Sudan University of Science and Technology

College of Graduate Studies

Effect of Intra-Row Spacing of Cowpea (*Vigna ungucilata* L.Walp.) Grown Under Rain-fed Conditions on Growth Attributes, Forage and Seed Yield in South Darfur State, Sudan

أثر التباعد داخل الصف علي مؤشرات النمو وإنتاج العلف والبذور في اللوبيا تحت ظروف الري المطري- ولاية جنوب دارفور- السودان

A Thesis submitted to the Sudan University of Sciences and Technology

In fulfillment of the requirements of the Degree of M.Sc in Range Science

By

Ibtisam Khamis Saeed Osman

B.Sc. Range Sciences (Honors)

Sudan University of Sciences and Technology

2010

Supervisor:

Prof: Babo Fadlalla

Co-Supervisor:

Dr.Abdulrhman M. Tahir

September
2020

Dedication

The fruit of this effort is dedicated to my Mother; she is the first one to help me; and to the spirit of my father in the abode of God.

To my beloved brothers and sisters

To my family members, friends and colleague

Acknowledgement

Foremost of all praise to Allah for giving me vigor and robustness to achieve this work fruitfully.

Sincere gratitude to Prof**. Babo Fadlalha,** my supervisor, for his effort, encouragement, guidance, valuable suggestions and boundless help. Sincere thanks to my co-supervisor Dr. Abdulrahman M. Tahir for his assistance during my field work. Thanks are also due to Prof. Faisal Mohammed Ahmed El hag, Prof. Adam Al doma, Dr.Hussein Adar, Dr. Mohammed Ibrahim, Dr. Ahmed Mohammed Lazim, Dr Mohammed Mahjoub for their encouragement.

Also I wish to thank the Range Science Department for hosting me and providing me with work space and facilities. I am also indebted to NAPA and CIDA projects, Dry land Institute, Soba and ARC Nyala station.

Also I am grateful to my colleagues Mubarak Kaki, Mohammed Osman, Mohammed Barno and Ibrahim Kabashi.

Special thanks are also due

to my friend Mastura Adam and technical colleagues.

Table of Contents

CHAPTER I

Introduction

CHAPTER II

Literature Review

CHAPTER III

Materials and Methods

CHAPTER IV

Results

CHAPTER V

Discussion

CHAPTER VI

Conclusion and Recommendations

CHAPTER VII

List of Tables

List of Appendices

Abstract

A field trial was conducted on a farmer's field near the village of Ori Jamaliy, Abga Ragil Administrative Unit, Belail Locality, around 7 kilometers to the south of Nyala city, South Darfur State, Sudan. The area lies in the low rainfall savanna belt of Sudan. The trial lasted for three seasons: 2013/14, 2014/15 and 2015/16. The purpose of the study was to investigate the effect of inter-row spacing on cowpea productivity and other growth attributes. The experimental design included four intra-row spacing's: 50, 75, 100 and 125 cm while inter-row spacing was 100cm.The parameters that were studied included plant growth, plant density, vegetation coverage, plant length, survival rate, dry matter production at flowering and at maturity, number and weight of bacterial nodules at flowering, number of plant pods, pod productivity per unit area, seeds productivity per plant and per unit area; and percentage of moisture in the soil, under rain-fed irrigation circumstances. Data from a complete randomized design with four replications and (8 x 5 m.) plot area were collected through the three seasons. The study showed that, intra-row spacing significantly affected plant density, the highest plant density was recorded at 50 cm and the lowest density was found with intra-row spacing of 125 cm, which were (13 and 4 plants per square meter respectively). Furthermore, there were significant differences due to intra-row spacing in terms of vegetation cover percentage; the greatest plant cover percentage was recorded at intra-row spacing of 50 cm reaching (80.4%) while intra-row spacing of 100 cm resulted in (53.4%). Moreover, plant length was significantly affected by intra-row spacing being (149.2 and 43.2cm) at intra-row spacing of 125 and 50cm respectively. On the other hand, survival rate percentage was not significantly affected though the highest was associated with intra-row spacing of 100cm being (85.4%) while intra-row spacing of 75 cm registered (51.7%). Furthermore, intra-row spacing had not significantly affected forage yield of cowpea, the highest fresh yield was obtained with intra-row spacing of 100 cm being 7.9 t/ha fresh weight or 1.9 t/ha dry matter weight. The lowest fresh yield was obtained with intra-row spacing of 75 cm being 5.6 t/ha equivalent to 1.7 t/ha dry matter. Moreover, the highest pods yield was registered with intra-row spacing of 100cm producing 52.3 pod/m^2 and lowest pods yield was 48.3 pods/m^2 obtained by intra-row spacing of 75cm. Also, seed production was not significantly affected by intra-row spacing; the 50, 75, 100 and 125 cm spacing produced 117.4, 107.2, 116.8 and 110.4 g/ m^2 respectively, which is equivalent to 1.17, 1.07, 1.17 and 1.10 t/ha respectively.

Nodule number and weight were not significantly different as a result of intra-row spacing, the highest number of nodules/plant was recorded by intra-row spacing of 75cm **(**71.0 nodules/plant), amounting to 0.47g/plant or (40kg/ha) or 0.04t/ha; while the lowest was recorded by intra-row spacing of 100cm (50 nodules/plant) amounting to 0.53g/plant equal (30kg/ha) or 0.03 t/ha.The study showed that, there were significant differences in percentage of moisture in the soil, the highest soil moisture was found at intra-row spacing of 100cm (7.7%) at a depth of 60cm, the lowest soil moisture percentage was recorded with intra-row spacing of 50 cm at a depth of 20 cm (1.4%). It was concluded that farmers may resort to wider spacing for cowpea forage and seeds production as this involves less cost in terms of seeds and labour under rain-fed conditions in South Darfur state of Western Sudan. This also allows intercropping where farmers can grow anther crop with cowpea which serves as insurance for food security under conditions of climate change.

المستخلص

أجريت تجربة في حقل مزارع قرب قرية أوري جمالي محلية بليل , وحدة أبقي راجل الإدارية التي تبعد حوالي 7 كيلومترات جنوب مدينة نيالا خلال ثلاث مواسم 14/2013, 15/2014 و16/2015. تقع هذه المنطقة في حزام السافنا قليلة الأمطار بالسودان. هدفت الدراسة الى التحقق من أثر تباعد النباتات داخل الصف عند الزراعة على إنتاجية اللوبيا وعلى مراحل نمو النبات الأخرى. تضمنت التجربة اربع معاملات وأربعة مكررات في تصميم عشوائي كامل وكانت مساحة الحوض الواحد (8*5)م^2. كانت المسافة بين النباتات في الصف (50سم ,75سم , 100سم و125سم) والمسافة بين الصف والأخر 100 سم. البيانات التي تم قياسها خلال ثلاث مواسم تضمنت النمو، كثافة النبات، التغطية النباتية، طول النبات، معدل بقاء النباتات على قيد الحياة، انتاج المادة الجافة في مرحلتي الازهار والنضج، عدد العقد البكتيرية في فترة الازهار،عدد القرون في النبات، إنتاجية القرون في وحدة المساحة، إنتاجية البذور في النبات وإنتاجية البذور في وحدة المساحة ونسبة الرطوبة في التربة تحت ظروف الري المطري.. اظهرت الدراسة أن المسافة بين النباتات في الصف أثرت معنويا علي الكثافة النباتية، حيث سجلت أعلي كثافة نباتية عندما كانت المسافة بين نبات وآخر 50سم وأدني كثافة نباتية وجدت عندما كانت المسافة بين النباتات 125سم. وبلغ عددها 13 و4 نبات في المتر المربع علي التوالي . كذلك وجدت فروقات معنوية بين المعاملات، من ناحية نسبة التغطية النباتية حيث سجلت أعلي نسبة تغطية مع المسافة 50سم وكانت (80.4%) بينما أعطت المسافة 100سم بين النباتات (53.4%). كذلك تأثر طول النبات معنويا بالمسافة بين النباتات حيث سجلت المسافات 125 سم و50 سم (149.2سم) و (43.2سم) علي التوالي. من ناحية أخري لم تؤثر المسافة بين النباتات معنوياً على نسبة البقاء على قيد الحياة ، فقد بلغت نسبة البقاء على قيد الحياة 85.4% عندما كانت المسافة بين النباتات 100سم بينما كانت 51.7% في المسافة 75سم. كذلك وجدت الدراسة أن المسافة بين النباتات لم تحدث أثراً معنوياً في إنتاج علف اللوبيا، حيث بلغ أعلي إنتاج أخضر بالمسافة 100سم (7.9)طن/هكتار أو 1.9 طن مادة جافة/هكتار . كما أن أدني إنتاج علف أخضرأحرز من المسافة 75سم وبلغ (5.6) طن/هكتار أي 1.7طن/هكتار مادة جافة. وقد سجل أعلي إنتاج قرون بواسطة المسافة100 سم وبلغ (52.3) قرن/م^2 وأدني إنتاج قرون كان (48.3) قرن/م^2 من المسافة75سم. أيضا لم يوجد أثر معنوي على إنتاج البذور حيث انتجت المسافات (100،75،50 و25سم) انتجت 117.4 ، 107.2، 116.8 و110.4جرام/ م^2 وهذا يساوي 1.07،1.17 ،1.17 و1.10 طن في الهكتار علي التوالي. كذلك لم يوجد اختلاف معنوي في عدد العقد البكتيرية نتيجة للاختلاف في المسافة بين النباتات على الصف. فقد وجد أن أعلي عدد من العقد البكتيرية سجل بالمسافة 75سم (71.1)عقدة/النبات تزن 0.47 جرام /النبات تساوي 40 كجم أو 0.4 طن/هكتار، بينما أدني عدد سجل للمسافة 100سم (50عقدة/النبات) تزن 0.53 جرام/ النبات تساوي 30كجم/هكتار أو0.3 طن/هكتار. أظهرت الدراسة أيضا أن هنالك إختلاف معنوي في نسبة رطوبة التربة حيث بلغت أعلي رطوبة تربة في المسافة 100سم (7.7%) عند العمق 60 سم، وأدني رطوبة تربة سجلت بالمسافة 50سم عند العمق 20سم (1.4%). استنتج من الدراسة انه ربما يكون من الافضل اللجوء الي المسافة الواسعة لإنتاج علف اللوبيا والبذور حيث أن ذلك يقلل من تكلفة البذور وتكلفة العمالة تحت ظروف الري المطري في ولاية جنوب دارفورفي غرب السودان، كما ان المسافات الواسعة تسمح بالزراعة المختلطة حيث يستطيع المزارع زراعة محصول آخر مع اللوبيا يوفر له تأميناً في مثل هذه الظروف المناخية المتقلبة.

CHAPTER I

Introduction

1.1 Introduction

Sudan is the third largest African country with an area of 1.88 million km^2.The livelihoods of the majority of its people depend on agriculture, largely on rain –fed agriculture in rural areas. Livestock are a major component of the agricultural production system depending mainly on natural rangelands. Productivity of rangelands is essentially a function of rainfall which is both insufficient in amount and variable in distribution over time and space.

This lead to severe feed shortages especially during the dry season when forage quantity and quality deteriorate significantly resulting in a feed gap that frequently results in large livestock mortalities if not adequately addressed. Livestock owners adopted the practice of feeding crop residues to mitigate the impact of dry season feed shortage. However, crop residues are known for their low nutritional value in terms of digestibility and crude protein both promoting low voluntary feed intake. Therefore, there is need for high value forages such as legumes to assist in overcoming this problem. Technical packages in forage science aiming to improve forage production, productivity and quality are desired. These packages should aim at improving animal production and increasing food security and income. The central Bureau of statistics (2008) classified the population of Sudan into rural (62.44%) and urban (37.56%). Rangelands contribute to the income and subsistence of a large sector of the population who are pastoralists or agro-pastoralists by increasing important forage feed resource that contribute about (70%) of the total feed requirements of the national herd of livestock.

Sudan is rich in animal resources which are estimated at 105.6 million herds (FMLFR, 2016).

The livestock national herd consists of cattle 30.1, sheep 39.3, goats 31.2 and camels 4.99 mostly raised under pastoral and agro–pastoral system in the traditional rain-fed lands (FMLFR, 2016). On the other hand, animal feed requirements in Sudan are estimated at 122.6 million tons in 2016. Darfur region annual rangeland production (all states) is about 40.8 million ton (FMLFR, 2016). However, which rangeland productivity around Nyala was estimated at 1.5 ton/ha (NAPA, 2013).

The total natural rangeland production of South Darfur is estimated at 27.1million ton. Only 70% of this forage is however available for animals (FAO, 2012).

In 2012, the total export of animals from Sudan was about 3.8 million head and total earnings from the 3.4 million head of sheep amounted to about 451 million US dollars (MLFR , 2012). Thus, the contribution of the sector to the national income was estimated at 18 - 25 % and it represented a livelihoods activity for about 60% of the population, as well as providing labor for about 40% of the population.

South Darfur state is located in western Sudan between latitudes 8 ˚ 30' and 13˚ 30' N, and longitudes 22˚ 28' and 28˚ 0' E. The state has different ecological zones varying from semi desert in the north to high rainfall savannah in the south. Different types of soil cover the state and range from sandy soil to clay soil and cracking clay soil. Rainfall ranges from 300 mm in the North to 800 mm in the South (Abu Suwar and Yahiya, 2010). Livestock number is about 15.5 million head including cattle 4.7, sheep 3.7, goats 4.2, horses 0.79, donkeys 1.27 and camels 0.9 (State MLFR 2016). Prevailing livestock production systems are transhumance, nomadic and sedentary. Rangelands face many problems such as land degradation and desert encroachment, irregular rainfall and expansion of both traditional and mechanized rain-fed cultivation. Seasonal fluctuations in quantity and quality are normal. In addition to cutting of browse trees and fodder plants for fuel and house construction, water shortage and inappropriate distribution of water points resulted in range deterioration.

