1, Machakos 66, Katumani 80 and Ken Kunde for the mean 100 Seed Weight. The variation among varieties could be attributable to the genotype's genetic potential and their growth habits. In a study, Jakusko et al. (2013) made observations that were similar. This is also corroborated by the findings of Kumar et al. (2015) who observed that genotype variations among cowpea seeds could be attributed to development of seed, inherent genotypic differences during crop growth, and maturation, as well as capacity to utilize reserve food material

4.7 Effect of spacing on seed weight per plant

The weight of seeds in each given plant was determined at harvest using an electronic balance.The outcome was as shown in Figure 4.8

Figure 4.8

The mean seed weight per plant at different spacing intervals



Generally, the weight of seed in each plant increased as intra-row spacing was increased. The variance analysis (ANOVA) at (α=0.05) showed absence of any differences that were significant at ($p>0.05$) for mean weight of seed per plant between the treatments hence there was no need to carry out a post Hoc test (Table 4.8).

The results imply there were no significant interaction effects ($p>0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80, Ken Kunde, and the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm for mean seed weight per plant. The results for the Variance analysis (ANOVA) for seed weight in each plant were as shown in Table 4.8

Table 4.8

Analysis of variance (ANOVA) for seed weight per plant
Dependent Variable: seed weight/plant (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	157.127	2	78.563	2.313	.123
VAR	100.871	3	33.624	.990	.416
SP	226.887	2	113.443	3.340	.054
VAR * SP	186.616	6	31.103	.916	.502
Error	747.300	22	33.968		

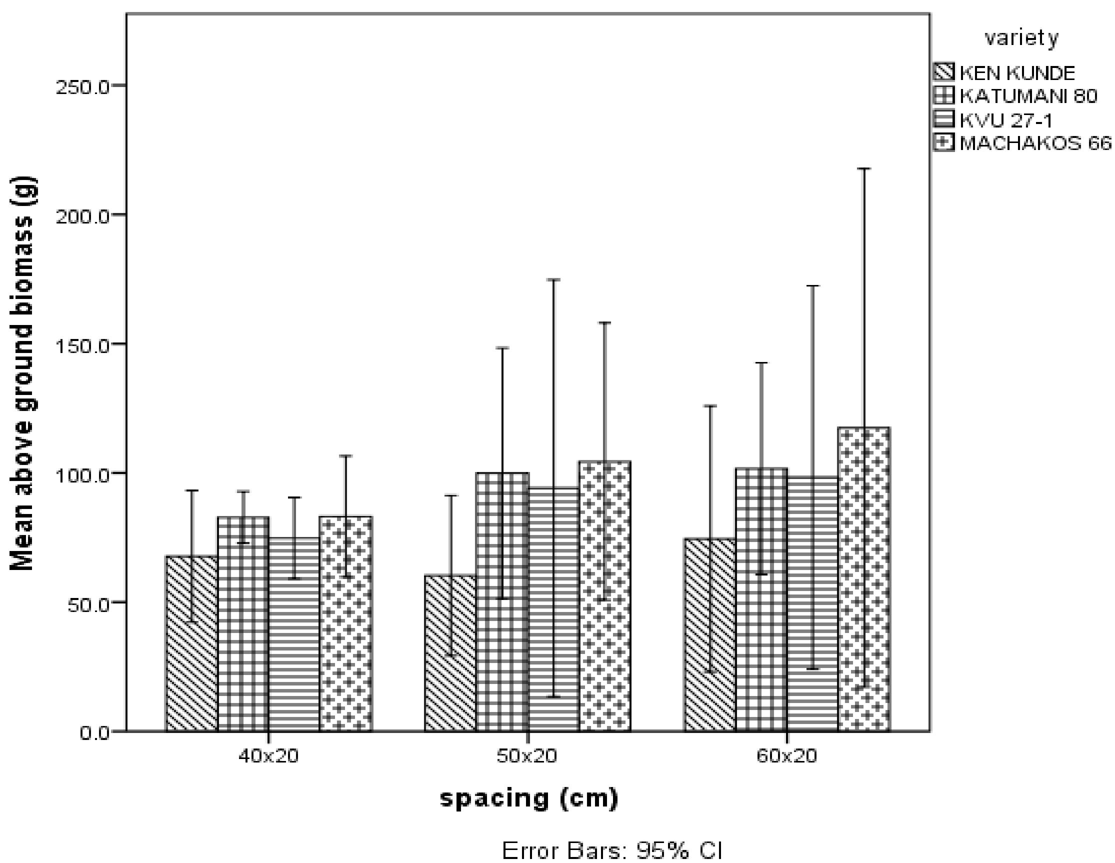
The increase in weight of seed in each plant with increase in intra-row spacing could be due to less competition for nutrients in wider spaced plants. This agrees with earlier findings by El Naim and Jabereldar (2010) that increasing plant population decreased seed yield per plant. There were similar findings by Kurum et al. (2019) who inferred that performance of cowpea meant for yield of grain is influenced to a great extent by genotypic factors that are inherent, the way they interact and the environment.

