EVALUATION OF INTRODUCED COWPEA BREEDING LINES IN SOUTH AFRICA

BY

TSOBEDI ABSALOM MASENYA

MINI-DISSERTATION

Submitted in (partial) fulfilment of the requirements for the degree of

Master of Science

in

Agriculture (Agronomy)

In the

FACULTY OF SCIENCE AND AGRICULTURE

(School of Agricultural and Environmental Sciences)

at the

UNIVERSITY OF LIMPOPO

Supervisor: Prof. J.A.N. ASIWE

2016

DEDICATION

I dedicate this dissertation to my family. My granny Ethel Masenya, my mom Dorcus Masenya, my aunts, Mpeky, Jacobeth and Baby Masenya for raising me up without a father, i appreciate all their support, love and guidance. I also dedicate this study to my brothers Peter, Sepaki and Thabo, young sisters Itumeleng, Golo and Tshego.

DECLARATION

I, declare that the mini- dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science Agriculture (Agronomy) has not previously been submitted by me for a degree at this or any other university; That it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

Masenya T.A	03 May 2016
___________________	________________
Surname, initials (title)	Date

ACKNOWLEDGEMENTS

First of all, I gloriously thank my God, Jehovah, for ushering me and protecting me throughout my studies and blessing me with a beautiful life.

Secondly, I give my warm hearted thanks to my supervisor, Prof J.A.N Asiwe for his patience and understanding and mentoring throughout this study.

I would love to recognize the University of Limpopo’s Department of Agriculture for granting me this prospect to contribute to the great field of science.

I hereby acknowledge the financial assistance from AgriLIFE A&M University, Texas, USA, the National Research Foundation on my research project and ARC/IITA for the germplasm.

Take this opportunity to thank my colleagues and friends, appreciating all the help, support and assistance of any kind towards completion of the study. Colleagues Thembi Zitha, Stanford Thosago, Vincent Mokoka, Shila Dolo. The friends are Mpho Molapo, Peter Chuene, Tebogo Ngoepe, Tshedza Raphalalani and Phuti Raphela. I’m grateful for all the help I got from Mr F.H Ndwambi, for driving me to and from the field.

Lastly, i acknowledge my family, i am nothing without them. All this is for them. For their unconditional Love.

ABSTRACT

Cowpea *(Vigna unguiculata (L.)* Walp) is an important annual leguminous crop in semi-arid and tropics, where it is mainly grown for consumption and livestock feeding. The crop has good morphological and biochemical qualities which make it well adapted to the semi-arid and tropics. However, farmers in South Africa currently lack good seed for planting and experience very low cowpea grain yields. The aim of this study was to evaluate 97 newly introduced cowpea germplasm for adaptation and yield parameters.

The study was conducted in two locations in Limpopo Province, with each location having two experiments, experiment I consisted of 57 early maturing cowpea germplasm, and experiment II consisted of 40 medium maturing cowpea germplasm, these materials were introduced from IITA, Nigeria and A&M University, Texas, USA. Both with one local check (Glenda). The first location was at Ukulima Farm near Modimolle in the Waterberg district during 2012/13 and the second was at University of Limpopo experimental farm Syferkuil during 2013/14 summer-planting season. The experiments were laid out as an incomplete randomized block design (lattice design), consisting of 3 replications, four rows per plot with intra row spacing of 25 cm and inter row spacing of 75 cm. Each row was 4m long.

The following agronomic variables were collected, in both locations; plant height, number of pods per plant, pod length, number of seed per pod, number of branches, hundred seed weight and grain and fodder yield. Data was subjected to ANOVA using statistical software, Statistic 9.2. The variances of the parameters measured were summarized in ANOVA table. The treatments that showed significant difference were separated using Duncan Multiple Range at 5% level of significance.

The result showed significant difference ($P<0.05$) among cowpea varieties for the following yield parameters; plant height, number pods per plant, number of branches, seed weight, pod weight and hundred seed weight. In experiment I the mean plant height, number of branches, mean pod length, total pod weight, weight of seeds per pod, hundred seed weight and number of seed per pod were respectively (100 cm, 21, 23 cm, 1413.4 kg/ha, 1121.62 kg/ha, 28.283g and 16) and were greater than the control Glenda (49 cm, 15, 14 cm, 777.82 kg/ha, 622.87 kg/ha, 13.300 g and 13). In experiment II the mean plant height, number of branches, mean pod length, total pod weight, weight of seeds per pod, hundred seed weight and number of seed per pod were respectively (97 cm, 21, 21 cm, 1546.19 kg/ha, 1245.11 kg/ha, 27.363 g and 16) and these were better than the control, Glenda (50 cm, 15, 17 cm, 795.11kg/ha, 661.01 kg/ha, 18.393 g and 13). Weight per 100 seeds showed that 51 and 32 breeding lines had weights higher than Glenda in the early and medium maturity trials, respectively.

The evaluated cowpea varieties varied in performance between the two locations. The above results indicate the superiority of the introduced breeding over the local check as well as the potentials of using these promising lines for the development of better adapted germplasm in South Africa. The lines with better agronomic characters and yield performance in the two locations are recommended for seed production to meet the immediate needs of farmers, after due registration with DAFF at Pretoria. Data generated from the studies will contribute useful information to the data-base of the characteristics of these cowpea lines.

Key words: Evaluation, Cowpea germplasm, Adaptation, *Vigna unguiculata*.

TABLE OF CONTENTS

Contents Page

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Analysis of variance (ANOVA) table for the field study

LIST OF PLATES

CHAPTER 1

INTRODUCTION

1.1 General introduction

Cowpea *(Vigna unguiculata (L.)* Walp) is an important annual grain legume. This leguminous crop is produced as a food crop for human consumption and fodder for animals in the semi-arid and tropics. Cowpea can be consumed virtually in all growth stages and it is also an important source of family income for poor families, particularly in developing countries (Singh *et al*., 1997). It also provides a rich source of protein and starch, as the seed contains on average of 23% -25% proteins and 50%-60% starch and 63.6% carbohydrate (Akyaw *et al*., 2014).