Forage quantity and carrying capacity are largely affected by annual precipitation. Range capacity of natural rangelands in the central part of South Darfur during favorable years is 2.8 ha per animal unit (Abu Suwar and Yahia, 2010).

Cowpea (*Vigna unguiculata* L.Walp) is grown by a large number of farmers in South Darfur where it serves a dual function of producing pods and seeds for human consumption and an important forage for livestock. However, the cultural practices of growing cowpeas are not adequately investigated.

Cowpea production is widely distributed throughout the tropics. Central and West Africa account for more than 64 % of the area with about 8 million ha, followed by about 2.4 million ha in Central and South America, 1.3 million ha in Asia and 0. 0.8 Million ha in East and Central Africa. Cowpea can be regarded as sort of sustainable farming in semiarid zone. It is one of the mandated crops addressed by the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. An estimated 14.5 million hectares of land is planted to cowpea each year worldwide. Global production of dried cowpeas in 2010 was 5.5 million metric tons; Africa was responsible for 94% of this (CGIAR, 2018). The seeds are a major source of plant protein and vitamins for humans.

In Sudan the total area cultivated is about 173,000 hectares, with productivity of 400-500kg/ha (El Naim, 2010a). Cowpea is adapted to the hot semi- arid zones with low fertility sandy soil. In 2015 forage production from cowpea amounted to 284.000 tones.

In Darfur region, the total area cultivated of green forage in 2016 was approximately 1680 hectares which produced 172.000 tons of green forage of cowpea, while South Darfur cultivated an area of about 420 ha, which produced 13350 tons of forage (FMLFR, 2016). The uses of cowpea in Darfur are various; the immature pods can be boiled with water and salt and eaten as (ballila), and also the seed can be boiled with water, oil, salt and sugar and eaten as (ballila) during the holy month of rammdan). They can also be cooked with meat, oil, onion, and other ingredients into a thick soup called (Barbur) and eaten with (asseda and kisraa) or bread, the seed can be softened by soaking in water, crushed and made into small balls that are tried in oil to be eaten with bread and this is called (Tammia). In Darfur cowpea is mostly used for making tammia. Nutritionally cowpea seeds contain between 20- 24 % protein, 63.3 % carbohydrates at maturity stage. Also, the forage contains 13.8% crude protein, 9.8 % ash, 36.2 % crude fiber and 38.2 NFE (Kearl *at el.* 1979).

1.2 Statement of the problem

At present the balance between the feed needed by animals and the feed available in South Darfur State is poorly known, and it was noticed that the present number of animals need more forage than the rangeland is offering. Therefore, with the prevailing livestock grazing systems, the negative impact on the rangeland and the environment, is expected to continue. This may be reflected in severe deterioration in both quality and quantity of rangelands and consequently reduced livestock production.

1.3 Justification

Inadequate forage production from rangelands and acute scarcity particularly during the dry season is impacting livestock production in South Darfur. The situation is aggravated by low nutritional value manifested in reduced dry matter digestibility and low crude protein content apart from other important nutrients. These limitations have to be mitigated in order to enhance livestock production. However, it is very difficult to have good quantity and quality of forage under open rangeland, so there is a need to cultivate high quality forage legumes such as cowpea in farms to obtain good quality forage under control in the farm. Cowpea is a crop that is grown by a large number of farmers in South Darfur. It is a dual-purpose plant producing pods for human consumption and high value forage for livestock. It thus requires studying the best cultural practices that produce highest yields.

1.4 Objectives

The general objective is to test cowpea performance with regard to forage and seed production under rain fed conditions of low rainfall savannah of South Darfur State.
The specific objective is to test the effect of planting cowpea under different treatments of intra-row spacing on forage and seed production.

1.5 Research Questions

What is the optimum intra-row spacing for forage and seed production from cowpea?
Which are the best growth stages for harvesting cowpea for forage yield and quality for feeding animals?
How much a local cultivar yields and what is the quality of the product?

CHAPTER II

Literature Review

2.1 Introduction

Cowpea (*Vigna unguiculata* L.Walp) is a food and animal feed crop grown in the semi-arid tropics covering Africa, Asia, Europe, the United States and central and south America. It originated and was domesticated in southern African and was later moved to East and West Africa and Asia. Moreover, more than 12.5million hectares are harvested worldwide, 98% of which is in African. Nigeria harvest 3.7million hectares annually. Further than 7.4 million tons of dried cowpeas are produced worldwide (2017), with Africa producing about 7.1million. Nigeria largest producer and consumer, Fifty-two percent of Africa production is used for food, 13%as animal feed, 10% for seeds, 9%for other uses, and 16%is wasted (IITA). It is a mandated crop identified by the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. On other hand, was estimated that Africa cultivated 12.3 million hectares of cowpea, amounting to 94% of total amount (CGIAR, 2018). The international cowpea area harvested was 12.316 million hectares which produced about 6.99 million tons (FAO, 2014). About 52% of Africa’s production is used for food, 13% as animal feed, 10% for seeds, 9% for other uses and 16% wasted. Nigeria is the largest producer and consumer of cowpea, producing 5.5 million ton of grain, followed by Niger, Burkina Faso, Tanzania, Myanmar, Mali, Cameron, Sudan, Mozambique and Kenya (FAO, 2016). The average global yield is estimated at 450 kg per hectare, the lowest of the major tropical grain legume. In 2016, productivity of cowpea forage ranged between 2.5 - 4 tones/ha around Nyala for demonstration farm area (CIDA, 2016).

2.2 Cowpea:

Cowpea *(Vigna unguiculata* L. Walp.) is a leguminous crop, which has been traditionally grown throughout the tropics and sub tropics. The young leaves and immature pods are eaten as vegetables. As cultivated land becomes limited and fertilizer prices continue to rise and the demand for food continue to increase, animal feed must be met by enhancing the productivity of the land already under cultivation. Legumes are the most important forage plants that can substantially improve the feed available for livestock as they can provide the essential protein for animals. They also improve soil fertility, food crop production and household nutrition through a more reliable supply of milk and meat. This crop can fix about 240 kg/ha of atmospheric nitrogen of which about 60-70 kg/ ha of nitrogen for remain succeeding crops grown in the rotation (CRI,2006; Aikins & Afuakwa, 2008)). Cowpea is a rapid growing cover crop that produces 2,500–4,500 lb/acre/yr of dry matter, while providing 100–150 lb/acre of N to the following crop (Clark, 2007). Moreover, cowpea produces significant amounts of nitrogen from the atmosphere and may be fixing 75-150kg N/ha for its benefit and the ensuing crop (Holland et al, 1991; (Mugendi et al, 2001).

In Sudan, cowpea is popularly grown under rain fed conditions in Kordofan and Darfur, where the rainfall ranges between 300- 500 mm (El Naim, 2010). On the other hand, in North Darfur where rainfall is about 250mm early maturing varieties of cowpea are grown, while in South Darfur State with a rainfall of 400-1000mm late maturing varieties are grown for seed production (NAPA 2010). Only very small scattered batches had been grown under irrigation in the northern Sudan. Cowpea also plays a significant role in providing soil nitrogen to cereal crops such as maize, millet and sorghum when grown in rotation, especially in areas where poor soil fertility is a problem. Its roots have nodules in which symbiotic soil bacteria called rhizobia help to fix nitrogen from the air. Cowpea can be used as a feed (grazed or harvested for fodder), or its pods can be harvested before maturity stage providing complementary proteins to cereals in some different dishes.

2.3 Importance of Cowpea

Cowpea is of major importance to the livelihoods of millions of people in the tropics. Resource-poor small-holder farmers derive food, animal feed, cash and manure from the crop. Dual purpose cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing nitrogen into the farming system through biological fixation. Dried leaves are preserved and eaten as a meat substitute.

Cowpea can be regarded as a point of sustainable farming in regions characterized by systems of farming that make limited use of purchased inputs. It provides fodder for livestock especially during the significant period of the dry season, and fertilization and replenishment of the soil through nitrogen fixation, which will ensure sustainable use of the farmer’s limited land (for a longer period without much depletion of its nutrients).

Cowpea is also grown as a dual-purpose crop the green pods used as a vegetable and the remaining parts as livestock fodder. It is very palatable, highly nutritious and relatively free of metabolites or other toxins. In West Africa where cowpea is very popular and is a staple food, utilization in family menus has advanced. In Nigeria, cowpea paste can be boiled or fried to produce a popular meal known as (Moinmoin) that is served with rice during celebration; and Akara, a dish served for breakfast. On the other hand, South Africa developed advanced food technology compared to West Africa countries where the cowpea utilization is poor because production is still in the hands of smallholder farmers.

Cowpea grain and fodder yields are very low in west Africa and Sudan, the main problems limiting production and expansion of cowpea as pointed out by El Naim et al. (2010a) and El (Naim et al. 2012) are: low yield potential of existing cultivars, low planting density of cowpea and narrow use of certified seeds by the cowpea farmers, mainly due to lack of marketing and failure to chance farmers, about the advantages of planting certified seeds as opposed to their own seeds.

The research so far focused on detecting the suitable varieties, plants per stand and evaluation of the performance of the variety in the rain-fed conditions.

2.4 Origin and Distribution:

Archaeological facts have resulted in contradicting views supporting Africa. Some literature reports that cowpea was introduced from Africa to India subcontinent approximately 2000 to 3500 years ago, at the same time as the introduction of sorghum and millet, while others state that before 300 BC cowpea had reached Europe and may be North Africa from Asia, due to the presence there of most original natural varieties. The Northern part of the Republic of South Africa (previous Transvaal region) was the estimation center of original of *Vigna unguiculata*. They further hypothesized that the species moved northwards from the Transvaal to Mozambique and Tanzania. Cowpea was grown throughout the tropics and subtropics and has become a part of the consumption of about 110 million people. Cowpea is believed to have originated from West Africa by some workers, as both wild and cultivated species are found in the region. Others think that, it originated from Southern Africa. Its production has distributed to East and central Africa, India, Asia South and Central America.

2.5 Climatic Requirements:

2.5.1 Temperature:

Cowpea grows best during summer. The lowest temperature for germination is 8.5 C̊ and for leaf growth 20 C̊. Cowpea is a warmth tolerance and drought tolerant crop. The optimum temperature for growth and development is around 30∘ C. Varieties differ in their response to day, some being insensitive and flowering within 30 days (FAO, 2005). The time of flowering of photosensitive varieties is dependent on time and location of sowing and may be more than 100 days. Even in early flowering varieties, the flowering period can be extended by warm and wet conditions, leading to maturity. The optimum sowing times are July to November in South Nyala. Early sown crops tend to have lengthened internodes, are less erect, have more vegetation and a lower yield than those sown at the optimum time (Craufurd et al.1996). The presence of nodular bacteria Bradyrhizobium spp make cowpea suitable for cultivation in hot marginal cropping areas of West Africa as well as in the cooler higher rainfall areas. However, cowpea is much less tolerant to freezing conditions.

2.5.2 Water Requirements:.

The early maturing varieties require high rainfall of up to 400 mm per year, those grown for seed have a critical period of high moisture requirement at flowering stage (Holland et al. 1991), while those cultivated for forage production prevail in areas of rainfall ranging between 750-1000 mm per annum (Khair, 1999). Fluctuation in rainfall affected negatively on cowpea growth in West Africa. Cowpeas utilize soil moisture efficiently and are more drought-tolerant than other crops such as groundnuts, soya beans and sunflower which require higher annual rainfall. Adequate rainfall is important during the flowering stage.

2.5.3 Soil Requirements:

Cowpeas are grown on a wide range of soils but the crop shows a preference for sandy soils, which tend to be less restrictive on root growth.. This adaptation to lighter soils is joined with drought tolerance through reduced leaf movement to decrease light and heat load under stress. Cowpeas succeed in well-drained soil and less so on heavy soils. It requires a soil pH of between 5 and 60pH.

2.6 Botanical Description:

Cowpea is an annual herb with variation in growth form. It may be erect, trailing or climbing. It has a strong taproot, the first pair of leaves is basic and opposite, while the rest are arranged in an exchange pattern and are trifoliate. The leaves are usually dark green in color; the leaf petiole is 5 to 25cm long. The stems are striate or slightly hairy with some purple shades. Flowers are racemose usually only two to a few flowers per inflorescence. The corollas may be pink, white, pale blue, dirty yellow or purple in color. Seeds differ significantly in size, shape and color and weigh 5 to 30 g/100 seeds. The coat color of seed may be smooth or wrinkled; with white, green, buff, red, brown, black, speckled, blotched, eyed (haulm white, surrounded by a dark ring) or mottled color.

2.7 Cultural practices:

2.7.1 Sowing date:

The date of planting is one of the most significant factors determining seed and forage yield of cowpea; however, cowpea planted in the period from March to October under irrigation condition such as Gazeir compared with earlier sowing gave higher yield depending on environmental conditions in the region (Khair,1999).

2.7.2 Spacing and seed rate:

Spacing is an important factor affecting the growth and yield of cowpea. Wide spacing of crop reduces competition among plants for soil moisture, nutrients, light and carbon dioxide for forage production. Abu Suwar (2005) stated that, seeds of Clitoria ternatea should be sown in holes on rows, with a distance of 15cm between holes and 80cm between rows under irrigation. Under rain-fed conditions in Kordofan state (El Naim 2010) recommended 50cm along rows. On the other hand, Alpha (2016) found that cowpea plant population of 266 666 plant /ha permit optimal seed and fodder yield when planting in double row spaced on ridges 75cm apart. Three seeds are planted at 20cm along ridges spaced 75cm apart (20×75cm) demonstrating 133 000 plants/ha for erect/semi-erect varieties and (50×75cm) or 60,000 plants/ha but thinned to two seedlings per hill, one week after germination. Seed rates range from 25kg to 30kg of good seed per hectare in experimental stations. Commercial seeding rates would depend on plant spacing (AFF, 2011).