4.8 Effect of spacing on above ground biomass

The above ground biomass was determined by harvesting the plant (from base to the highest tip) at physiological maturity and weighing the dried biomass using an electronic weighing balance. The outcome was as shown in Figure 4.9

Figure 4.9

The mean above ground biomass at different spacing intervals



There was a general increase in mean above ground biomass with increase in intra - row spacing interval (decrease in plant population). The variance analysis (ANOVA) at ($\alpha=0.05$) showed existence of differences that were significant at ($p<0.05$) in the mean above ground biomass for different treatments (Appendix 4). A Post hoc test was done to find out where the differences were and the results are as shown in Table 4.9 for Variety and Table 4.10 for Spacing.

Table 4.9

LSD summary for mean above ground biomass

Variety	**Machakos 66**	**KVU 27-1**	**Katumani 80**	**Ken Kunde**
Machakos 66		**12.600**	**6.867**	**34.156***
KVU 27-1			**-5.733**	**21.556***
Katumani 80				**27.289***
Ken Kunde				

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.9 at ($p<0.05$), it can be concluded there existed differences that were significant in the mean above ground biomass between variety Machakos 66 and Ken Kunde, KVU 27-1 and Ken Kunde and also ($p<0.05$) between Katumani 80 and Ken Kunde. There were no differences that were significant ($p>0.05$) between Machakos 66 and KVU 27-1, Machakos 66 and Katumani 80 and finally between KVU 27-1 and Katumani 80.

The results imply existence of interaction effects that were significant at ($p<0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80 and Ken Kunde for the mean above ground biomass. The variation among varieties could attributable to the genotype's genetic potential and their growth habits. In a study, Nwofia et al. (2014) made observations that were similar.

Table 4.10

LSD summary for mean above ground biomass

Spacing	40x20	50x20	60x20
40x20		**-12.567**	**-20.850***
50x20			**-8.283**
60x20			

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.10 at ($p<0.05$), it can be concluded there existed differences that were significant in the mean above ground biomass between spacing 40x20 cm and 60x20 cm. There were no differences that were significant ($p>0.05$) between 40x20 cm and 50x20 cm, and between 50x20 cm and 60x20 cm.