Cowpea is cultivated in several continents, this include Asia, Africa, South and Central America. Due to lack of archaeological evidence, there is contradicting views in relation to the origin of cowpea (Singh *et al.,* 2003; Imran *et al*., 2010). Cowpea is compatible in agricultural production systems; it could be used for erosion control especially the spreading type, because of its quick growth which results in quick cover (Singh *et al.*, 2002), or used as fodder and haulms, is highly palatable, very nutritious, and has no antinutritive factors, good for animal feeding.

It plays an important role in soil fertility improvement, suppression of weeds and dry grain after maturity. Cowpea like most legumes has the ability of fixing atmospheric nitrogen, having the advantage of growing well even under poor and low levels of nitrogen and less fertile soils (Hall and Ehlers, 1997). Cowpea thrives in dry environments, due to its morphological as well as biochemical qualities. The deep rooted system and less water loss through the stomata and its earliness in maturity are some of the factors that make cowpea adaptable to hostile environments (Gomez, 2004). Cowpea has a competitive niche in sandy soils, but susceptible to excessively wet conditions, and poorly drained soils (Valenzuela and Smith, 2002).

However, production and productivity of cowpea in South Africa is low due to lack of improved varieties and good quality seeds for planting. Other limiting factors include drought, biotic stresses that include weeds, diseases and insect pests. Lacks of suitable varieties and limited breeding work occasioned by insufficient funding have resulted in low productivity and low rate of adoption of improved varieties by farmers (Asiwe, 2009).

2.1 RESEARCH PROBLEM

1.2.1 Problem statement

Production of cowpea in South Africa is limited by lack of improved varieties and good quality seeds for planting. Majority of germplasm introduced into South Africa are not characterized for adaptation and as such their usefulness for deployment in breeding programs as well as consideration for release to farmers cannot be ascertained. To effectively determine the usefulness of any introduced germplasm accessions, evaluation is necessary.

3.1 Hypothesis

The yield components and characteristics of introduced cowpea breeding lines do not differ.

4.1 Motivation

Since food production is inversely proportional to teaming population growth in South Africa, there is a need to increase food production to avoid food insecurity. The evaluation of introduced cowpea varieties for adaptation and subsequent deployment for breeding or release in South Africa will contribute to alleviation of food insecurity and poverty. Evaluation of the introduced cowpea breeding lines will help to determine their breeding or agronomic values. The study will benefit small-holder farmers in South Africa by planting varieties that are high yielding and well adapted to the South African environment. In addition, the study will enhance the productivity of cowpea farmers as well as increasing their family income, and indirectly increasing employment for all in the value chain. The data generated from the studies will contribute useful information to the data base of the characteristics of these cowpea lines.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin and diversity of cowpea

Cowpea (*Vigna unguiculata (L.)* Walp) is a tropical, annual herbaceous legume; it is a dicotyledon plant classified in the family Fabaceae, subfamily Faboideae, tribe Phaseolinae, order Fabales and genus *Vigna* order Leguminosae (Singh *et al.*, 1997). Cowpea is one of the common names in English: other English cowpea names are Bachapin bean, Black-eyed pea, Crowder pea, China pea and Cowgram. In Afrikaans it is called Akkerboon, Swartbekboon, Koertjie; in Zulu: Isihlumaya; in Venda: Munawa (plant), Nawa (fruits) Imbumba, Indumba; in Shangaan: Dinaba, Munaoa, Tinyawa, in Sepedi: Dinawa, in French: Niebe. It is also known internationally as Lubia, or Frijol. Irrespective of the name they are all species *Vigna unguiculata*, which in older reference may be identified as *Vigna sinensis* (L) (Gomez, 2004). The genus *Vigna* consists of over one hundred different species widely found in the tropical and sub-tropical regions, and has great morphological and ecological diversity (Oyewale and Bamaiyi, 2013).

The precise origin of cultivated cowpea has been a matter of speculation and discussion for many years. Asia and Africa could be independent centers of origins for the crop, based on early observations which showed that the cowpeas present in Asia are very diverse and morphologically different from those growing in Africa (Timko and Singh, 2008). Other literature indicated that although domestication occurred in West Africa, Southern Africa is the center of origin, also the distribution of diverse wild cowpea from Ethiopia to South Africa lead to the proposition that East and Southern Africa are primary centers of diversity, while West and Central Africa are secondary centers of diversity (Sariah, 2010; Padulosi and Ng, 1997). Cowpea today is widely adapted and grown throughout the world, through regular evaluation.

2.2 Botany, characterization, and environment conditions

Cowpea is an herbaceous short term, annual leguminous plant which is grown in many tropical and subtropical countries (Singh and Sharma, 1996) and is also summer legume crop which have trifoliate leaves. Cowpea is primarily a short day plant or in some instances, day-neutral (Ehlers and Hall, 1997). They are two main groups of growing habits of cowpea, they include prostrate or indeterminate type and erect or determinate type and they can be distinguished from one another by different factors such as seed size and colour, taste, yield and time to maturity (Kabululu, 2008).

The crop is characterised by a very strong taproot and more lateral branching roots spreading in the soil surface as compared to other legumes crops. The categorization of the crop includes number of pod per plant, number of seed per pod, pod length, pod weight, number of days to reach flowering and podding (Davis *et al*., 1992). Cowpea is characterized by two or three pods per peduncle and often four or more pods are carried on a single peduncle if growing conditions are very favorable. The presence of these long peduncles is a distinguishing feature of cowpea and this characteristic also facilitates hand harvesting. Pods are cylindrical and may be curved or straight, with between 8 and 15 seeds per pod (Kabululu, 2008). Usually, cutivated cowpea seed weighs between 8 and 32 mg and ranges from round to kidney shaped.

Cowpeas can be cultivated on a wide range of soils; however the crop performs well on sandy soils, which tend to be less restrictive on root growth. Cowpea is more adaptable to wide range of soils because is more tolerant to infertile and acid soils than many other crops, but performs best on well-drained sandy loams or sandy soils where soil pH is in the range of 5.5 to 6.5, with rainfall of 760 - 1520 mm during the growing period (Davis *et al.*, 1992). This adaptation to lighter soils is due to adaptability mechanism of cowpea such as, the less restrictive root growth, coupled with drought tolerance through reduced leaf growth, less water loss through the stomata and leaf movement to reduce light and heat load under stress (National Department of Agriculture, 2009). Cowpeas are mostly susceptible to cold soils than common beans.