The recommenced cowpea spacing is 75×20 with two seeds planted per stand . From the results obtained, it can be concluded that, if the crop is grown for seed yield, high plant population (12 plants m^2) is recommended in North Kordofan State. El Naim (2010) reported that, intra-row spacing of 50 cm is recommended in cultivation of cowpea in North Kordofan of Sudan for maximum grain yield production. Likewise, (Malami et al, 2012) noted that, wider inter-row spacing of 100cm produced the highest dry matter with *Vigna unguiculata* L. Walp Variety Kanannado in the semi-arid region of North-West

Nigeria. Furthermore, Jakusko (2013) found that increasing spacing from 45×35cm to 75×25cm significantly increased number of pods per plant. Also yield increased with decrease in row spacing and due to that a closer spacing of 45×25cm was suggested. However, during maturity at the end of rainy season 45×30cm produced a fewer number of pods per plant compared to 60×30cm and 75×30cm row spacing as number of pods increased with increased plant density. Plants produced fewer numbers of pods at highest densities than those at the lowest densities. Planting density of 56000 plants /ha however, seems to be generally suitable for all the three cultivars tested in terms of forage production and should be recommended for smallholders (Sithomol et 2011).

2.8 Chemical composition:

Cowpea seed contains (20 -24 %) protein, 63.3 % carbohydrates and 1.9 % fat (Davis, 1991). Furthermore, Suliman and Mabrouk (1999) assessed the chemical composition of cowpea seed under Sudan conditions and reported 400g/kg dry matter, 80.2 g/kg crude protein and 132.8g/kg crude fiber. Cowpea makes quite good hay but care must be taken to maintain the leaves. The stem takes some time to dry and should be conditioned for be quick drying.

On the other hand, Kearl (1982) stated that chemical analysis of dry cowpea leaves dry matter consists of (EE 2.9%, NFE 30.4%, CF 30.0%, Ash 12.4% and CP 24.4%; while seed of cowpea contains (2.15% EE, 60.0% NFE, 5.7% CF, 5.9% Ash and 26.3% CP). In contrast, cowpea hay demonstrated different percentages of forage quality including (1.8%, 38.8%, 33.0%, 11.8% and 14.7%, EE, NFE, CF, Ash and CP, respectively. Other reports stated that the seed contains 24% crude protein, 53% carbohydrates, and 2% fat (FAO, 2012). Also, Tarawali et al. (1997) and Relwani (1970) recommended use of cowpea in combination with cereals and other crops in an intensive scheme for lactating cows to maintain milk yield of >5 l/cow/ day. Tarawali et al. (1997) also found that crude protein content in analyzed seeds and leaves ranges from 22 to 30% on a dry weight basis. Trials of varieties of cowpea in India, gave dry matter yield of > 4 t/ha with crude protein contents of up to 26 % (Ralwani et al. 1970). In Pakistan, the cowpea recommended for forage recorded dry mater yield of 5.7 t/ha for the best variety .The seed was reported to contain 24% crude protein, 53% carbohydrate and 2%fat (FOA, 2012).

2.9 Effect of intra-row spacing on growth parameters of cowpea :

Intra-row and inter-row spacings are important factors dominating the plant density, and finally crop production. Thus, the effect of plant density on yield needs suitable controlling and organizing practices. Spacing trails in a number of countries, have usually presented varying differences in production within different plant species the results of experiments in Sudan and other parts of the world reported that, closer intra-row spacing of plants produced the highest yield (Lazim, 1972; Khair, 1999; El Awad, 2004 and El Naim 2010 a).

2.9.1 Plant cover percentage

Plant density has a significant effect on forage yield at vegetative and flowering stages of growth (Sithomola et al (2011). High plant density increases ground cover percentage while increased seed rate also increases plant cover as reported by Abdullah (2008). Omokanye (2003) observed that, plant mortality was nil for some varieties and ground cover was high for V.TVU12349 and Kananado with about 100% and 90% ground cover respectively compared with other varieties at early flowering stage.

2.9.2 Plant height(cm)

Plant height differed for both inter-row and intra- row spacing at seedling stage though no differences were found at the subsequent flowering stage (8 weeks). At the end of the experiment at maturity stage (12 weeks) inter and intra-row spacing of 50cm and 25cm produced the tallest plants (20.9 and 22.1cm)respectively, the mean plant height values recorded in this trial falls within the range of 15-80cm reported by Anon (2011). Futuless et al. (2010) reported a mean value of 25.1cm for cowpea. Increasing plant density decreased plant height in all samples. Increased plant height with increased inter-row and intra-row spacing, was also reported by Mohamed et al. (2002). In contrast, (El Naim, et al 2010 b) found that, increasing plant per stand decreased plant height. Malami (2012) reported that, the growth of cowpea is affected by a narrow spacing such as the plant height increased with decreased inter-row and intra row spacing.

2.9.3 Plant density

Plant population had insignificant effect on the time to flowering and maturity (El awad, 2004). Closer inter-row and intra-row spacing recorded highest counts, while wider inter-row and intra-row spacing recorded least counts of plants (Malmai,2012) High plant population at 12 plants / m^2 is recommended in North Kordofan State, Sudan (El Naim)

(2010b). The number of plants increased as the seeding rate increased (Abdullah, 2008). Also, Lehouerou (1981) noted the direct effect of rainfall fluctuation. Although seasonal distribution of rainfall and total amount of precipitation are most significant factors on plant density, Sithomol (2011) found that planting density of 56000 plants per hectare seems to be the most suitable for all cultivars of cowpea grown in terms of forage production and should be recommended for the smallholders.

2.9.4 Survival rate percentage:

The seed rate of other forage crops such as *(Clitoria ternatea*) had clear effect on plant survival rate of drought tolerant of plants. Abdullah (2008) and Abu Suwar (2005) found that, the lower seed rate had less survival rate compared to the higher one.

2.9.5 Dry matter, pods and seeds yield

Intra-row spacing of 50 cm was suggested in cultivation of cowpea in North Krodofan of Sudan for maximum grain yield production (Jaberaldar et al, 2010). On the other hand, increasing number of plants per stand significantly increased grain yield per unit area but reduced number of pods per plant, the local cultivar however, was late in maturity and had heavier weight and greater grain yield per plant (El Naim et al 2010). Joseph et al. (2014) showed that, the use of inter-row spacing of 60cm resulted in significantly less weed infestation and higher cowpea pod and grain yields than those of 75 and 90cm spacing .

Azzakh et al. (2012) reported that, seeding rate of 35 kg /fed with 30 cm row- spacing significantly increased all agronomic characters over all cuts and recorded 42.64 t/fed and 8.49 t/fed for total fresh and dry yield respectively. This was considered as the best recommended treatment for cowpea under increasing seeding rate as. The highest yield per unit area was produced from closer spacing. El Naim et al. (2012) noted that, the number of plants/stand had a significant effect on most of the attributes measured. Increased plants/stand significantly increased grain yield per unit area although it reduced the number of pods per plant. The local cultivar was late in maturity, had heavier weight, greater grain yield per plant and larger final grain yield (t/ha). Also, the Ein Elgazal cultivar was earlier in maturity and scored the highest values of yield indicator. Obuo et al. (2000) found that, the highest yield was obtained by inter-and intra-row spacing of 45×30cm with one plant per hill, compared to intra-row spacing of 75×30cm, are two plants per hole, Enyi (1969) stated that, the spacing of 90cm between rows gave a good grain yields, which the intra-row spacing of 30cm produced higher productivity than 90 and 60cm. Rima et al. (2013) reported that intra-row spacing significantly affected yield parameters,.Malami (2012) found that wider inter-row spacing of 100cm and intra-row spacing of 75cm increased dry matter yield, Likewise increasing seed rate led to a decrease in number of grains per pod, the widening of space of sowing cowpea resulted in greater dry matter yield than the close spacing (Grantz and Hull 1982). Jakusko (2013), stated that increasing spacing significantly increased pods and seed per plant, while the seed rate per plot was higher in narrow spacing. Intra-row spacing affected guar fresh and dry weight, dry matter yield increased with increased intra-row and inter-row spacing (Abdullah, ,2008). The seeding rates of 8kg/ha scored the highest dry matter yield compared with the other rates which recorded the lowest (Abdullah, 2008). Regarding the effect of plant density on fresh and dry yield, it was demonstrated that planting density of two plants per hole recorded significantly higher fresh and dry (11.17 and 1.95 ton/fed^{-1}) forage yield than planting density of one plant per hole which recorded (35000 plant/fed) and yielded 9.17 and 1.55 ton/ fed) respectively (Helmy 2013). Yield increased with decrease in row spacing which justified that closer spacing of 45cmx25cm should be adopted for the erect varieties (Jakusk 2009) and Hamad (2004) who found that increasing plant density decreased grain yield per plant. A decrease in number of grains per pod was associated with increasing seed rate. The higher yield was recorded with narrow spacing, while wide spacing produced least yield per plot and seed /ha (Jakusko 2009). Increasing plant density increased seed yield per unit area. The wider spacing produced higher number of pods per plant and heavier seeds by local varieties, (Lazim 1972).

2.9.6 Nodules number and weight

The planting density affected nodules number and weight. Increasing plant density increased number of nodules and weight per plant (Helmy 2015). Likewise, rising cowpea population from low to medium, increased plant density and led to a rise in number of nodules (Oroka 2010). The crop of cowpea can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60-70 kg ha^{-1} nitrogen for succeeding crops grown in rotation with it (Aikins and Afuakwa, 2008)). Cowpea fixed approximately 84Kg/ha of nitrogen when suitable Rhizobia are available with suitable efficiency (Khair 1999). On the other hand, cowpea produced a significant portion of total of nitrogen needs from the atmosphere and may fix 75-150kgN/ha for its benefit and the ensuing crop.

2.9.7 Soil moisture content

Intra-row spacing had a significant effect on soil moisture content whether cowpea is grown alone or intercropped with other crops. Abdullah (2008) found that, during July, at the depth of 40cm, the lowest soil moisture content was recorded by seed rate of 2Kg, and the highest soil moisture content by both seeding rate of 5Kg and 8Kg, while in September and November (2004), at depths of 20cm, 40cm and 60cm in November 2005, the seed rate of 2Kg scored the highest soil moisture content. *Clitoria ternatea* and *Macroptilium atropurpureum*)Some studies indicated that intra-row spacing of cowpea had no significant effect on soil moisture content. Archer et al. (1989) found that, the higher roots densities of narrower planting resulted in more rapid depletion of soil water content. Fultion et al. (1969**)** reported that, highest yield was obtained where high soil moisture level (minimum available soil moisture 25% at 40cm), were combined with high population. High plant population increased yield only where soil moisture levels were high. Zhou et al. (2010) found that, the soil moisture content decrease with evapotranspiration increase after reproductive growth stage.

CHAPTER III

Materials and Methods

3.1 Study area:

The experiment was conducted at Ori Jamily at locality of Belil at Abga ragil administrative site, 7 km south of Nyala town in South Darfur State, during the rainy seasons of (2013, 2014 and 2015). The experimental site lies at latitude 11̊.99' N and longitude 24̊.50' with altitude of 661meter ASL. The main idea of the experiment was to test cowpea performance with regard to forage and seed production under rain fed conditions of low rainfall savannah. A rain gauge was fixed at the experimental site, and the total annual rainfall was recorded during 2013/2014, 2014 /2015 and 2015 /2016 seasons. Before the implementation of the experiment five soil samples were taken randomly from different locations of the experimental site and chemical and physical properties of the soil were determined. The variety of cowpea was sourced from local market in Nyala. Purity and germination tests of cowpea (*Vigna unguiculata*) were performed at Nyala Research Station of the Agricultural Research Corporation (ARC), Sudan. Pure live seeds percentage was determined by using the formula of Krishnaswamy, (1990). Seeds were then sown at the rate of 4-5 seeds per hole and later thinned to 2-3 plants per hole after two weeks.

3.2 Land preparation and experimental design:

Figure 1: Land preparation and experimental design

The land of experimental site was prepared by traditional tools (donkey drawn plow).The land was divided into four plots with four replicates. The size of the plot was (8×5) m. Four spacing treatments of (*Vigna unguiculata*) were applied along the rows which included 50cm, 75cm, 100cm and 125cm. The treatments were arranged in randomized complete design (RCD) with four replicates. Cowpea was planted with fixed spacing between rows of 1m. Sowing date during 2013 was on 23rd of July, 2014 on 22nd of August and 2015 on 27th of August. At sowing five cowpea seeds were placed at each hole. At seedling stage the plants were thinned down to three plants per hole after four weeks from planting.

3.3 Parameters measured:

Figures 2: Soil moisture content assessment

The moisture content of soil (also referred to as water content) is an indicator of the amount of water present in soil. It is the ratio of the mass of water in a sample to the mass of solids in the sample, expressed as a percentage.

During the rainy seasons of 2013/ 2014, 2014/ 2015 and 2015/ 2016 random samples of soil were taken at three depths (20 cm, 40cm and 60cm) from each plot at seedling, flowering and maturity stages of growth for determination of soil moisture content. All soil moisture samples were weighed as wet and as dry and the percentage soil moisture content was determined.

3.3.2 Percent plant cover:

Figures 3: Plant covers percentage

The vegetation cover as defined is the relative area covered by plants inside a designated area .

A quadrate of (1×2) m^2 divided in to four quarters was placed randomly at each plot and fixed, and then the vegetation ground cover percentage was estimated visually at seedling, flowering and maturity stages in each time the visual estimate was done by the same person.