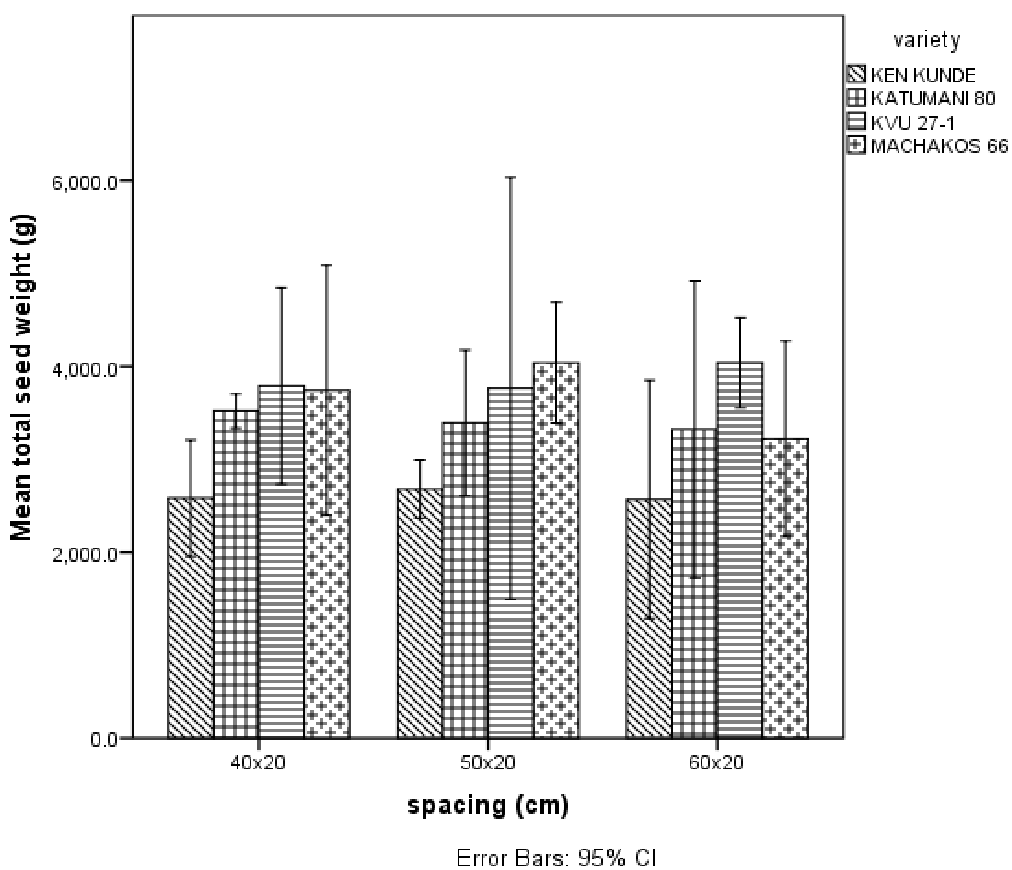
The results imply there were significant interaction effects ($p<0.05$) between the density resulting from plant population due to varied spacing intervals of 40x20 cm, 50x20 cm and 60x20 cm for the mean above ground biomass. The increase in the mean above ground biomass with increase in spacing could be attributed to less completion for space, nutrients and light compared to the case in the closely spaced plants. This is in agreement with previous findings by Nwofia et al. (2014) who observed increase in dry matter per plant with increase in spacing. This also in agreement with the findings by El Naim and Jabereldar (2010) that increasing plant population increased competition among plants for nutrients, carbon dioxide, light and soil moisture.

4.9 Effect of spacing on total seed weight per plot

The total weight of seed in each plot was determined at harvest using an electronic weighing balance. The outcome was as shown in Figure 4.10

Figure 4.10

The mean total seed weight per plot at different spacing intervals



Comparatively, there was a general increase in mean total seed weight with decrease in intra-row spacing. The variance analysis (ANOVA) at ($\alpha=0.05$) showed existence of differences that were significant at ($p<0.05$) in mean total weight of seed for different treatments (Appendix 5). A Post hoc test was done to find out where the differences were and the outcome was as shown in Table 4.6 for varieties.