The optimum temperature for growth and development is around 30 °C. The time and location of sowing may influence the time of flowering of photosensitive varieties and may be more than 100 days (National Department of Agriculture, 2009). The optimum recommended sowing time is December to January (Singh *et al.,* 2011). Even in early flowering varieties, the flowering period can be extended by warm and moist conditions, leading to asynchronous maturity (Valenzuela and Smith, 2002).

2.3 Importance and utilization of cowpea

2.3.1 Food uses and nutritional benefits of cowpea

Cowpea is an important crop to the livelihoods of millions of people, especially poor people in less developed countries living in the subtropics and tropics (Quin, 1997). Cowpea production remains the most prominent food legume cultivated by smaller-holder farmers majorly in most of the Sub-Saharan African countries and could be the solution to the increasing world demand of less expensive proteins with good nutritional and functional properties, particularly in developing and under-developed countries where the supply of food of animal origin is limited due to non-availability and high cost (Singh *et al*., 2002). The chemical composition of cowpea is similar to that of most edible legumes; it contains about 24% protein, 62% soluble carbohydrates and small amounts of other nutrients. Thus, most of its nutritional value is provided by proteins and carbohydrates (Lambot, 2002).

Singh *et al*. (2002) reported that cowpea can be consumed at all stages of growth as a vegetable crop, all parts of the plant can be used as food and it is a good food security item because it mixes well with other recipe, the dry seed are used in various dish preparations or meals (Agbogidi and Egho, 2012). The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature snapped pods are usually used in the same way as snap beans, often being mixed with other foods.

Green cowpea seeds are boiled as a fresh vegetable, or may be canned or frozen. Dry mature seeds are also suitable for cooking and canning (Davis *et al*., 1992). In addition, consumption of legumes has been related to many beneficial physiological effects in stabilizing various metabolic diseases such as coronary heart disease and colon cancer (Bazzano *et al*., 2001). Besides its nutritious and its health related benefits, cowpea provides many farmers, largely smaller farmers in South Africa with source of income and also farmers tend to generate income in purchase of cowpea beans, which are inexpensive, considerably cheaper than rice or any other dietary fibre type (Adeniji, 2007).

2.3.2 Soil amendments and fodder uses of cowpea

Cowpea makes a valuable contribution towards human food and livestock fodder and its dual-purpose character makes it a very attractive crop where land is becoming scarce (Singh *et al*., 2003). Cowpea is well-adapted to the semi-arid regions of the tropics where other food legumes do not perform well. Cowpea has the unique ability to fix atmospheric nitrogen through its nodules and grows well even in poor soils with more than 85% sand, less than 0.2% organic matter and low levels of phosphorus (Singh *et al*., 2003). The nitrogen content of cowpea is about 1.5%, farmers can take advantage of the natural ability of cowpea to fix atmospheric nitrogen, as these ability leads to more fertile soils and making fertilizer availability less of a perquisite (Valenzuela and Smith, 2002).

Coupled with these attributes, its quick growth and rapid ground cover checks soils erosion and root decay in situ produces nitrogen-rich residues that improve soil fertility and structure. Together, these characteristics have made cowpea an important component of subsistence agriculture particularly in the dry savannas of the Sub-Saharan Africa vitamins (Singh *et al*., 2003). It is also used as a green manure crop (Davis *et al*., 1992; Zyl and Sadi, 2005). Cowpea is compatible in plant production systems, because of its quick growth, it could be used for erosion control especially the spreading type and establishment and its residues increasing organic matter in turn improving soil structure through decomposition of this residues and it has excellent heat and good drought tolerance (Magloire, 2005). However, In spite of all the positive characteristics, it is a fact that there is presently a shortage of good seed and a lack of available improved cultivars in South Africa (Asiwe *et al*., 2012). The lack of improved varieties and high yielding varieties in South Africa may be due to lack of introduced varieties and evaluation for characterization.

2.4 Cowpea production in the world

There are some indications that recent FAO statistics underestimate the production of cowpea and also with correspondence with scientists in several countries and cowpea researchers at the International Institute of Tropical Agriculture (IITA), estimated cowpea production to be under an area of 14 million ha, with 8 million ha (64%) in West and Central Africa and with over 4.5 Mt annual productions (Singh *et al*., 1997). The important cowpea growing countries in West and Central Africa are Benin, Burkina Faso, Cameroon, Chad, Ghana, Mali, Niger Republic, Nigeria, Senegal, and Togo (Lambot, 2002).

Most of the world cowpea production comes from the West-Central Africa where countries such as Nigeria, Niger, Burkina Faso, Senegal, Ghana, Cameroon and Mali are the most important producers. Nigeria contributes more than 50% of the total world cowpea grain production, cultivating on about 5 million ha and over 2 million tons production annually (Magloire, 2005). The largest cowpea market in the world is Dawanau Market in Kano in Northern Nigeria. Cowpea storage capacity in Dawanau Market exceeds 200,000 metric tons (Mashili, 2007).

Niger Republic is the second largest producer with 3 million ha and over 650 000 tons production. Cowpea is grown with an estimated 45 000 tons annual production of dry cowpea seed and a large amount of frozen green cowpeas in Southern America (Singh *et al*., 2003). India is the largest cowpea producer in Asia and together with Bangladesh, Indonesia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and other Far Eastern countries, there may be over 1.5 million ha under cowpea in Asia (Singh *et al*., 2002). There is a need to make concerted efforts to collect accurate statistics on cowpea area and production in different countries.