3.3.3 Plant density:

Figure 4: Plant density

Density in vegetation measurement refers to the number of individuals per unit area, for example number of plants/m^2. On the same fixed quadrate of (1×2m) plant density of cowpea was counted as number of plants/m^2 and recorded.

3.3.4 Plant height(cm):

Figure 5: Plant height measurement

The height of a plant is the perpendicular distance from the soil at its base to the highest point reached with all parts in their natural position.Within the same fixed quadrate of (1×2) m^2 that was located in each plot three plants were randomly selected and marked, and the cowpea plant height was measured at the three stages of growth namely seedling, flowering and maturity and the average plant height was recorded.

3.3.5 Determination of number and dry weight of nodules:

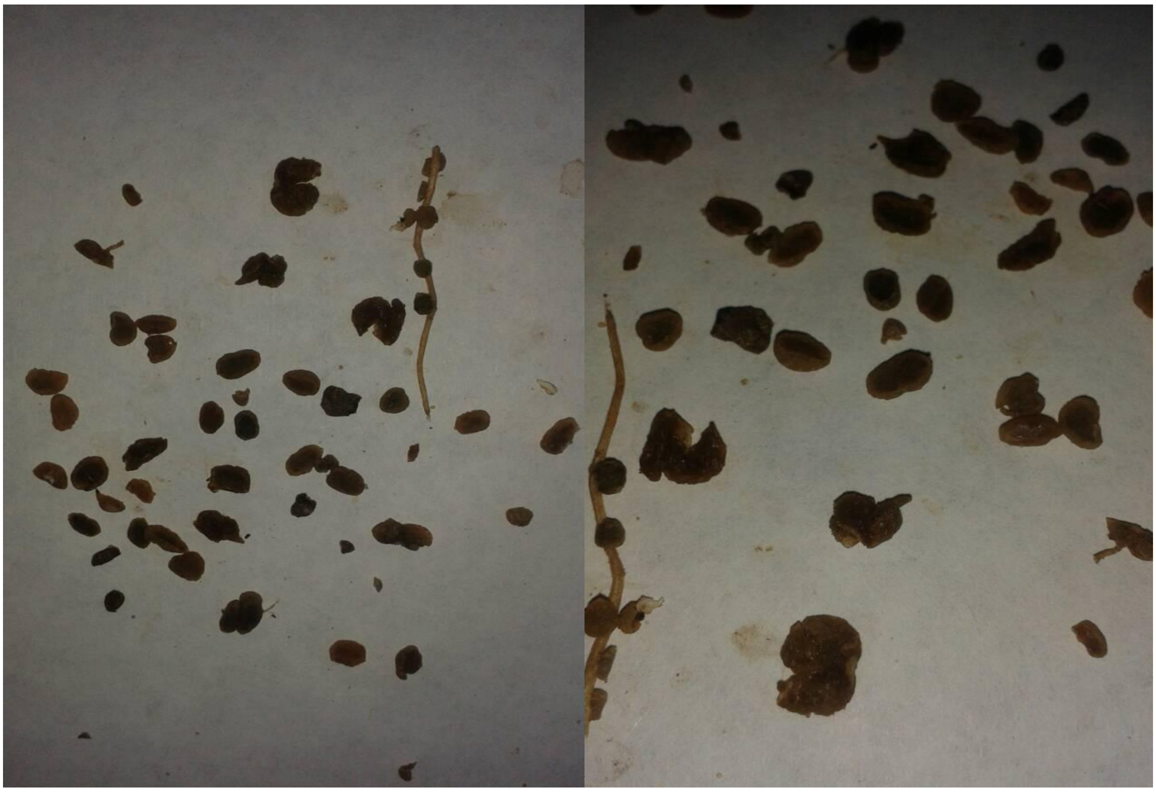

Figure 9: Nodule yield

Many legumes have root nodules which provide a home for symbiotic nitrogen-fixing bacteria called rhizobia. This relationship is particularly common in nitrogen-limited conditions. The Rhizobia convert nitrogen gas from the atmosphere into ammonia, which is then used in the formation of amino acids and nucleotides. Nitrogen fixation by legumes is thus a partnership between a bacterium and a plant (Lindemann, 1990). Plant samples were randomly taken from each plot after seven weeks post sowing separated into shoots and roots and soil was carefully washed from the roots. The numbers of nodules were recorded for each treatment, oven dried at 72 C̊ to constant weight and weighed for nodule dry weight determination .

3.3.6 Dry matter yield:

A quadrate of (1x2m^2) was randomly located within each plot, at flowering and maturity stages. Cowpea forage sample from each quadrate from each plot was clipped at (5 cm) above ground surface and then put inside paper bags and was weighed as fresh and then put inside an oven at 72C̊ for 72 hours and weighed as dry. Dry matter yield was determined in kg/ha.

At maturity stage a quadrate was randomly located within each plot and pods were collected, air dried, weighed and the seeds yield was determined in kg/ha.

3.3..7 Pods and seed yield:

Figure 8: Pods and seeds

Pods were collected from an area of (1x2) m^2 and number of pods determined. Pods were put inside paper bags, air dried, cleaned and seeds weighed.

3.3..8 Chemical compositions:

Proximate analysis is a system for estimating the chemical composition of a feed or material for feeding purposes. The principle of the analysis is to separate the feed components into moisture, ash, crude fiber, crude protein, ether extract and nitrogen free extract.

At flowering and at maturity stages of growth samples were obtained from the middle of each plot for yield estimation. Samples were air dried and chemical analysis was done for dry matter% (DM), crude protein% (CP), crude fiber % (CF), Fat% and ash (AOAC 1990). Moreover, neutral detergent fiber, (NDF%), acid detergent fiber% (ADF) and acid detergent lignin% (ADL) were determined using Van Soest (1981) methods that separate cellulose and hemicellulose in the fiber component from lignin. Kjeldahl method was used to determine the total nitrogen content which was multiplied by 6.25 to obtain crude protein.

CHAPTER IV

Results

4.1 Effect of different intra-row spacing of cowpea *(Vigna unguiculata*) on growth parameters and yield

4.1.1 Plant density:

The effect of intra-row spacing on plant density of forage cowpea is demonstrated in table (1). There were significant differences at ($P<0.05$), between closer and wider intra-row spacing in all three stages of growth. The 50cm intra-row spacing produced the highest density at all growth stages, the seedling stage recorded the highest density (13 plants/m^2), followed by flowering stage (11plants/m^2) and maturity stage (10 plants / m^2). In addition, the lowest density was obtained when intra-row spacing was 125cm at all stages, seedling stage scored (6 plants/m^2), while flowering and maturity stages recorded (4 plants m^2/).

Table (1) Effect of intra-row spacing of cowpea on plant density (Plant/m^2)

Spacing	**Plant density (Mean of three seasons)**		
	Seedling stage	**Flowering stage**	**Maturity stage**
50cm	13.0	11.0	10.0
75cm	12.0	7.7	7.7
100cm	7.7	6.3	5.7
125cm	6.0	4.3	4.0
Mean	**9.8**	**7.2**	**7.0**
SE±	1. 68	1. 46	1. 09
Pro>f	0.001**		
LSD	**2.3**		
CV%	34.5	40.5	31.0

** Highly significantly different at the 0.05 level of probability according to least significant difference.

4.1.2 Plant cover (%):

Results of plant cover are shown in table (2). There were significant differences between treatments in plant cover % at ($P<0.05$) which decreased with increased intra-row spacing at all growth stages. At seedling stage, the 50cm intra-row spacing recorded the highest plant cover% (73.4%), followed by intra-row the 75cm intra-row spacing (62.5%) followed by 125cm (55.5%) while intra-row spacing 100cm recorded (53.4%). During flowering stage, the 50cm intra-row gave highest cover% (80.4%), followed by 75cm intra-row spacing (79.6%), while the widest intra-row spacing of 125cm gave lowest cover (61.7%). At maturity stage however, the 50cm intra-row spacing recorded 77.5%, followed by intra-row spacing of 100cm (74.6%), while 125cm gave (65.4%). Overall, results indicated that the highest plant cover was attained by intra-row spacing of 50cm at flowering stage, while the lowest plant cover was associated with intra-row spacing of 100cm at seedling stage.

Table (2) Effect of intra-row spacing of cowpea on plant cover (%)

Spacing	**Plant cover (Mean of three seasons)**		
	Seedling	**Flowering**	**Maturity**
50cm	73.4	80.4	77.5
75cm	62.5	79.6	68.4
100cm	53.4	79.2	74.6
125cm	55.5	61.7	65.4
Mean	**61.2**	**75.2**	**71.5**
SE±	4. 51	4. 52	2. 78
Pro>f	0.001**		
LSD	**8.3**		
CV%	14.7	12.0	7.8

** Highly significantly different at the 0.05 level of probability according to least significant difference

4.1.3 Plant height (cm):

Different treatments of intra-row spacing of cowpea planting are represented in table (3). No significant differences between treatments were observed on plant height during the three growth stages. At the seedling stage the highest plant height was obtained by the treatment of 125cm spacing which recorded (61.1cm), followed by intra-row spacing of 100cm (57.4cm), while the lowest plant height was recorded by the treatment of 50cm spacing (43.2cm). At flowering stage, the treatment of 125cm recorded the highest plant height (149.2cm), and then intra-row spacing of 100cm (132.9cm), while the treatment of intra-row spacing of 75cm obtained the lowest plant height recorded (114.0cm). At the maturity stage, the treatment of intra-row spacing of 125 cm resulted in the highest plant height (163.9cm), followed by intra-row spacing of 100cm (154.5cm), while intra-row spacing of 75cm showed the lowest height (133.2cm). In summary, the greatest plant height was recorded by intra-row spacing of 125cm at maturity stage, while the lowest plant height was scored by intra-row spacing of 50cm at seedling stage.

Table (3) Effect of intra-row spacing of cowpea on plant height (cm)

Spacing	**Plant height (Mean of three seasons)**		
	Seedling	**Flowering**	**Maturity**
50cm	43.2	122.8	144.5
75cm	51.9	114.0	133.2
100cm	57.4	132.9	154.5
125cm	61.1	149.2	163.9
Mean	**53.4**	**129.7**	**149.0**
SE±	3.89*	7. 56*	6. 60*
Pro>f	0.8NS		
LSD	**17.14**		
CV%	14.6	11.6	8.9

NS Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.4 Plant survival rate (%)

The different treatments of intra-row spacing of cowpea planting had insignificant effect on plant survival rate % during all three growth stages. These are shown in table (4). At the flowering stage the highest plant survival rate was obtained by the treatment of 100cm intra-row spacing which recorded (80.4%), followed by intra-row spacing of 50cm, while the lowest plant survival rate was recorded by the treatment of 125cm intra-row spacing which was (65.8%). At maturity stage, the treatment of 50cm intra-row spacing record the highest plant survival rate (69.8%), while a slightly lower survival rate was observed with intra-row spacing of 100cm and 75cm (67.9%) and (51.7%) respectively. The overall, highest survival rate was obtained by intra-row spacing of 100cm at flowering stage, while the lowest plant survival rate was recorded by intra-row spacing of 75cm at maturity stage. However, there is no difference.

Table (4) Effect of intra-row spacing of cowpea on plant survival rate (%)

Spacing	**Plant survival rate (Mean of three seasons)**	
	Flowering	**Maturity**
50cm	77.5	69.8
75cm	69.7	51.7
100cm	85.4	67.9
125cm	65.8	57.8
Mean	**74.6**	**61.8**
SE±	3. 77	4. 28
Pro>f	0.2	
LSD	**45.3**	
CV%	10.1	13.8

Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.5 Fresh yield (ton/ha):

Different treatments of intra-row spacing of cowpea planting had insignificant differences ($p>0.05$) on fresh forage yield at all growth stages (Table 4). At the flowering stage the highest fresh yield was obtained by the treatment of 100cm intra-row spacing which recorded (7.9 ton/ha), followed by intra-row spacing of 50cm (7.2ton/ha), while the lowest fresh yield was scored by the treatment of 75cm intra-row spacing (5.6 ton/ha). At maturity stage, the treatment of 125cm intra-row spacing recorded the highest fresh forage yield at (4.9ton/ha), followed by intra-row spacing of 50cm at (4.3ton/ha), while the treatment of intra-row spacing of 75cm obtained the lowest fresh forage yield at (3.3ton/ha). The combined analysis for growth stages showed that the highest fresh yield was scored by intra-row spacing of 100cm at flowering stage, while the lowest fresh yield by intra-row spacing of 75cm at maturity stage.

Table (5) Effect of intra-row spacing of cowpea on fresh forage yield (ton/ha)

Spacing	Fresh forage yield (Mean of three seasons)	
	Flowering	**Maturity**
50cm	7.2	4.3
75cm	5.6	3.3
100cm	7.9	3.9
125cm	6.3	4.9
Mean	**6.8**	**4.1**
SE±	0.51	0.34
Pro>f	0.08	
LSD	**7.0**	
CV%	14.9	16.4

4.1.5 Effect of intra-row spacing on dry matter forage yield (ton/ha):

Different treatments of intra-row spacing of cowpea had insignificant (p >0.5) effect on dry matter yield during both flowering and maturity growth stages, (Table 5). At the flowering stage the highest (dry oven) dry yield was obtained by the treatment of 125cm intra-row spacing which recorded (2.2ton/ha), followed by intra-row spacing of (50cm and 100cm) at the same level reaching (1.9ton/ha), while the lowest dry yield was scored by the treatment of 75cm intra-row spacing producing (1.7ton/ha). At maturity stage, the treatment of 125cm,100cm and 50cm intra-row spacing recorded the highest dry yield which was (1.4ton/ha) at the same level, while the treatment of intra-row spacing of 75cm obtained the lowest dry yield s at (1.3ton/ha). In summary, the table describes dry yield during growth stages and the highest dry yield was scored by intra-row spacing of 125cm at flowering stage, while the lowest dry yield by intra-row spacing of 75cm at maturity stage.