Table 4.11

LSD summary for total Seed weight per plot

Variety	Machakos 66	KVU 27-1	Katumani 80	Ken Kunde
Machakos 66		-197.000	255.667	1058.889*
KVU 27-1			452.667*	1255.889*
Katumani 80				803.222*
Ken Kunde				

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.11 at ($p<0.05$), it can be concluded there existed differences that were significant in mean total weight of seed between variety Machakos 66 and Ken Kunde, KVU 27-1 and Katumani 80, KVU 27-1 and Ken Kunde, and also ($p<0.05$) between Katumani 80 and Ken Kunde. There were no differences that were significant ($p>0.05$) between Machakos 66 and KVU 27-1 and finally between Machakos 66 and Katumani 80. The results imply existence of interaction effects that were significant at ($p<0.05$) between cowpea varieties KVU 27-1, Machakos 66, Katumani 80 and Ken Kunde for the mean total seed weight.

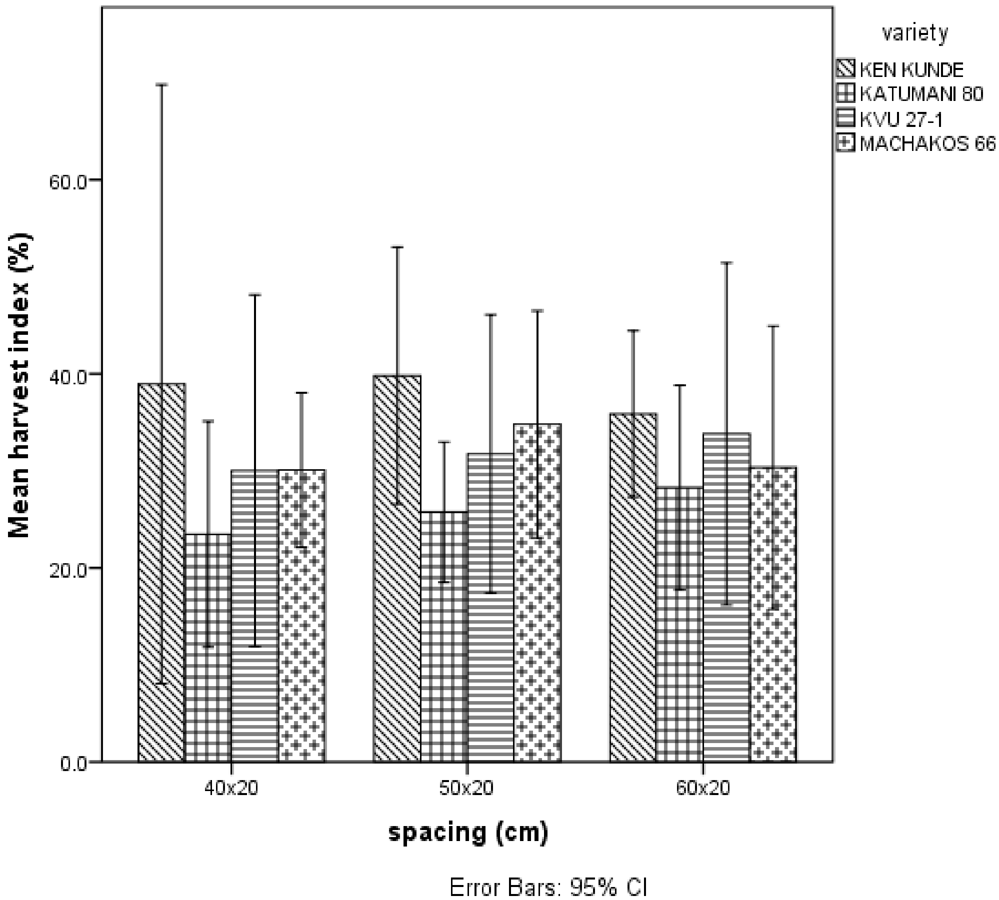
Among the varieties under investigation, KVU 27-1 had the highest yield (2,310 kg/Ha) followed by Machakos 66 (2,120 kg/Ha), Katumani 80 (1,860 kg/Ha) and Ken Kunde (1,050).The results showed improvement over the 350 - 450 kg/ha achieved in the area, where farmers use farm saved local varieties namely Kiringongo and Kaemakoko. The variation among varieties could be attributable to the genotype's genetic potential and their growth habits as well as variation in leaf area index. This is in agreement with previous findings by Kumar et al. (2015) who observed that genotype variations among cowpea seeds could be attributed to seed development, inherent genotypic differences during crop growth, and maturation, as well as capacity to utilize reserve food material. This is also in line with the findings of Kamara et al. (2018) that light interception increases with high plant density as well as dry matter and yield components such as pods and seeds.