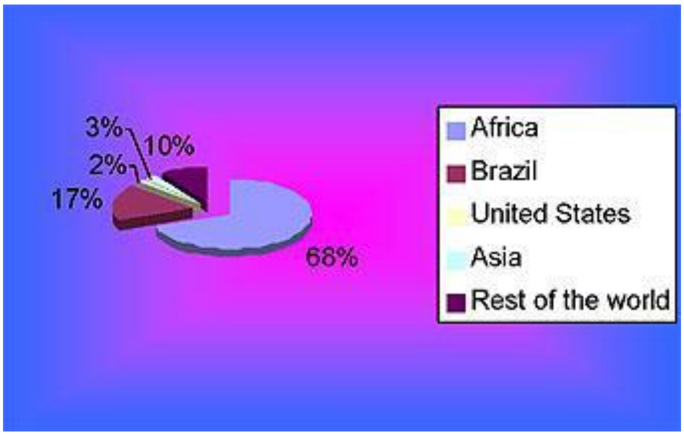

Plate 1: Cowpea production in the world (Gomez, 2004)

2.5 Cowpea production in South Africa

Cowpea is regarded as the pivot of sustainable farming in semiarid areas and tropics, this include South Africa. Production of cowpea in South Africa is done under dry land, mostly by small holder farmers. There are no records indicating the size of area under production and quantities produced by the smallholder farmers in South Africa (National Department of Agriculture, 2009).

Asiwe (2009) reported that the efficient research in the cultivation of cowpea have reduced drastically in the last thirty years in South Africa. This could be as a result lack of funding by the government to boost its production as well as the lack of interest by researchers in promoting the improvement of the crop. It was further attributed that sound knowledge of effective agronomic practices, absence of good seeds for cowpea production in some of the provinces most especially Kwazulu-Natal, Limpopo and Mpumalanga (Adebowale, 2011). Acreage cultivated per farmer was also very small because grain yield was very low.

In South Africa, cowpea production is relatively not as high in magnitude compared to other stable crops such as maize, due to lack of economic support for production in-contrast to stable crops. These assessments confirmed that cowpea production in South Africa is still at subsistence level and needs a lot of improvements in terms of yield enhancement and reducing the constraints to its production (Asiwe, 2009).The consequence of this is that, varieties which are cultivated are not improved, which means less quality fodder and grain produced. If cowpea production is to be increased in South Africa, new better yielding varieties and well adapted varieties have to be introduced so that farmers would likely adopt them into their production systems.

2.6 Production constraints of cowpea

2.6.1 Abiotic stress: Drought stress of cowpea

Drought stress represents one of the most important abiotic constraints limiting cowpea production in the arid and semi-arid zones of Africa (Abdou Razakou *et al.,* 2013). The excessive poorly distributed or scarcity rainfall and high diurnal temperature contribute largely to drought in most developing countries (Asiwe *et al.*, 2005). Despite cowpea being more drought tolerant than many other crops, still moisture availability is the major constraints to growth and development, especially during germination and flower setting.

Erratic rainfall affects adversely both plant population and flowering ability, resulting into tremendous reduction of grain yield and total biomass in general (Timko and Singh, 2008). Magloire (2005) reported that drought stress of cowpea at the flowering stage is the most susceptible to severe imposed stress (-14 to -28 bars leaf water potential). Drought stress during the vegetative stage irreversibly reduced leaf area and caused significant yield decline.

Flower and pod abscission during severe moisture stress also serves as a growth-restricting mechanism (National Department of Agriculture, 2009). Drought can significantly influence plant performance and survival and can lead to major constraints in plant functioning, including a series of morphological, physiological and metabolic changes (Hayatu and Mukhtar, 2010). Stomatal conductance, transpiration and photosynthesis are affected due to water stress. Drought affects photosynthesis directly and indirectly and consequently dry matter production and its allocation to various plant organs (Hayatu and Mukhtar, 2010). Many aspects of plant growth are affected by drought stress; these include leaf expansion, production and promote senescence and abscission.

Cowpeas react to serious moisture stress by limiting growth (especially leaf growth) and reducing leaf area by changing leaf orientation and closing the stomata (Timko and Singh, 2008). Under drought conditions, early maturing varieties could be the coping strategy, because they mature early, they can avoid stress during the maturity stage. Planting of more adaptable or resistance varieties to drought conditions can be a coping strategy to drought stress, hence evaluation is necessary to evaluate more adapting varieties (Timko and Singh, 2008).

2.6.2 Biotic stress

The biotic factors include insect pests, parasitic flowering plants, as well as viral, fungal and bacterial diseases (Emechebe and Lagoke, 2002).

2.6.3 Insect pest

Cowpea is highly attractive to pests and aphids than most legumes; the unimproved cowpea plant has a low level of resistance to insects and consequently produces very low crop yields (Egho and Enujeke, 2012). Insect-pests attack and damage the crop at all growth stages. Insect pests belong to the major biotic stresses in cowpea growing regions in both developing and developed countries (Ndong *et al.,* 2012). Asiwe (2009) reported that major and important insect pests of cowpea found in South Africa were aphids, pod-sucking bugs and cowpea weevil.

Early aphid infestation, especially during seedling stage, often results in total crop failure. Cowpea aphid (Aphis craccivora Koch) is an important pest of cowpea in most tropical areas where cowpea is grown (Karungi, 2000). Losses in grain or foliage attributed to field pests of cowpea ranges from 20% to almost 100%, cowpea aphids feed on tender young leaves, shoots, succulent green stems and pods. The damage caused by adults and nymphs and is either direct through depleting plants assimilates through sucking and through injection of its toxic saliva to the plant or through transmission of virus particles that in turn cause disease to the plant (Sariah, 2010). They also secrete honeydew that usually forms sooty mold which compromises plant photosynthesis.

The most damaging of all insect pests are those that occur during flowering, thrips *(Megalurothrips sjostedti)* infestation on flowers, results in tremendous yield losses. Yield loss due to thrips infestation ranged between 20 to 80% (Luka *et al.*, 2014). Under severe infestation, a 100% yield loss has been observed, cowpea crop has been reported to be infested with two species of thrips, *Sericothrips occipitalis* and

Megalurothrips sjostedti (Thripidae). Plant parts mainly attacked by thrips are flower buds and later the flower themselves; flower damage by thrips is characterized by a distortion, malformation and discoloration of the floral parts (Sariah, 2010). Flower abortion is of normal magnitude in plants that are infested with thrips.

Amongst the most damaging insect pests are those that occur during podding stages, which include the legume pod borer (*Maruca vitrata*) and a complex of pod and seed suckers, of which *Clavigralla tomentosicollis* is the dominant (Karungi *et al*., 2000). Pod sucking bugs are accountable to yield reduction of up to 14% to 80% per season of planting. Adults and nymphs of pod bugs suck sap from green pods, causing abnormal pod and seed formation (Karungi *et al*., 2000).