Table (6) Effect of intra-row spacing of cowpea on dry matter yield (ton/ha)

Spacing	Means of three seasons	
	Flowering	**Maturity**
50cm	1.9	1.4
75cm	1.7	1.3
100cm	1.9	1.4
125cm	2.2	1.4
Mean	**1.9**	**1.3**
SE±	0.10	0.05
Pro>f	0.3NS	
LSD	**1.22**	
CV%	10.9	7.7

Not significant difference at the 0.05 level of probability according to least significant difference**.**

4.1.7 Pods yield:

The four different intra-row spacing treatments of cowpea showed no significant differences (P >0.05) on pod yield during maturity stage, as illustrated in table (7). The highest pods yield per plant was recorded by intra-row spacing of 100cm (19.3g/plant), followed by intra-row spacing of 75cm which was (17.3g/plant), while the intra-row spacing of 50cm, gave the lowest score (14.7g/ plant). When measured as yield per square meter, the intra-row spacing of 100cm, resulted in the highest pods yield recording (52.3g/plant), the intra-row spacing of 125cm and 50cm scored (51.7g/m^2 comment: 50 cm scored 50.0 g/m^2 not 51.7) and (50g/m^2) respectively. In summary, the highest yield of pods was scored by intra-row spacing of 100cm (per plant and per m^2), while least pods weight was recorded by intra-row spacing of 75cm.

Table (7) Effect of intra-row spacing of cowpea on pods yield (g)

Spacing	Mean of three seasons	
	Pods per plant	**Pod per/m^2**
50cm	14.7	50.0
75cm	17.3	48.3
100cm	19.3	52.3
125cm	16.7	51.7
Mean	**17.0**	**50.6**
SE±	0.95	0.83
Pro>f	0.8NS	
LSD	**8.3**	**18.6**
CV%	11.1	3.3

Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.8 Seed yield:

The different intra-rows spacing treatments of cowpea *(Vigna unguiculata* L.Walp) had no significant effects on seeds yield during harvest (Table 8).The intra- row spacing 100cm produced the highest seed yield (74.5g/plant), followed by intra-row spacing of 125cm (72.9g/plant), while the intra- row spacing of 50cm produced lowest seeds yield (66.2g/plant). Seed yield per square meter was highest with the intra- row spacing of 50cm which gave (117.4g/m^2), followed by the intra- row spacing of 100cm (116.8g/m^2) while the intra-row spacing of 75cm was lowest recording (107.2g/m^2) and spacing of 125cm yielded 110.4 g/m^2. Overall, the table illustrated that, the highest seed yield per metre square was recorded by intra-row spacing of 50cm, while the lowest yield was recorded by intra-row spacing of 75cm in terms seed weight per plant.

Table (8) Effect of intra-row spacing of cowpea on seed yield (g)

Spacing	Mean of three seasons	
	Seeds per plant(g)	**Seeds (g)/m^2**
50cm	66.2	117.4
75cm	66.3	107.2
100cm	74.5	116.8
125cm	72.9	110.4
Mean	**69.7**	**112.9**
SE±	2.18	2. 49
Pro>f	0.8NS	
LSD	21.7	44.3
CV%	6.3	4.3

Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.9 Nodules yield (Number/plant and weight in g/plant)

Different intra -row spacing treatments of cowpea had no significant effect on nodules number and nodule weight during the flowering stage (Table 9). Intra-row spacing of 75cm produced the highest number (71.3 nodules/plant), followed by intra-row spacing of 50cm (67.0 nodules/plant),while the lowest number of nodules was produced by intra-row spacing of 100cm (49.7 nodules/plant).On the other hand, the weight of fresh nodules, recorded the highest value in case of intra-row spacing of 100cm (1.3g/plant),while intra-row spacing of 50cm and 75cm gave the lowest weight (0.66g/plant and 0.50g/plant respectively). Finally, the dry weight of nodules was highest with intra-row spacing of 75cm (71.3nodules/plant), followed by intra-row spacing of 50cm and 125cm (67nodules/plant, 56.3nodules/plant) respectively, while the intra-row spacing of 100cm gave the lowest yield recording 49.7 nodules /plant.

Table (9) Effect of intra-row spacing of cowpea on nodules yield (number per plant and g/plant)

Spacing	Mean of three seasons		
	Number of nodules/plants	**Fresh weight (g/plant)**	**Dry weight (g/plant)**
50cm	67.0	0.66	0.33
75cm	71.3	0.50	0.47
100cm	49.7	1.3	0.53
125cm	56.3	0.73	0.47
Mean	**61.1**	**0.79**	**0.45**
SE±	4.93 ^{ns}	0. 18 ^{ns}	0. 04 ^{ns}
LSD	41.7	0.8	0.49
CV%	16.1	44.3	16.2

Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.10 Soil moisture content (%):

Soil moisture content showed no significant differences at the three different depths of 20cm, 40cm and 60cm. Analysis of difference, table (9), revealed that, those were no significant at (P≤0.05) during seedling, flowering and maturity. At seedling stage, the highest percent of soil moisture content for intra-row spacing of 100cm was (7.7%) at depth 60cm, followed by intra-row of 50cm amount (6.2%) at depth (60cm), while the a lowest for intra-row spacing of 50cm was (3.6%) at depth (20cm). At flowering stage, the highest percentage of soil moisture content at depth of 60cm (7.0%) for intra-row spacing of 75cm was .4.0%), Soil moisture was much less for intra-row spacing of 125cm and 50cm, which recorded (3.9%) and (1.4%) at depths of 60cm and 20cm respectively. At maturity stage, at depth of 60cm, the highest soil moisture content was obtained by intra-row spacing of 75cm, followed by intra-row spacing of 100 and 50cm. At depth of 40 cm the highest moisture content was obtained by 50 and 75 cm spacing. (3.5%). while at the depth of 20 cm the 50 cm intra-row spacing resulted in the highest soil moisture content (2.8%) followed by the 75 cm intra-row spacing (2.3%), overall, the highest soil moisture content was recorded by intra-row spacing of 100cm at seedling stage in depth (60cm), while the lowest by intra-row spacing of 50cm at flowering stage in depth 20cm.

Table (10) Effect of intra-row spacing of cowpea on soil moisture content (%) at three depths

Spacing	Soil moisture (%) Mean of three seasons								
	Seedling			Flowering			Maturity		
	20cm	40cm	60cm	20cm	40cm	60cm	20cm	40cm	60cm
50cm	3.6	5.3	6.2	1.4	2.6	2.7	2.8	3.5	3.1
75cm	4.0	4.7	4.6	1.7	3.0	4.0	2.3	3.5	4.2
100cm	4.9	5.9	7.7	2.2	3.3	3.6	1.7	3.4	3.5
125cm	4.9	5.4	5.3	2.0	2.2	3.9	1.9	3.3	2.9
Mean	**4.4**	**5.3**	**5.9**	**1.8**	**2.8**	**3.6**	**2.2**	**3.4**	**3.4**
SE±	0.33*	0.25*	0.8 0*	0.18	0.24	0.3 7	0.21	0.05	0.287
Pro>f	0.5NS	0.08NS	0.07NS	0.5NS	0.08NS	0.07NS	0.5NS	0.08NS	0.07NS
LSD	**1.03**								
CV%	14.9	9.2	22.7	19.5	17.1	16.5	19.5	5.0	16.9

Not significantly different at the 0.05 level of probability according to least significant difference**.**

4.1.11 Effect of growth stage on forage quality:

Cowpea forage nutrititive value in terms of dry matter, fat, crude protein content, crude fiber, ash, NFE, ME, NDF, ADF and ADL is shown in table 11. Earlier growth stages resulted in relatively higher crude protein and metabolizable energy contents and lowered fiber percentage.

Table (11) Chemical analysis of cowpea plant at flowering and at maturity stages

Stage	DM%	Fat%	CP%	CF%	Ash%	NFE%	ME MJ/kg DM	NDF%	ADF%	ADL%
Flowering	92.78	2.47	14.15	16.5	6.15	36.48	10.81	22.34	13.48	3.22
Maturity	93.63	1.11	10.93	35.42	9.69	53.84	8.73	34.92	31.68	8.84

The tables (11) describe information about chemical composition at two growth stages of flowering and maturity of cowpea forage. Crude protein decreased by 3.2 percentage units from flowering to maturity. It is well known that crude protein content decreases with advance in plant age (Khair, 1999). Crude fiber, neutral detergent fiber, acid detergent fiber and acid detergent lignin all increased with plant maturity. For example, acid detergent lignin increased by 5.62 percentage units from 3.22 % to 8.84%. Cell wall constituents usually increase with plant maturity (Van Soest, 1994). Moreover, Metabolizable energy decreased by 2-08 MJ/kg DM from 10.81 to 8.73 MJ/kg DM.

Table (12) Chemical composition of different plant parts of cowpea at flowering stage

Plant	DM%	Fat%	CP%	CF%	Ash%	NFE%	ME MJ/kg DM	NDF%	ADF%	ADL%
Leaves	92.02	5.94	17.27	16.15	15.95	25.22	8.33	22.34	26.04	4.63
Leaves& stems	93.05	0.275	13.56	35.42	9.19	55.37	9.11	35.56	28.04	7.33
Seeds& pods	92.65	0.51	17.78	13.92	5.18	36.48	10.68	30.68	13.48	3.32
All plant	93.63	1.11	10.93	23.04	9.69	42.95	8.73	36.12	32.2	3.22

Table (13) Chemical composition of cowpea plant parts at maturity stage

Parts of plant	DM%	Fat%	CP%	CF%	Ash%	NFE%	ME MJ/kg DM	NDF%	ADF%	ADL%
Leaves	92.85	6.25	11.59	28.23	12.78	42.85	8.33	40.16	35.15	4.99
Leaves& stems	93.06	0.51	12.53	35.42	9.14	54.03	10.67	47.04	38.98	8.03
Seeds& pods	92.99	11.27	16.76	15.24	5.9	34.40	10.15	50.18	41.81	8.34
All plant	93.63	1.11	10.93	34.26	9.69	36.48	8.73	34.92	31.68	8.84

Tables (12 and13) illustrate chemical composition of the different parts of plant at flowering stage and maturity. Generally protein is higher at flowering compared with maturity stage while cell wall contents increased with maturity. Also leaves are richer in protein compared with whole plant though pods contain the highest protin content compared with all other plant parts. It is well established that increased cell wll contents lead to a reduction in digestibility and feed intake (Van Soest, 98).

The results of the present study are in line with those of (Suliman and Mabrouk, 1999**)** who noted that the chemical composition of cowpea under Sudan conditions was 400g/kg dry matter, 80.2 g/kg crude protein and 132.8g/kg crude fiber. Likewise, the seed is reported to contain 24% crude protein, 53% carbohydrates, and 2% fat (FAO, 2012). The leaves and flowers can also be consumed. As well **(**FOA, 2012) reported that cowpea leaves dry matter contained 24% crude protein, 53% carbohydrate and 2% fat. On the other hand (Kearl, 1982) presented that chemical analysis of cowpea leaves dry matter consisted of (EE 2.9%, NFE 30.4%, CF 30.0%, Ash 12.4% and CP 24.4%, while *Vigna sinensis* seed contains (2.15% EE, 60.0% NFE, 5.7% CF, 5.9% Ash and 26.3% CP). In contrast, hay of cowpea demonstrated different percentage of forage quality including (1.8%, 38.8%, 33.0%, 11.8% and 14.7%, EE, NFE, CF, Ash and CP, respectively. Also (Davis 1991) found that cowpea seed contains (20-24%) protein, 63.3% carbohydrate and 1.9% fat. Also crude protein content of fodder cowpea ranged between 15.2% -21.6% (Dmokanye,A. Tand Onifade, O.S (2003).

Similarly Tarawali et al. (1997) found that, crude protein content in seeds and leaves ranges from 22 to 30% on a dry weight.

CHAPTER V

Discussion

5 Effect of intra-row spacing of cowpea on growth attributes:

The significant increase (P<0.05) in plant density of cowpea (Table1) with decreased intra-row spacing at all three stages of growth is in line with Mohamed (2008) who found highly significant differences between treatments regarding spacing. Abdullah (2008), El Naim et al (2010 b) and El Naim et al (2011) also reported that, seed rate had significant effect on plant density. Moreover Malami et al (2012) stated that, closer inter-row and intra-row spacing recorded highest plant counts, while wider inter-row and intra-row spacing scored lowest counts. However, the results of El Naim et al (2010 a) showed that intra-row spacing had no significant effect on plant density. In addition, El Awad (2004) found that plant population had no effect on the time to flowering and maturity. Also, Hamad (2004) noted that, plant spacing treatments had no significant effect on all growth attributes. The findings of the present study agree with those of Mohamed (2008), El Naim et al (2011), Malami (2012) and Abduallh (2008), but disagreed with those found by El Naim et al (2010b), Hamad (2004) and El Awad (2000). The latter three reports found that spacing and plant density had no significant effect on all growth attributes and plant population at time of flowering and maturity. This result might be due to number of holes per square meter which means more plants and more competition for soil moisture within plant root.

Plant cover% was found to differ significantly among the different treatments at (P<0.05), being higher with closer intra-row spacing (Table2). This may be explained by that high density of plants resulting in high ground vegetation cover which reduced evaporation from soil surface. The results from this study are in agreement with those obtained by Sithomola (2011) and Abduallh (2008), who reported that plant density had a profound effect on vegetation ground cover; when plant density increased cover also increased. Increasing seed rate thus raises plant cover percentage. On the other hand, El Naim et al (2010 b) noted that increasing plant population significantly reduced the number of leaves per plant. On the other hand, Malami et al(2012) sated that intra-row spacing affected width of leaf, number of leaves and canopy spread. This is in line with the findings of the present study. The results, however, are in contrast with those found by El Naim et al (2010 b) and El Naim et al (2011) who noted decreased stem diameter, greater number of leaves per plant and larger leaf area.