4.10 Effect of spacing on harvest index

The harvest index (HI) was determined by dividing the total seed yield per plant by the above ground biomass per plant and expressing it as a percentage. The outcome was as shown in Figure 4.11

Figure 4.11

The mean harvest Index at different spacing intervals



The variance analysis (ANOVA) at (α=0.05) showed existence of differences that were significant at ($p<0.05$) in mean harvest index for the different treatments (Appendix 6). A Post hoc test was done to find out where the differences were and the results are as shown in Table 4.12 for varieties.

Table 4.12:

LSD summary for Harvest Index

Variety	Machakos 66	KVU 27-1	Katumani 80	Ken Kunde
Machakos 66		-.111	5.911*	-6.467*
KVU 27-1			6.022*	-6.356*
Katumani 80				-12.378*
Ken Kunde				

. The mean difference is significant at the 0.05 level.

From the LSD summary, Table 4.12 at ($p<0.05$), it can be concluded there were significant differences in the mean harvest index between variety Machakos 66 and Katumani 80, Machakos 66 and Ken Kunde, KVU 27-1 and Katumani 80, KVU 27-1 and Ken Kunde and also ($p<0.05$) between Katumani 80 and Ken Kunde. There were no differences that were significant ($p>0.05$) between Machakos 66 and KVU 27-1.

The results imply existence of interaction effects that were significant at $p<0.05$ between cowpea varieties KVU 27-1, Machakos 66, Katumani 80 and Ken Kunde for the mean harvest index. The variation among varieties could be attributable to the genotype's genetic potential and their growth habits. Jakusko et al. (2013) obtained results that were similar. He indicated that cowpea varieties had effect that is highly significant on harvest index since they differ in the partitioning of assimilates to the grain.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results of this study that was carried out in Mtepeni Ward, Kilifi County, to evaluate the effect of plant population and different varieties on growth and yield of cowpea, revealed that there were differences that were statistically significant ($P < 0.05$) between the treatment means for pod length, 100 seed weight, above ground biomass, total seed weight per plot and harvest index. There were no significant differences ($P > 0.05$) between treatment means on height of plant, number of branches, number of pods in each plant, number of seeds in each pod and weight of seeds per given plant

The Cowpea varieties had varied responses to variation in spacing. The mean number of branches, mean number of pods per plant, mean number of seeds per pod, mean seed weight per plant and the mean above ground biomass increased with variation of spacing intervals (increase) from 40x20 cm to 60x20 cm. This was generally attributed to less competition for space, soil nutrients, soil moisture and less abortion of reproductive parts.

The mean plant height decreased with variation of spacing intervals (increase) from 40x20 cm to 60x20 cm due to competition for light and space whereas the mean for total seed weight per plot decreased with variation of spacing intervals (increase) from 40x20 cm to 60x20 cm as a result of decreased plant population denseness and variation in leaf area index.

KVU 27-1 had the highest mean pod length, mean 100 seed weight and highest grain yield of 2,310 kg/ha. The yields of Machakos 66, Katumani 80 and Ken Kunde were 2,120 kg/ha, 1,860 kg/ha and 1,050 kg/ha respectively. Machakos 66 had the highest mean above ground biomass.

The highest mean pod length (which is one of the desired yield attributes) was realized at the spacing interval of 40x20 cm. The highest mean above ground biomass was at the spacing interval of 60x20 cm.