Cowpea suffers severe grain damage in storage due to the bruchid, *Callosobruchus maculatus (F)*. The bruchid causes irreversible losses to stored grain, with initial infestation beginning at the field level from where it is carried over to storage. These results not only in direct weight loss but also reduces grain quality making the seed unfit for human consumption or for planting (Opolota *et al*., 2006).

2.6.4 Weeds effect on cowpea

Weeds are a serious problem in cowpea production and, if not well managed, can harbour pests and reduce both the yield and the quality of the grain. Fodder yield can also be reduced (Dugje *et al*., 2009). Cowpea is not a strong competitor with weed, especially at the early stage of growth. The parasitic weed (striga) poses a major threat to cowpea production in Africa. Two striga species and its distribution in Africa have been reported. *Striga gesneriodes* is mostly found in Sudan and West Africa, while *Alectra vogelii* is found in Guinea, Sudan, West and Central Africa and part of Eastern and Southern Africa (Timko and Singh, 2008).

Field observation revealed that yield loss varied from 3.1% to 36.5% depending on the susceptibility of the cowpea genotypes to *Striga* pathogen. Other ways in which weeds impact cowpea growth is by reducing product quality. Either the crop grown has received less water and nutrients due to competition from weeds and is therefore lower in quality or quantity or the crop has been infected with a disease carried by the weeds or damaged by insects that live in the weeds (Sheley and petroff, 1999). Weeds and especially noxious or invasive weeds have more of an impact than just on the agricultural community. They can alter the environment in several ways such as reducing the plant biodiversity, animals, insects and microorganisms. They can create monocultures, which are undesirable habitat for the native plants, animals, insects and other microorganisms (Sheley and petroff, 1999). Even if they don't create a monoculture they can eliminate certain species critical to other species survival.

2.7.1 Fungal diseases

Cowpea diseases induced by species of pathogens belonging to various pathogenic groups (fungi, bacteria, viruses, nematodes, and parasitic flowering plants) constitute one of the most important constraints to profitable cowpea production in all agro ecological zones where the crop is cultivated (Aliyu *et al*., 2012). Cowpea is attacked by atleast 35 diseases; the occurrence and severity of these individual diseases vary from place to place and the stage of plant growth. The average yield losses due to diseases range from 50% to 80% but under severe infestation, the crop may be completely destroyed (Singh *et al*., 1983).

The fungal diseases include: damping-off (*Pythium* spp.) may occur on seedlings under moist conditions and in dense plantings. Root rot (*Verticillium* spp.) and stem rot (*Fusarium* spp.) may also be a problem (Magloire, 2005). Cowpea is susceptible to powdery mildew (*Erysiphe polyqoni*) during wet winter months and under humid conditions. Other diseases that affect cowpea include Anthracnose (*Colletotrichum lindemuthianum)*, Charcoal Rot (*Sclerotium bataticola*) and Band Fusarium Wilt (*Fusarium oxysporum vr. tracheiphilum)* (Oyewale and Bamaiyi, 2013). Bacterial pathogens include*;* bacterial pustule, bacterial blight, anthracnose cercosa leaf spot, wilt and stem rot, septoria, web blight etc. (Singh *et al*., 1983).

2.7.2 Viral diseases

Viral diseases are among the most agriculturally important and biologically intriguing groups of plant pathogens, and cause serious economic losses by reducing yields and quality of the crop Worldwide, 20 viruses have been reported to occur on cowpea, but only eight viruses are known to infect cowpea in Africa (Orawu *et al*., 2005).These Viral diseases include, Cowpea aphidborne mosaic virus (CABMV) Genus potyvirus, blackeye cowpea virus (BLCMV) Genus potyvirus, cowpea mosaic virus (CPMV) Genus comovirus, cowpea mottle virus (CPMOV) Genus carmovirus (Oyewale and Bamaiyi, 2013).

Losses due to viral infections are estimated to be between 10 and 100%. Cowpea yields, especially among subsistence farmers, are generally low due to biotic stress, especially diseases remain a major constraint to production on a large scale (Orawu *et al*., 2005). Viruses constitute major constraints in all agro ecologies where cowpea is grown and for an effective diagnosis of virus diseases, an adequate knowledge of the viruses and the strains occurring in the main cowpea-growing areas of Africa is a pre-requisite for effective control (Aliyu *et al*., 2012).

2.8 Control measures

There are several methods suggested for managing abiotic stresses, such as: chemical, biological and agronomic control or cultural practice, and host-plant resistance (Oyewale and Bamaiyi, 2013).

2.8.1 Cultural practices and physical practices

Cultural practices are economical, environmentally safe and less hazardous to humans and often less toxic to ecologically beneficial insects as well as the development of resistance by insect pest (Oruonye and Okrikata, 2010). Insect pest and diseases problems on cowpea can be reduced by use of proper cultural practices which involve ecological manipulations, like proper planting time, planting densities, correct pesticides, insecticides application, intercropping and catch crops reduces incidence of insect pest damage and aphid infestation (Adipala *et al*., 2000).

There are many good reasons to plant on time, planting on time helps to prevent the crop from being hit by drought before it has matured, which means the yield is more likely to be good. Planting with the first good rains also means the crop will grow quickly and be strong when pest and disease problems arise (Mousavi and Eskandari, 2011). Also, some pests and diseases don’t have an impact on crop yield if they attack the crop when it is nearing maturity. Intercropping and crop rotation are an example of sustainable agricultural systems following objectives such as: ecological balance, more utilization of resources, increasing the quantity and quality and reduce yield damage to pests, diseases and weeds. One important advantage of these sustainable agricultural systems is its ability to reduce pest and disease damage (Mousavi and Eskandari, 2011).

Addressing pest problem, using correct plant densities can be the most effective of cultural practices, for example, a series of experiments were undertaken in eastern Uganda, a major cowpea growing area of the country, one trial evaluated the effect of different densities (30 x 20 cm^2, 60 x 20 cm^2, 90 x 20 cm^2 and 120 x 20 cm^2), which corresponded to approximately 183,333; 100,000; 66,667; and 50,000 plants/ha, respectively) (Karungi *et al*., 2000). Results indicate that planting at the on-set of rains, with the 30 x 20 cm^2, 60 x 20 cm^2 densities were the best cultural practices as far as pest management was concerned. Planting catch crops such as cotton and alfalfa reduce incidence of cowpea infestation, by attracting insect away from the intended pest (Adipala *et al*., 2000).