Wider intra-row and inter-row spacing resulted in taller plants (Table 3). This might be due to a reduced competition over soil nutrients and light. These results are comparable with those of Mohammed (2002) who found that plant height increased with increasing intra-row and inter-row spacing. Though El Naim et al (2012) noted that increasing plant population significantly increased plant height, other reports e.g. Malami (2012), Mohammed (2000) and El Naim et al (2010 a) found that narrow spacing had insignificant effect on plant height. This might be attributed to genotype factors and also to competition for light and Co_2 to complete vegetative growth. In addition, El Naim et al (2010 b) found that the local cultivar (Buff) had significantly taller shoots with wider spacing which is in concurrence with this study which found taller plants with wider spacing. In the present study plant survival rate was not affected by intra-row spacing (P>0.05) (Table 4) which is in line with results obtained by Abdullah (2008) and Abu Suwar (2005), who worked on *Clitoria ternata*. These authors also did not find significant differences in survival rates as a result of seed rate. Moreover, Omokanye (2003) found that plant mortality was nil for other varieties. Ground cover was higher for variety V. TVU 12349 and Kananado with about 100% and 90% ground covered respectively compared with other varieties at early flowering stage.

The higher fresh and dry matter yields of cowpea (ton/ha) at flowering and at maturity stages of growth, as a result of intra-row spacing (Tables 5 and 6), were not significant (P>0.05). The slight variation in green and dry matter forage yield (ton/ha) may be due to low competition among plants when spacing is wide, reducing competition for nutrients needed for the development of stem diameter, leaf area and more vigor. These results are similar to those of Mohamed (2008) who reported that intra-row spacing led to a noon-significant increase in fresh and dry weight of guar. Abdullah (2008) found that a seeding rate of 8 kg/ha scored a higher dry matter yield compared with a seed rate of 2 kg/ha which was much lower. The results also agreed with Jakusko (2013), Obuo et al (2000), Rima et al (2013) and Azzakh et al (2012) who worked with erect cowpea varieties where they reported yield increases with a decrease in intra- row spacing. They recommended the adoption of closer spacing for the erect varieties. In Nigeria Singh et al. (1997) reported that farmers growing cowpea obtained an average of 2.3 ton/ha of fodder which is in line with what was found in the present study. On the other hand Enyi (1969) stated that spacing of 90cm between rows and 30 cm within rows produced higher yields than spacing of 90 and 60cm between and within rows respectively. Likewise, Obuo et al (2000) stated that higher yields were obtained by inter-and intra-row spacing of 45×30cm respectively with one plant per hill compared with inter and intra-row spacing of 75×30cm and two plants per hole. Thus, inter and intra-row spacing of 45×30cm resulted in optimum yields for the three cowpea varieties. In addition, Malami (2012) reported that the wider inter-row spacing of 100cm and intra-row spacing of 75cm increased dry matter yield, but differences were not significant. El Naim et al(2010a) found no significant effect of spacing on vegetative growth attributes measured.

The results from this study found non-significant effect of intra-row spacing on pod and seed yields (Tables 7 and 8). The small increases in number of plants per unit area with plant density may be attributed to interference between branches reducing the ability to produce nodes. These results resemble those of El Naim et al (2010a) who found no significant effect of intra-row spacing on yields of pods and seeds. However (50cm) intra-row spacing produced higher yield than wider spacing under rain-fed conditions though differences were not significant. Likewise, Hamad (2004), El Naim et al (2010a) and El Naim et al (2012), reported that increasing plant density decreased grain yield per plant, grain yield per unit area and reduced number of pods per plant. The work of El Naim et al (2010b) was on a late maturing local cultivar characterized by heavier grain weight and greater grain yield per plant. Jakusko (2013) and Enyi (1969) found that spacing of 90 cm between rows gave a good grain yield and number of pods compared with narrow spacing. Furthermore, Lazim (1972) stated that the wider spacing produced higher number of pods per plant and heavier seeds. On the other hand, El Naim (2012) noted that increased plants/stand increased grain yield (t/ha). The local cultivar (Beldi) gave the utmost grain yield per unit area; however, it seems to be a grain than fodder type variety as it is late maturing with lowest fodder yield. On the other hand, Rima et al (2013) reported that spacing of 30 cm at 30 kg/ha^{-1}seed rate resulted in significantly higher seed and forage yield under rain-fed conditions. These results are in line with what was found in this study.

Intra-row spacing in the present study was found to have no significant effect on nodules number and weight (Table 9). This might be due to high competition between plants and to the distribution of root system. The wider spacing resulted in larger nodules but their number was less compared with close spacing thus compromising the effect of the heavier weight per nodule. This finding is in disagreement with Helmy (2015) and Oroka (2010) who found that nodule number and weight increased significantly with increased plant density. The differences may be related to varietal and locational considerations. Moreover, Berchie (2014) indicated that the nodules number was usually lower at maturity than at earlier stages of growth. The depression was especially associated with the soil moisture content which decreased at maturity leading to disintegration of nodules and thus to a decrease in number and weight. The present study supports above results. Similarly, Agyeman et al. (2014) showed that increased forage yield was associated with decreased nodule counts and vice versa. These authors found nodules numbers ranging from 15 to 20 nodules per plant. The results from the present study disagree with the findings of these authors. In fact, the opposite was true. The data obtained from the present study are in line with findings by Aikins and Afuakwa (2008) and Khair (1999) who reported that *Rhizobia* with suitable efficiency can produce nodules in the range of 60-70 kg/ha and 84 kg/ha respectively. On the other hand, Clark (2007) reported that nitrogen fixed by cowpea contributed 100-150 Lb. of N / acre to the following crop.

Robert and John (2015) found that perennial forage legumes such as sweet clover, alfalfa and true clover may fix 250 -500 Lb. of nitrogen per acre. Other authors e.g. Frankow-Lindberg and Dahlin (2013)) and Burton (1972) reported that nitrogen fixation by legumes can be in the range of 25-75 Lb. of N/acre /annum in a natural ecosystem. The results of the present study are not in line with these reports. Likewise, Cardoso *et al.,* (2007) reported increases in the number of root nodules and nodule weight of legumes under intercropping compared to sole crops.

The different treatments resulted in significant differences ($P<0.05$) in soil moisture content (%) (Table 10), the closer spacing resulted in higher soil moisture content especially at seedling and flowering stages compared with wider spacing. Plants grown at narrow intra-row spacing resulted in increased soil cover which reduced evaporation from soil surface. This explanation agreed with Goodall (1981) and Abdullah (2008) who reported that the vegetation cover protects the land surface and decreases evaporation rate with increased seed rate. On the other hand, Ghanbari et al (2010) noted that, high ground cover reduces water evaporation thereby improving soil moisture retention. Fultion et al. (1969) and Zhou et al.(2010) reported that the higher plant densities at narrow spacing resulted in higher soil moisture content, probably due to a decreased evapotranspiration and quick expenditure of soil water content than those from wider spacing.

CHAPTER VI

Conclusion and Recommendations

6. Conclusion:

Closer intra-row spacing of cowpea significantly increased plant cover percentage, plant density and plant height. It also recorded greater forage yield at the two stages of flowering and maturity though differences are not significant. In contrast the wider intra-row spacing of cowpea resulted in higher but not significant seed yield compared with closer spacing. Narrow intra -row spacing also increased soil moisture content at seedling stage while at flowering stage it is the wider intra-row spacing that resulted in higher soil moisture content.

Difference in the intra row distance did not result in any significant effect on the various yield parameters cowpea in south Darfur. The appropriate recommendation should be use the widest intra-row spacing it economize seed rate.

6.2 Recommendations:

1. Intra-row spacing of cowpea of 50cm is recommended when farmers' objective is forage production under rain-fed conditions in South Darfur State of western Sudan.
2. Intra-row spacing of 100cm is suggested when the objective is seed production.
3. Intercropping may be an option for seed production as a strategy for climate change adaptation under unreliable conditions of rainfall.

References:

Abdullah, Z. (2008). Effect of seedling rate on plant growth attributes and yield of Clitoria ternatea and Macroptilium atropurpureum under rain-fed conditions in semi-arid zone of South Darfur, Sudan.M.Sc Thesis of University of Nyala .

Abu Suwr.O.A(2005). Forge production in Sudan in Arabic .

Agyeman, K., Berchie, J. N., Osei-Bonsu., Tetteh, N. E. and Fordjour, J. K. (2015). Growth and Yieldand Yield Performance of Improved Cowpea (Vigna Unguiculata L.) Varieties in Ghana. Published by Scienceby Science and Education Centre of North America. Accessed on 01/01/2015.

Aikins, S. H. M. and Afuakwa, J. J. (2008). Growth and dry matter yield responses of cow pea to different sowing depths. Journal of Agricultural and Biological Science ©2006-2008, Vol. No.3, No.5 and No.6, September – November. Journal of Agricultural and Biological Science ©2006-2008 Asian Research Publishing Network.

Al Wad O. Abu Suwar and El Hadi O. Yahia(2010). Pastoralist and seasonality: their effects on range productivity and carrying capacity in a semi-arid rangeland of Sudan (Southeast Darfur, Institute of desertification and desert cultivation studies , university of Khartoum.

Alpha, Y. K. (2016). Effect of plant density on the performance of cow pea in Nigeria Savannas (IIAT), International Institute of Tropical Agriculture, Ibadan, Nigeria.

Alyassa, A. M. (2008). Effect of Spacing on Growth and Forage Yield of Guar (C*yamopsis tetragonoloba* L.Tayp) B.Sc. Agronomy (Honors) Sudan University of Sciences and Technology

Amal A. Helmy, Hend H.M. Hassan and Hoda I.M. Ibrahim(2015).Influence of Planting Density and Bio-Nitrogen Fertilization on Productivity of Cowpea, Forage Crops Research Department, Field Crops Research. Institute, ARC, Giza, Egypt**.** American-Eurasian J. Agric. & Environ. Sci., 15 (10): 1953-1961, 2015

Anon ymous(2011).*Vigna unguiculata*. Tropical Forages. Http://www.tropicalforages.info/key/forages/media/html/Vigna-unguiculata.htm 13.08.2011

Archer[1] and H.C.Strauss[2](1989). The Effect of Plant Spacing on the Water Status of Soil and Grapevies. S. Afr. J. Enol. Vitic., Vol. 10 No. 21989.Department of Viticulture. University of Stellenbosch.7600Stellebosch Republic of South Africa

Azzakh, S., Abd El naby, Z. M. and Nasr, N. M. N., (2012). Influence of seeding rates and row spacing on forage yield and quality of cow pea (*Vigna sinensis* L.). J. Plant Production, Mansoura Univ., Vol. 3 (2): 217 - 227, 2012. better harvestBetter harvest of guar in Rajasthan. Indian Farm. 32:10-11.

Burton, J. C., (1972). Nodulation and Symbiotic Nitrogen fixation, In Hanson, (Ed,) Alfalfa science and technology, (monograph 15; p p 229-246). Madison, WI: American Society of Agronomy.

Cardoso, E. J. B. N., Nogueira, M. A. and Ferraz, S. M. G. (2007). Biological N_2 fixation and mineral N in common bean–maize intercropping or sole cropping in Southeastern Brazil. *Exploratory Agriculture* 43: 319–330.

CGIAR(2018),Consultative Group International Agriculture Research. http://www.cgiar.org/our-strategy/crop-factsheets/cowpea/. Access on 17th Jan 2018.

Chemining'wa, G. N. and Nyabundi, J. O. (1994). Effect of proximity between intercropped maize and beans on growth and yield of maize under varying nitrogen levels. East African Agricultural and Forestry Journal 9: 269 - 279.)

CIDA (2016), Based on information available from project Canadian International Development Agency**.**

Clark, A. (ed.) (2007). Cowpeas: *Vigna unguiculata*. In: Managing cover crops profitably. 3rd ed. Sustainable Agriculture Research and Education, College Park, MD. p.125–129. http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Legume-Cover-Crops/Cowpeas (accessed 6 Jun. 2012)

Craufurd, P.Q. and Wheeler, T. R. (1991), Effect of drought and plant density on radiation interception, radiation-use efficiency and partitioning of dry matter to seed cowpea. Exp. Agric. 35:309-325.htt://doi.org/10.1017/S0014479799003105 published online by Cambridge University Press: 01 July 1999.

CRI Crops Research Institute (2006). Cowpea Production Guide: Introduction to Cowpea Production.Availableonline:
http://www.cropsresearch.org/publications/pdf/cowpea_Introduction.pdf

Davis,W.et al (1991). Cowpea A crop field manual, University of Wisconsin. (Also availableatwww.britannica.com

El Naim, A. M., Hagelsheep, A. M., Abdelmuhsin, M. E. and Abdalla, A. E.(2010 a). Effect of intra-row spacing on growth and yield of three cowpea (*Vigna unguiculata* L.Walp) Varieties under rain-fed, Research Journal of Agriculture and Biological Sciences, 6(5): 623-629, 2010.INSInet Publication.

El Naim, A. M., Jabereldar, A. A. (2010 b). Effect of plant density and cultivars on growth and yield of cow pea (*Vigna unguiculata* L.Walp). Australian Journal of Basic and Applied Sciences. August 2010. Australian Journal of Basic and Applied Sciences, 4(8):3148-3153.2010. INSS 1991-8178.