5.2 Recommendations

From the study, the following recommendations can be made;

When cowpea is grown with grain yield as the main motive, the spacing interval of 40x20 cm is recommended

For agricultural practitioners who may be interested in growing cowpea with maximum biomass yield as the motive, the spacing interval of 60x20 cm is recommended

Cowpea variety KVU 27-1 and spacing interval 40 x 20 cm are recommended for maximum cowpea grain yield in Kilifi County.

More research work should be carried out to further evaluate the effect of different spacing intervals on growth and yield of the various cowpea varieties.

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APPENDICES

APPENDIX 1: SOIL ANALYTICAL DATA FOR THE STUDY SITE

Soil analytical data

Field	Mtwapa ATC			
Sample Description	Block A		Block B	
Soil depth cm	top		top	
Fertility results	value	class	value	class
***Soil pH**	6.79	Slightly acidic	6.40	Slightly acidic
***Total Nitrogen %**	0.13	Scanty	0.06	Scanty
*** Org. Carbon %**	1.28	Scanty	0.51	Scanty
***Phosphorus (P)-ppm**	26	low	26	low
Potassium (K)- me %	0.08	low	0.10	low
Calcium-me %	2.3	sufficient	2.9	sufficient
Magnesium me %	2.15	sufficient	2.40	sufficient
Manganese(Mn)-me %	0.19	sufficient	0.23	sufficient
Copper (Cu)- ppm	4.20	sufficient	1.39	sufficient
Iron ppm	26.7	sufficient	42.4	sufficient
Zinc ppm	2.89	Scanty	3.32	Scanty
Sodium me %	0.14	sufficient	0.12	sufficient
Elect. Cond m S/cm				

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APPENDIX 2: ANALYSIS OF VARIANCE (ANOVA) FOR POD LENGTH

Tests of Between-Subjects Effects

Dependent Variable: Pod Length (cm)

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
BK	1.722	2	.861	2.124	.143
VAR	184.234	3	61.411	151.501	.000
SP	3.371	2	1.685	4.158	.029
VAR * SP	2.465	6	.411	1.014	.442
Error	8.918	22	.405		

APPENDIX 3: ANALYSIS OF VARIANCE (ANOVA) FOR 100 SEED WEIGHT

Tests of Between-Subjects Effects

Dependent Variable: 100 seed weight (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	1.056	2	.528	1.130	.341
VAR	95.861	3	31.954	68.398	.000
SP	1.722	2	.861	1.843	.182
VAR * SP	3.389	6	.565	1.209	.339
Error	10.278	22	.467		

APPENDIX 4: ANALYSIS OF VARIANCE (ANOVA) FOR ABOVE GROUND BIOMASS
Tests of Between-Subjects Effects

Dependent Variable: above ground biomass (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	3993.769	2	1996.884	6.209	.007
VAR	5883.097	3	1961.032	6.097	.004
SP	2645.029	2	1322.514	4.112	.030
VAR * SP	1050.900	6	175.150	.545	.769
Error	7075.671	22	321.621		

APPENDIX 5: ANALYSIS OF VARIANCE (ANOVA) FOR TOTAL SEED WEIGHT PER PLOT

Tests of Between-Subjects Effects

Dependent Variable: total seed weight (g)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	898397.389	2	449198.694	2.451	.109
VAR	8218687.667	3	2739562.556	14.949	.000
SP	202254.222	2	101127.111	.552	.584
VAR * SP	1054935.333	6	175822.556	.959	.475
Error	4031792.611	22	183263.301		

APPENDIX 6: ANALYSIS OF VARIANCE (ANOVA) FOR HARVEST INDEX

Tests of Between-Subjects Effects

Dependent Variable: harvest index (%)

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
BK	249.247	2	124.623	4.249	.028
VAR	689.942	3	229.981	7.842	.001
SP	35.060	2	17.530	.598	.559
VAR * SP	89.304	6	14.884	.508	.796
Error	645.207	22	29.328		