Physical control of cowpea is the use of some physical components of the environment, such as temperature, humidity, mechanical shock, and pneumatic control to the detriment of pests. In some cases heavy rain may reduce the number of aphids, for example the black cowpea aphid, which is very exposed on the pods (National Department of Agriculture, 2009). Frequently, parasites and predators prevent the infestation from becoming established throughout a field (Vincent *et al*., 2003). Hot temperatures higher than 30 °C frequently inhibit build-up of large densities of aphids. If a few plants are seriously affected these can be pulled up and burnt or fed to livestock. Old plants that have been harvested are best removed from the field, as these often host the aphids.

Handpicking of beetles is not frequent because most species are known to give blisters. To speed up handpicking, a basic homemade net could be used for catching the flying beetles (National Department of Agriculture, 2009). Physical and cultural control methods are less cost effective but labour consuming and time consuming; hence use of biological control can sometimes be an effective management strategy.

2.8.2 Biological control

Biological control, which is nothing else than exploiting naturally occurring mortality factors by the manipulation of antagonistic and or parasitic organisms, is regaining substantial interest in cowpea cropping systems (Tamo *et al*., 2010). The advantage of biological control is it a perfect integration with other pest control options, apart from inappropriate use of broad-spectrum pesticides. In field plantings, soil fumigation with a broad-spectrum fumigant controls fungus (Moses, 2006). The effectiveness use of biological methods is unquestionable, however the method requires knowledge and good implementation, is for these reason that famers, smaller holder famers in particular may not prefer to use biological control methods.

2.8.3 Bio-chemical control

Through co-evolution of pests and plants, the host-plant naturally developed protective mechanisms that help them to successfully survive insect pest attack. Cowpea's attraction for insects may be an advantage if the planting also attracts a sizable population of beneficial insects, but it is not if pest outbreaks occur and then move on to attack a cash crop (Oke and Akintunde, 2013).

Careful weekly monitoring is important to ensure that the cowpea planting is not becoming a source of pests on the farm. Similarly to biological control, bio-chemical control may not be conducive and appropriate to be effectively implemented by small holder farmers as it requires appropriate knowledge (Oke and Akintunde, 2013). Most of the farmers find use of botanical and chemical insecticides more effective than use of biological control and bio-chemical control strategies.

2.8.4 Botanical insecticide

As a result of the problems of pesticide resistance and negative effects on non-target organisms including man and the environment, organo chloride has been banned in developed countries, these resuscitated the idea of botanical insecticides as a promising alternative to pest control (Sariah, 2010). Botanical insecticides are naturally occurring chemical extracted from plants which break down readily in the soil and are not stored in plant or animal tissue. They are biodegradable and harmless to the environment. Also, the possibility of insect developing resistance to botanical insecticide is less likely. Over 2000 species of plants are known to possessed insecticidal activities (Oyewale and Bamaiyi, 2013). However, Often their effect are not long lasting as those of synthetic pesticides. Botanical insecticides, unlike chemical insecticides are generally pest specific and are relatively harmless to non-target organisms, which may result in untargeted pest damaging the crop. Botanical insecticides control strategies for management of insects and pests can be used in situations where farmers cannot afford chemical pesticides.

2.8.5 Chemical insecticides

Chemical insecticides are the most effective control measure against cowpea insect pest. Where they have been used, application is usually in the form of emulsifiable concentrate or wettable powder formulations, mixed with water and applied by lever operated knapsack sprayer using hydraulic cone nozzles (Sariah, 2010). Chemical insecticides are the most effective because they turn to be specific to removal of insects.

Although synthetic-chemical pesticides can be used to control some pests economically, rapidly and effectively, most of them cause serious negative impacts, such as; toxicity and residual effects to humans, target plants, foods and other living things, induction of insect/pathogen resistance resulting to ineffectiveness of pesticides; harmful effects to non-target beneficial organisms and unbalanced ecosystem due to pollution of soil, water and environment (Kawuki *et al.*, 2005). In addition, most farmers are not well equipped to protect themselves when using toxic chemicals (Fatokun, 2009), also due to the high cost of chemical pesticides, accessibility may be a problem to small holder farmers.

2.8.6 Host-plant resistance and early maturing cowpea germplasm

Host-plant resistance to insect pest damage is the most economically and environmentally sound method of pest management for both large scale and subsistence cowpea production. This approach is less labour intensive and more secure compared to other methods, thus very appropriate for resource-limited farmers (Hall *et al.*, 2003). Due to these merits, developing varieties with sustainable resistance to these insect pests and other biotic stresses is a major goal of national and international cowpea breeding programs. Reductions in applications of pesticides are an important goal for cowpea research programs in Africa, hence varieties which are resistance to pests are particularly important because they can enhance productivity, product quality and environmental conditions as well as decrease input costs and enhance profits (Hall *et al.*, 2003). New cultivars also can facilitate the extension of improved farming systems. It can be much easier to extend improved crop management, storage and processing methods if they are recommended as part of a package that includes a new cultivar, especially if the cultivar is very attractive to farmers and consumers. The expenses to the farmer are limited because he only has to buy the seed and health risks associated with insecticide application are avoided, it is therefore evident that breeding for resistance to post–harvest pests is important for small and large-scale farmers alike (Ahmed and Yusuf, 2007). However, integrated pest management remain the best option to reduce risk of crop losses due to insect pest, diseases and increase grain yield for the resource poor farmers (Asante *et al.*, 2001).

There is a need for development of early maturing cultivars with regionally acceptable grain quality and resistance to some important diseases and pests including bacterial blight (*Xanthomonas campestris*), cowpea aphid-borne mosaic virus (CABMV), cowpea aphid (*Aphis craccivora*), root-knot nematodes (*Meloidogyne incognita* and *M. javanica*), cowpea weevil (*Callosobruchus maculatus*) and the parasitic weeds (*Striga gesnerioides* and *Alectra vogelii*) (Hall and Ehlers, 1997). Earliness is important in South Africa because early cultivars can escape drought and some insect infestations, can provide the first food and marketable product available from the current growing season, and can be grown in a diverse array of cropping systems. Hall and Ehlers (1997) reported that new early maturing cultivars with indeterminate growth habits have been very effective in the extremely dry and hot environment of the Sahel.