El Naim, A. M., Jabereldar, A. A. and Mohammed, E. A, (2011). Effect of seed rate and cultivars yield component of cow pea (*Vigna unguciulata* L.Walp) in Kordofan state, Sudan. International Journal of current Current research Research, 2(1):142-147).

El Naim, A. M; Jabereldar, A. A; Ahmed, S. E; Ismaeil, F. M. (2012). Determination of Suitable Variety and Plants per Stand of Cowpea (*Vigna Unguiculata* L.Walp) in the Sandy Soil, Sudan. Advances in Life Sciences 2012, 2(1): 1-5.

Enyi, B. A. C. (1969). A spacing and Time of Planting Trial with Cowpea (*Vigna unguiculata* (L) Walp). Ghana Journal of Science Vol.13.No .1

FAO (2005)., Food and Agricultural Organization, Cowpea production database for Nigeria 1990-2004 retrieved from: http//www.faostat.fao.org.

FAO (2012). Food and Agriculture Organization. An introduction to Africa pastureland production in Strange. LR.N(ed).Rome, (Italy).

FAO (2014). Food and Agriculture Organization. Grassland species index. *Vigna unguiculata* http://www.fao.org/ag/AGP/AGPC/doc/Gbase/data/p000090.htm).

FAO (2016). Food and Agricultural Orgnazation,FAO.org/faostast.accessed on 1Aug.2018

FRA, (2015), Global Forest Resources Assessment, Report to FRA

Frankow Lindberg, B. E. and Dahlin, S. A. (2013). Nitrogen fixation, nitrogen transfer and yield in grassland communities including a deep-rooted legumes or non-legumes species. Plants and soil, 370.567-582.

Fulton (1969). Relationships among soil moisture stress plant population row spacing and yield of corn. Research Station, Canada Department of Agriculture, Harrow, Ontario.

Futuless, K. N., Bake, I. D. And Tizhe, W. (2010). Effect of sowing date and on yield components of cow pea (*Vigna unguiculata L. Walp)* in Mubi North local government area, Adamawa state, Nigeria. New York Science journal 3(11):98-102.

Ghanbari, A., Dahmardeh, M., Siahsar, B. A. and Ramroudi, M. (2010). Effect of maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. J. Food, Agric & Environ. 8 (1): 1 0 2 - 1 0 8).

Gomez, K.A. and Gomez, (1984). Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons Inc., New York.

Goodall, D. W. and Perry, R. A. with the assistance of Howes, K. M. W. (1981). International Biological Program, Arid Land Ecosystem. Cambridge University Press., Volume 2. First edition.

Grantz, D. A. and Hull, A. E. (1982). Earliness of an indeterminate crop, (*Vigna unguiculata L. Walp)* as affected by drought, temperature, and plant density. Australian Journal of Agricultural Research 33,531-540.

Gulden (1996). Interseeding Legumes into Chile: Legume Productivity and Effect on Chile Yield. HortScience: a publication of the American Society for Horticultural Science

Hamad, M. S. (2004). Effect of planting density on the performance of three cultivars of cowpea. M.Sc Thesis University of Khartoum, Sudan.

Herbert, S.J and F.D Baggerman,(1983). Cowpea response to row width, density and irrigation, Agron.J.75:982-986.

IITA (1996). Annual report (1995). IITA Samaru, Nigeria, 41-43, Ibadan Nigeria.

IITA, International Institute of Tropical Agriculture, (2003) and 2018). Crop and farming system. retrieved Retrieved from: http://www.iita.org / crop/cow pea/htm.

Imungi J.K and N.N Porter (1983). Nutritional content of row raw and cooked cowpea leaves. London Publishers pp 321-326.
ISSN 1818-6769.

Jakusko,1 U.I. Anasunda2 and A.B. Mustapha3(2013),Effect of inter-row spacing on some selected Cowpea (Vigna unguiculata (L) Walp) varieties in Yola, Adamawa State, Nigeria. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 2, Issue 3 (Jan. - Feb. 2013), *PP 30-35www.iosrjournals.org/*www.

Jayaram, R. and Ramaiah, S. (1980). Response of cow pea (*Vigna sinensis* L.Savi) to phosphorus and growth regulator. Madras Agriculture Journal.,67:102-105.

Joseph, A. A; Osipitan. O., Segun., T. L., Adeyen; R. O. and Afolami., S. O. (2014). Growth and yield performance of cow pea (*Vigna unguiculata* L.Walp). Influence influenced by row spacing and period of weed interference in South west Nigeria. Journal of Agricultural Science; Vol.6, No4; 2014. **www.----** Online accessed on Sep. 15.2014.

Kearl, L. C. (1982). Nutrient Requirements of Ruminants in Developing Countries. International Feedstuffs Institute, Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322, USA. ISBN 0-87421-116-6

Kearl, L. C., Farid, M. F. A., Harri. L. E., IIoyd, H and Wardah, M. F (1979). Arab and Middle East tables of feed composition ACSAD, and UTAH State University.

Khair M.A.(1991). Principle of Forge production in Sudan in Arabic,ARC Sudan Madani.

Krishnaswamy, V. and Seshu, D. V. (1990).. Germination after accelerate aging and associated characters in rice varieties Seed Science and Technology, 18: 147-15.

Lazim, M. and Nadi, A.H. (1974) Growth and yield of irrigated sesame 1. Effect of population and variety on vegetative growth, Experiment Agriculture, 10: 65-69.

Lazim,M.H. (1972). Haricot bean variety and spacing experiment. Annual report, Hudaeiba Research Station, Damer, Sudan

Le Houerou, H. N. (1980). Role of browse in the Sahelian and Sudanian Zones, In: Browse in Africa, the current state of knowledge, H.N. Le Houerou (ed), ILCA, Addis Ababa, Ethiopia.

Le Houerou, H. N. (1981). Long –term dynamics in arid-land vegetation and ecosystems of North African. Division of land resources management, Western Australian, Cambridge university University pressPress.PP357-383.

Lindemann,(1990). Soil microbiologist Nitrogen fixation by legumes , college of agriculture and home economics . Guide A-129 http://www.cahe.nmsu.edu/pubs/_a/a-129.htmi.ASTM,2001 Annual book of ASTM standards, Conshohocken,PA,2001 copyright, American Society for testing and materials, 100 Barr Harbor West Drive, Conshohcken,PA 19428-2959.Reprinted with permission.

Malami., B. S. and M. sama'ilaSama'ila., M. (2012). Effects of inter and intra- Rowrow spacing on growth characteristics and fodder yield of cow-pea (*Vigna unguiculata*(L) Walp Var.Kanannado), Department of animal science ,Faculty of Agriculture ,Usmanu Danfodiya University , in the semi-arid North West Nigeria. Nigeria Journal of basic and applied science.125-129. Available online at http://www.ajol.info/index.php/njbas/index. htt://www.ajol.info/index.php/nibas/index Nigerian Journal of Basic and Applied Science (June,2012), 20(2): 125- 129.

Ministry of Livestock Fisheries and Rangelands,2012, Report (2012).

Mohammed, L. Z. (2002). The effect of intra-rows pacing and starter nitrogen fertilizer on growth and yield of cowpea, (*Vigna unguciulata* L.Walp). MSc thesis, University of Khartoum, Sudan.

Mohammed.A.A (2008). Effect of Spacing on Growth and Forage Yield of Guar (C*yamopsis tetragonoloba* L.Tayp),Thesis MSc University of Khartoum.

NAPA Documentation study, (2013). National Adaptation Program for Action, South Darfur State, Sudan.

National Animal Production Research Institute, Ahmadu Bello University, P.M.B. 1096, Shika - Zaria, Nigeria.

National Research Research councilCouncil, (1976). Nutrient requirements of sheep. National academy Academy of scienceScience, Washington, D.C, USA.

Obuo., **J. E., Okurut-Akhol., H.; Ergenyu A., Okwang., D. and Omadi., J. R. (2000).** Effect of Inter-row spacing Plant Stand per hill on the Yield of Cowpea. Uganda Journal of Agricultural Sciences, 5:1-3.

Omokanye*, O.S. Onifade, J.T. Amodu, R.O. Balogun & M.S.Kallah(2003). Evaluation of Dual-purpose Cowpea (*Vigna unguiculata*(L.) Walp.) Varieties for Grain and Fodder Production atShika, Nigeria.TROPICULTURA, 2003, **21**, 1, 42-46**.**

Oroka, F. O. (2010). Responses of rice and cow pea intercropping to nitrogen fertilizer and plant population (1): Nodulation, Nitrogen fixation and agronomic efficiency. World Journal of Agricultural Sciences 6(2), 154-159.

Rima Taipodia1 and A. T. Nabam(2013). Impact of Time of Sowing, Spacing and Seed Rate on Potential Seed Production and Fodder Quality of Cowpea [Vigna Unguiculata (L.) Walp. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 4, Issue 4 (Jul. - Aug. 2013), PP 61-68 www.iosrjournals.org www.iosrjournals.org.

Robert and John, (2015). Nitrogen fixation by legumes, New Mexico University, College of Agriculture Consumer and Environmental Sciences.

Robertson, J.B., Van Soest, P. J., (1981).The detergent system of analysis. In: James, W. P. T., Theander, O. (Eds.) the analysis of dietary fiber in food. Marcel Dekker, NY, chapter 9, pp. 123-158. University of Idaho; College of Natural Resources, Principles of Vegetation Measurement and Assessment and Ecological Monitoring and Analysis.

RRF, (2015), Risk Finance Project for Climate change, South Darfur State, Sudan.

Singh, B. B. and Tarawali, S.A. (1997). Cowpea and its improvement: Key to sustainable mixed crop/livestock farming systems in West Africa. In Renard, C. (ed.). Crop residues in sustainable mixed crop/livestock farming systems. International Crop Research Institute for the Semi-arid Tropics (ICRISAT), ILRI and CAB International, Wellington, UK. Pp79-100.

Sithomola L. P. and Odhlambo J. J. O. (2011). Effect of planting density on growth and yield of three cow pea cultivars Department of soil science, University of Venda Private Bag X5050. Thohoyandou 0950, South Africa.

Sulieman, Y.R. and Mabrouk, A.A.(1999). The nutrient composition of Sudanese feeds.Bulletin III.Central Animal Nutrition Research Laboratory, Kuku Khartoum North.

Tarawali, S. A., B. B. Singh, M.Peter and S. F. Blade, (1997), Cowpea haulms as fodder; In: B. B. Singh, D. R. Mohan Raj, K. Dashiell and L. E. N. Jackai (Eds.). pp. 313 - 325, Advances in cowpea research. Co-publication of international institute of tropical agriculture (IITA) and Japan international research centre for agricultural sciences (JIRCAS), IITA. Ibadan, Nigeria.

The Central bureau of statistics (2008), sited by El Wakeel,A.S1(2015). Impacts of Climate Change on Biodiversity in Sudan, Sudan Academy of Sciences Journal- - Special (Climate Change),Vol.11,2015,83-94.

Zhou,GM.Yang,S.JSun,Y.Hchen (2010). Plant and row Spacing effect of Soil water and yield of rainfed Summer Soybean in the northern Chain. Agronomy College of Shandong Agriculture University, State Laboratory Biology, Taian, P.R.China.

المراجع العربية

1- عوض عثمان أبو سوار.(2005) إنتاج الاعلاف في السودان.

2- محمد أحمد خير(1991).أساسيات إنتاج محاصيل الأعلاف في السودان.

3- وزارة الثروة الحيوانية والسمكية والمراعي. ولاية جنوب دارفور(2016).ورقة الوضع الحالي للثروة الحيوانية.

Appendices

Appendix (1): Annual rainfall in South Darfur State – Nyala area (2003 -2012),

Year	**Rainfall in (mm)**
2003	626.1
2004	432.4
2005	487.3
2006	449.5
2007	459.3
2008	498.6
2009	304.2
2010	304.2
2011	379.0
2012	462.4
2013	312.5
2014	476.9
2015	237.5

Source: Sudan Meteorological Authority.