Several screening methods to identify genotypes with resistance to major cowpea insect pests have been developed. The development of resistant cultivars and early maturing cultivars has been universally considered the most effective method to control diseases caused by viruses in cowpea, indicating that an increase in the number of virus-resistant genotypes will generate more alternatives for breeders to produce resistant cultivars (Aliyu *et al*., 2012).

However, despite of the evaluation of many cowpeas accessions, plants with high levels of resistance to most of the major insect pests and early maturing varieties have not yet been released to farmers. Traditionally, morphological and agronomic traits coupled with statistical methods have been successfully used in various agronomic and breeding programs for the identification of accessions resistant to biotic and abiotic stresses (Sariah, 2010).

2.8.7 Integrated pest management (IPM) control

Integrated Pest Management (IPM) attempts to find the optimum combination of control tactics including cultural, biological, physical, and chemical control that will reduce pest population below the economic threshold (Asante *et al.*, 2001). IPM is a safer, usually less costly and reduced-risk option for effective pest management (Oruonye and Okrikata, 2010). An IPM program prevent pests from causing significant losses, encouraging natural enemies, saving money while producing a high quality product, enhance the agricultural productivity and usually has the highest probability of cost effectiveness (Cork *et al*., 2009).

The concept of economic thresholds (ET) in integrated pest management has been introduced to regulate the application of pesticides so that pesticides should be used only when necessary (Ajeigbe and Singh, 2006). One example of IPM approach is the study in Uganda, combining of cultural control practices such as intercropping and time of planting with three applications of pesticides (*dimethoate* and *cypermethrin*) at budding, flowering and podding stages was more effective than the standard weekly spraying regime and gave the highest yields of 791 kg/ha (Cork *et al*., 2009).

However, IPM approaches would not necessarily be embraced by all African legume farmers, even with the promise of higher yields, but it does provide an ideal starting point for adoption of the principles of IPM in a low input system (Cork *et al*., 2009). The challenge to sustainable use of plant protection products is a long-term one. It involves helping farmers to properly control pests in such a way that they do not only minimise immediate risks from dangerous pesticides but also reduce the possibility of accumulating future stocks (Degri *et al*., 2012).

2.9 Collection of cowpea germplasm

Cowpea (*Vigna unguiculata (L.)* Walp) is an important food legume and a valuable versatile crop in the traditional cropping system of South Africa. Availability of better cultivars serve as a stimulus in the development of the rural areas, by increasing the output of the agricultural system using additional inputs (Hall *et al*., 2003). Indetermining the value of any germplasm lines introduced, the germplasm lines must be characterized to determine the genes and agronomic traits that they have.

Cowpea germplasm is maintained in collections around the world with varying levels of accessibility and documentation. The largest collections are held by the IITA with more than 14,000 accessions. The collection can be accessed via an electronic database maintained through the CGIAR-Singer system are good for, and their adaptability to the new environment (Asiwe *et al*., 2012). Breeding programs in Africa (including programs in Botswana, Burkina Faso, Ghana, Kenya, Nigeria, and Senegal) also have substantial germplasm collections. The condition of some of these collections, which are important reserves of local diversity, could be improved with funding for germplasm maintenance and facility repair (Singh, 2007).

Collection of cowpea germplasm has being done in several countries, only little germplasm collection has being done South Africa. Several evaluations and germplasm collection have been conducted by the Agriculture Research Council (ARC) on cowpea by Prof J.A.N Asiwe in South Africa, but due to unreliable funding, characterization of introduced breeding lines has not yielded positive results (Asiwe *et al*., 2012). The provision of research fund by A&M Agri-Life, Texas, USA to characterize the introduced lines could fill the gap. There is need for continuous germplasm evaluation and collection to increases the cowpea outflow and chances of releasing better yielding varieties.To characterise the germplasm lines, they need to be evaluated in the field under optimum environmental conditions and disease pressure (Asiwe *et al*., 2012). It is at this backdrop that the aim of this project is drawn, to evaluate 97 introduced cowpea lines for yield components.

2.10 The essence of the study

Although production of cowpea is widespread worldwide, the yield is less to be desired, averaging 4.5 million tons over 14 million ha throughout the world, and average cowpea yields on the farmers' fields are less to be desired (< 300 kg/ha-1) (Chiulele, 2010; Takim and Uddin, 2010). The resulted low yields are attributed to a number of the biotic stresses such as insect pests, nematodes, diseases and parasitic weeds and abiotic stresses such as drought, high temperature, low soil fertility, low pH and aluminium toxicity (Chiulele, 2010).

Farmers in South Africa, especially in Limpopo Province grow unimproved landraces as a result of unavailability of improved and locally adapted cultivars (Asiwe, 2009). Furthermore, poor cultural practices, insect pest infestation and photoperiod sensitivity contribute to low productivity.The development of cowpea cultivars with enhanced yielding levels and characterization is necessary in South Africa, as most evaluated varieties are not characrized for adaptation. However, there is no visible progress in developing varieties that are high yielding among the germplasm and cultivated landraces grown in the country (Chiulele, 2010).

More cowpea germplasm lines need to be evaluated in order to identify new and better adapted germplasm under South African conditions. Improved cowpea production will alleviate food insecurity and poverty in the country. Two strong reasons given by farmers for cultivating cowpea were source of family income and food (Asiwe, 2009). Cowpea productions serve as source of income for small-holder farmers in most undeveloped countries in the tropics. Hence evaluating this introduced germplasm could contribute to breeding for more adaptable better yielding varieties.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Description of experimental site

The study was conducted over two locations in Limpopo Province, with each location having two experiments, location one was at Ukulima farm near Modimolle in the Waterberg district, during 2012/13-summer planting season and location two was at University of Limpopo experimental farm Syferkuil during 2013/14 season. The Limpopo Province (24.0000° S, 29.0000° E) is in the northern part of South Africa, with an area of 12.3 million hectares and a population of 4.9 million. The Limpopo Province has warm to hot summers with moderate winters, average summer temperatures rise to 28.1°c and drop to 17°c and average winter temperatures range from 19.6°c to 4.7°c.