Appendix (2): Soil characteristics (0-60 cm) of the experimental site before and after planting of cowpea

Soil characteristics	**Before planting**		**After planting**	
	2013	2015	2013	2015
pH	6.6	5.8	6.0	5.5
Total N%	0.023	0.020	0.04	0.023
Total P (mg/^{1}g)	6.52	5.72	9.60	7.04
Total K (mg/g)	0.232	0.106	0.06	0.114
E.C.e dsm^{1}	39.4	66.2	47.9	30.9
$CaCO_3$%	10.0	11.5	12.9	10.5
O.C%	0.016	0.016	0.04	0.04
CS%	72.2	73.2	69.7	71.2
C%	8.0	10.0	10.2	12.0
SI%	9.4	7.6	7.9	5.8
FS%	10.4	9.6	12.2	11.0

CS =Coarse Sand, **FS** = Fine Sand, **SI** =Silt, **C** =clay, **$CaCO_3$**= Calcium carbonate, **O.C**= organic carbon, **ECe** = **E**xchange **C**ation Electric

Appendix (3) Effect of intra-row spacing of cowpea on plant density /m^2, at different growth stages

Spacing	**2013**				**2014**				**2015**				
	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	**Mean**
50cm	14.0	12.0	10.0	**12.0**	7.0	5.0	6.0	**6.0**	18.0	16.0	14.0	**16.0**	**11.0**
75cm	13.0	10.0	9.0	**11.0**	8.0	3.0	5.0	**5.0**	15.0	10.0	9.0	**11.0**	**9.0**
100cm	6.0	5.0	5.0	**5.0**	7.0	3.0	5.0	**5.0**	10.0	9.0	9.0	**9.0**	**6.0**
125cm	6.0	4.0	3.0	**4.0**	6.0	3.0	4.0	**4.0**	8.0	6.0	5.0	**6.0**	**5.0**
Mean	**10.0**	**6.0**	**6.0**	**8.0**	**7.0**	**4.0**	**5.0**	**5.0**	**13.0**	**10.0**	**9.0**	**11.0**	**8.0**
SE±	1.87	1.47	1.4	**1.47**	0.91	0.92	0.60	**0.52**	0.97	1.19	1.45	1.6	**1.1**
LSD	**2.02**			**3.35**	**4.86**			**3.59**	**3.38**			**4.39**	**3.10**
CV%	54.1	49.0	45.1	44.6	30.4	21.2	40.0	23.1	54.0	61.6	57.8	54.4	35.9
Pro>f	0.001**			*	0.117 NS			NS	0.001**			*	*

Appendix (4) Effect of intra-row spacing on plant cover (%) of cowpea, at different growth stages

Spacing	2013				2014				2015				
	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	**Mean**
50cm	76.3	77.5	73.8	**75.9**	80.0	83.7	77.5	**80.4**	63.8	80.0	81.3	**75.0**	**77.1**
75cm	65.0	86.3	73.8	**75.0**	71.3	82.5	62.5	**72.1**	51.3	70.0	68.8	**63.3**	**70.1**
100cm	38.8	75.0	71.3	**61.7**	75.0	85.0	77.5	**78.2**	46.3	77.5	75.0	**66.3**	**69.0**
125cm	38.8	31.2	57.5	**55.8**	76.3	72.5	70.0	**72.9**	51.3	81.3	68.8	**67.1**	**65.3**
Mean	**54.7**	**67.5**	**69.1**	**67.1**	**75.7**	**80.9**	**71.9**	**75.9**	**53.1**	**77.2**	**73.4**	**67.9**	**70.4**
SE±	9.5	12.4	3.9	4.9	1.8	2.9	3.6	2.02	3.8	2.6	2.8	2.7	**2.5**
LSD	**5.64**			**27.33**	**14.10**			**10.43**	**13.98**			**10.34**	**26.8**
CV%	34.7	36.6	11.3	14.7	4.7	7.0	10.1	36.6	7.7	6.9	11.2	7.2	6.9
Pro>f	0.001**			NS	0.17NS			NS	0.02*			NS	NS

Appendix (5) Effect of intra-row spacing on plant height (cm) of cowpea at different growth stages

Spacing	2013				2014				2015				
	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	Seedling	Flowering	Maturity	**Mean**	**Mean**
50cm	27.0	85.3	92.0	**68.1**	58.3	162.3	220.5	147.03	44.3	120.8	121.1	90.4	101.8
75cm	29.3	84.5	97.0	**70.3**	82.3	178.0	221.3	160.5	44.3	79.5	81.2	68.3	99.7
100cm	27.3	94.3	115.0	**78.8**	91.5	183.5	222.8	165.9	53.3	120.9	125.6	99.9	114.9
125cm	29.5	114.3	124.8	**89.5**	95.5	198.8	226.5	173.6	58.4	134.5	140.6	105.8	122.9
Mean	**28.25**	**91.8**	**105.8**	**76.7**	**81.9**	**180.4**	**222.8**	**161.8**	**50.1**	**109.4**	**115.5**	**91.7**	**109.8**
SE±	0.66**	8.9**	8.6**	5.8	5.6	5.9	2.9	3.5	3.5	12.9	11.1	8.9	5.49
LSD	**11.56**			**32.04**	**26.38**			**19.51**	**43.81**			**32.39**	**105.3**
CV%	4.6	16.7	18.7	15.4	14.9	2.7	7.8	4.7	13.7	22.3	20.3	19.8	10.0
Pro>f	0.03*			NS	0.7NS			*	0.7NS			*	NS

Appendix (6) Effect of intra-row spacing on plant survival rate (%) of cowpea, at different growth stages

Spacing	**2013**			**2014**			**2015**			
	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	**Mean**
50cm	71.8	62.0	**66.9**	74.3	68.5	**71.3**	86.3	78.8	**82.5**	**73.4**
75cm	71.8	55.8	**63.6**	58.0	34.8	**46.4**	79.3	64.5	**71.9**	**60.6**
100cm	83.3	69.0	**76.1**	81.5	44.3	**62.9**	91.5	90.5	**91.0**	**76.7**
125cm	55.5	53.0	**54.3**	60.0	56.5	**58.3**	82.0	63.8	**72.9**	**61.8**
Mean	**70.6**	**59.9**	**65.3**	**68.4**	**51.0**	**59.7**	**84.8**	**74.4**	**79.6**	**68.2**
SE±	5.7	3.6	4.5	5.7	7.8	5.2	2.7	6.4	4.6	4.06
LSD	**38.25**		**9.58**	**50.6**		**25.27**	**48.85**		**12.23**	**14.49**
CV%	16.1	11.8	13.8	16.5	30.4	17.4	6.3	17.2	11.2	11.9
Sig. level	NS		*	NS		NS	NS		NS	*

Appendix (7) Effect of intra-row spacing on fresh yield (t/ha) of cowpea at different growth stages

Spacing	**2013**			**2014**			**2015**			
	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	**Mean**
50cm	5.7	**1.7**	**3.7**	7.9	3.6	**5.8**	8.0	7.6	**7.8**	**5.8**
75cm	6.5	**1.7**	**4.1**	4.3	2.9	**5.6**	6.0	5.2	**5.6**	**5.1**
100cm	5.6	**1.9**	**3.9**	6.6	4.0	**5.3**	11.7	5.9	**8.8**	**6.0**
125cm	5.8	**1.9**	**4.4**	5.8	4.2	**5.0**	7.4	8.5	**8.5**	**5.6**
Mean	**5.88**	**1.79**	**4.01**	**6.11**	3.7	**5.4**	**8.38**	**6.80**	**7.68**	**5.73**
SE±	0.60	0.06	0.32	0.76	0.26	0.17	1.22	0.76	0.73	0.21
LSD	**2.49**			**5.74**			**12.91**			**3.59**
CV%	7.5	6.4	7.9	24.7	14.1	6.7	29.1	22.4	18.8	7.15
Sig. level	NS		NS	NS		NS	NS		NS	NS

Appendix (8) Effect of intra-row spacing on dry matter yield (t/ha) of cow pea, at different growth stages

Spacing	**2013**			**2014**			**2015**			
	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	Flowering	Maturity	**Mean**	**Mean**
50cm	1.6	0.8	**1.2**	1.9	1.7	**1.8**	2.4	1.7	**2.05**	**1.7**
75cm	2.0	1.2	**1.6**	0.8	1.2	**0.95**	2.3	1.5	**1.9**	**1.5**
100cm	1.9	1.1	**1.5**	1.5	1.5	**1.5**	2.5	1.6	**2.0**	**1.7**
125cm	2.0	1.1	**1.5**	2.0	1.4	**1.2**	2.6	1.6	**2.2**	**1.6**
Mean	**3.7**	**1.2**	**1.5**	**1.6**	**1.5**	**1.4**	**2.5**	**1.6**	**2.03**	**3.2**
SE±	0.21	0.25	0.17	0.46	0.36	0.37	0.20	0.09	0.13	0.15
LSD	**0.65**			**2.97**			**1.65**			**0.95**
CV%	11.1	20.8	11.4	32.9	22.9	25.5	8.2	5.6	6.3	9.4
Sig. level	NS		NS	NS		NS	NS		NS	NS

Appendix (9) Effect of intra-row spacing of cowpea on pods yield per plant and per (m^2). Seasons (2013/14 – 2015/16)

Spacing	**2013**		**2014**		**2015**	
	Number of pod/plant	Number of pods/ m^2	Number of pods/plant	Number of pods/ m^2	Number of pods/plant	Number of pods/ m^2
50cm	26.0	50.0	8.0	15.0	10.0	85.0
75cm	28.0	67.0	8.0	13.0	16.0	65.0
100cm	42.0	74.0	6.0	19.0	10.0	64.0
125cm	33.0	67.0	6.0	13.0	11.0	75.0
Mean	**32.0**	**64.0**	**7.0**	**15.0**	**12.0**	**73.0**
SE±	3.7	5.12	0.82	1.42	1.44	4.94
LSD	**15.7**	**22.9**	**2.5**	**6.3**	**6.6**	**26.6**
CV%	23.1	16.0	23.4	18.9	24.0	13.5
Sig. level	*	*	NS	NS	NS	NS

Appendix (10) Effect of intra-row spacing on seed yield of cowpea at maturity stage

Spacing	**2013**		**2014**		**2015**	
	Seed/plant	**Seed(g/ m^2)**	**Seed/plant(g)**	**Seed (g/ m^2)**	**Seed/plant(g)**	**Seed(g/m^2)**
50cm	62.0	76.5	75.8	127.3	60.8	148.5
75cm	88.8	114.0	66.0	93.3	44.0	114.3
100cm	90.3	118.0	76.3	111.0	56.8	121.3
125cm	98.5	123.8	56.3	77.3	63.8	130.0
Mean	**84.87**	**108.6**	**68.6**	**102.2**	**56.3**	**128.5**
SE±	7.95	10.7	4.75	10.85	8.72	7.4
LSD	35.94	11.5	4.56	60.66	26.84	62.98
CV%	18.7	19.7	13.8	21.2	15.5	11.5
Sig. level	*	*	NS	NS	NS	NS

Appendix (11) Effect of intra-row spacing of cowpea on nodules yield per plant (g)

Spacing	**2013**			**2014**			**2015**		
	Number nodule	Fresh nodule wt	Dry nodule wt	Number nodule	Fresh nodule Wt.	Dry nodule Wt.	Number nodule	Fresh nodule Wt.	Dry nodule Wt.
50cm	63.0	0.9	0.4	67.0	0.5	0.3	71.0	0.6	0.3
75cm	72.0	0.11	0.6	69.0	0.7	0.5	73.0	0.7	0.3
100cm	48.0	1.0	0.7	47.0	2.2	0.5	54.0	0.7	0.4
125cm	54.0	1.2	0.9	58.0	0.5	0.3	57.0	0.5	0.2
Mean	**59.2**	**0.65**	**0.5**	**60.2**	**1.1**	**0.4**	**63.3**	**0.62**	**0.27**
SE±	5.25	0.20	0.05	6.8	0.42	0.05	4.52	0.05	0.10
LSD	47.65	0.24	0.22	41.23	2.83	0.96	37.73	0.28	0.29
CV%	17.7	61.5	20.0	22.6	76.4	25.0	14.2	16.1	74.1
Sig. level	NS	*	*	NS	NS	NS	NS	NS	NS

Appendix (12) Effect of intra-row spacing of cowpea on soil moisture content (%)

	Year	Stage	Depth	50cm	75cm	100cm	125cm	Mean	SE±	LSD	CV%	L.sig
Mean of soil moisture content at three depths (cm)	**2013**	**Seedling**	20	3.2	3.9	4	4.8	3.9	0.33		16.9	
	2013	**Seedling**	40	4.8	4.9	4.1	5.6	4.8	0.31		12.9	**
	2013	**Seedling**	60	5.4	3.8	7	7	5.8	0.75		25.9	
	2013	**Flowering**	20	1.2	1.2	2.4	1.3	1.6	0.25		31.3	
	2013	**Flowering**	40	2.6	2.8	3.3	2.9	2.9	0.14	1.65	9.7	**
	2013	**Flowering**	60	2.7	4	3.8	3.4	3.5	0.29		16.3	
	2013	**Maturity**	20	2.1	2	1	1.8	1.7	0.25		29.4	
	2013	**Maturity**	40	3.9	4	3.9	4.9	4.2	0.24		11.4	**
	2013	**Maturity**	60	2.9	4.9	3.2	3.8	3.7	0.44		23.8	
	2013	**M**		3.2	3.5	3.7	3.9	3.6	0.15	0.79	8.3	*
	2014	**Seedling**	20	3	4	5.9	6.8	4.9	0.77		31.4	
	2014	**Seedling**	40	5.3	4	7.9	5.7	5.7	0.81		28.4	NS
	2014	**Seedling**	60	7	4.8	9.4	3.8	6.3	1.24		39.3	
	2014	**Flowering**	20	1.3	4.4	4.2	1.9	2.9	0.79		54.4	
	2014	**Flowering**	40	1.4	3.9	4.5	1.9	2.9	0.75	3.21	51.7	NS
	2014	**Flowering**	60	1.8	5.2	4.5	4.1	3.9	0.8		41.1	
	2014	**Maturity**	20	2.8	1.4	1.3	1.3	1.7	0.37		42.9	
	2014	**Maturity**	40	3.1	2.9	2.9	2.9	3	0.05		3.3	NS
	2014	**Maturity**	60	3.9	3.7	3.9	3.9	3.9	0.05		2.6	
	2014	**M**		3.5	3.8	4.9	3.6	3.9	0.33	2.34	16.7	NS
	2015	**Seedling**	20	4.6	4.1	4.7	3.3	4.2	0.32		15.2	
	2015	**Seedling**	40	5.5	5.2	5.6	5	5.3	0.14		5.3	NS
	2015	**Seedling**	60	6.1	5.1	6.8	5.2	5.8	0.41		13.9	
	2015	**Flowering**	20	1.8	-0.4	0.04	2.9	1.1	0.75		13.6	
	2015	**Flowering**	40	3.8	2.3	2.1	1.9	2.5	0.9	2.64	7.2	NS
	2015	**Flowering**	60	3.7	2.9	2.6	4.4	3.4	0.41		23.8	
	2015	**Maturity**	20	3.4	3.6	2.7	2.7	2.9	0.26		17.8	
	2015	**Maturity**	40	3.6	3.6	3.4	1.4	3	0.55		36.6	NS
	2015	**Maturity**	60	2.9	4	3.4	1.2	2.9	0.6		41.4	
		M		4.1	3.7	3.4	2.6	3.5	0.32	2.34	18.3	NS