Ukulima location

The first study was conducted at the Ukulima farm (24°32'58.1" S, 24°06'21.1" E, 1237 m asl), with two experiments. The Ukulima farm is said to receive about 623 mm of rainfall per annum and the climate of the study site was classified as semi-arid (Fenta, 2012).

Syferkuil location

The second study was conducted at the University of Limpopo experimental farm Syferkuil (23^{o}50’ S; 29 º 4´ E), with two experiments. The climate of the study site was classified as semi-arid with the annual precipitation of roughly ±495 mm per annum (Moshia, 2008).

3.2 Land preparation

The field was prepared the same way in both locations, with relevant conventional field implements like plough and harrow and tractor, so as to obtain a desirable and good field for the planting of the trial. The land was prepared similarly in both locations.

3.3 Treatments, experimental design and layout

The study had two experiments in each location, experiment I having 57 early maturing cowpea germplasm and experiment II having 40 medium maturing cowpea germplasm. Ninety seven (97) cowpea lines and one local check (Glenda) were used in both locations. These materials were introduced from IITA, Nigeria and A&M University, Texas, USA. The experiments were laid out as an incomplete randomized block design (lattice design), consisting of 3 replications, four rows per plot with intra row spacing of 25 cm and inter row spacing of 75 cm.

Each row was 4m long, the plot size being 0.25m x 0.75m x 4m. The planting method used was drilling. Weed control was carried through application of 30ml Dual and 200 ml Gramozone in 15 litres of water using knapsack, while insect pest control was done through the application of insecticide Karate, applied at 180ml in 15 litres of water using knapsack. Insect control was done at seedling stage and during pod formation to avoid insect damage.

3.4 General data collection

The following yield parameters were collected virtually the same way in the two locations in the two experiments.

3.5 Plant height

Plant height were measured and taken randomly from two plants from the net plot at plant maturity in each plot, using a meter ruler.

3.6 Number of pods per plant

Five plants were sampled randomly from each plot in order to take the number of pods per plant. The number of pods was taken from the randomly selected five plant sample in the two mid rows in each plot counted manually.

3.7 Pod length

Five plants were sampled randomly from each plot in order to take pod length. Pod length from three pods of each of the five sampled plants in each plot were measured to determine the average length using ammeter rule.

3.8 Number of seed per pod

Five plants were sampled randomly from each plot in order to take number of seed per pod. Number of seed from the three pods of the five sampled plants in each plot was counted manually, to determine the average number of seed in each pod.

3.9 Hundred seed weight

Hundred seed was collected from the net plot and counted and weighed to determine hundred seed weight.

3.10 Grain and fodder yield

Grain and fodder yield were determined from the net plot to measure the genetic potential of the varieties for grain and fodder yields.

3.11 Data analysis

Data was subjected to ANOVA using statistical software, Statistic 9.2. The variances of the parameters measured were summarized in ANOVA Table. The treatments that showed significant mean differences were separated using Duncan Multiple Range at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and discussion

Ninety seven (97) cowpea breeding lines used in this study were separated into two experiments, experiment one (I) having 57 early maturing cowpea varieties and experiment two (II) having 40 medium maturing cowpea varieties. The following morphological yield parameters were collected; plant height, number of seed per pod, pod length, numbers of branches, number of pods per plant, seed weight, pod weight and hundred seed weight.

4.2 Experiment I (early maturity cowpea germplasm) results

The results showed significant difference ($P<0.05$) among cowpea varieties in the two locations for the following yield parameters; plant height, number pods per plant, number of branches, seed weight and pod weight, indicating considerable genetic variability for these traits. However there was no significance difference ($P \geq 0.05$) between the two locations for the following yield parameters; number of seed per pod, pod length and hundred seed weight.

4.3 Plant height

The results of the study indicated there was significant difference ($P \leq 0.05$) for the measured plant height in the two locations (Table 1). Cowpea breeding lines planted at Ukulima farm (UKF) performed better than those planted in Syferkuil farm (SYF), with a mean of (63.19 cm) and (51.15 cm) respectively (Figure 1). Variety IT98K-205-8 had the best mean plant height of 100.1cm in UKF, whereas IT86D-1010 was the best performing in SYF, with a mean value of 63.00 cm. Variety TVU 13464 had the lowest mean among the evaluated cowpea varieties in both locations, with a mean of 41.33 cm in UKF and 35.00 cm in SYF.

The best five cowpea germplasm at UKF in an increasing order were IT98K-205-8, IT86D-1010, IT98K-589-2, IT83D-442 and TX08-49-1. However, at SYF the best five cowpea germplasm were IT86D-1010, IT98K-589-2, IT84S-2246, IT83D-442 and TX12-471. Three lines that performed well at UKF performed well also at SYF, these three lines (IT86D-1010, IT98K-589-2, and IT83D-442) were stable in both locations. The results indicated that 54 of the 57 cowpea varieties planted at UKF performed better than Glenda (local check), while 30 of the 57 lines planted at SYF were better adaptable than Glenda.

The results showed that the cowpea varieties were more adaptable at UKF than at SYF. The observed variation between varieties in both locations for the evaluated cowpea varieties may be due to climatic factors (e.g. rainfall etc.). The result of the study are in line with the result of Basaran *et al*. (2011) who attributed that the variation in plant height could be due to the difference in the amount of rainfall between two locations and the distribution of the rain (Appendix 1). Kelechukwu *et al.* (2007) observed that cowpea height is varietal dependent as certain varieties are taller than others. The results showed location influenced the performance of the evaluated cowpea breeding lines.

Table 1: Analysis of variance for plant height for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	686.1	343.1		
Location	1	12396.1	12396.1	198.58	0.0050
Error rep*location	2	124.8	62.4		
Variety	56	15676.3	279.9	4.85	0.0000
Location*variety	56	11805.0	210.8	3.66	0.0000
Rep*location*variety	224	12916.4	57.7		
Total	341	53604.8	13335.0		

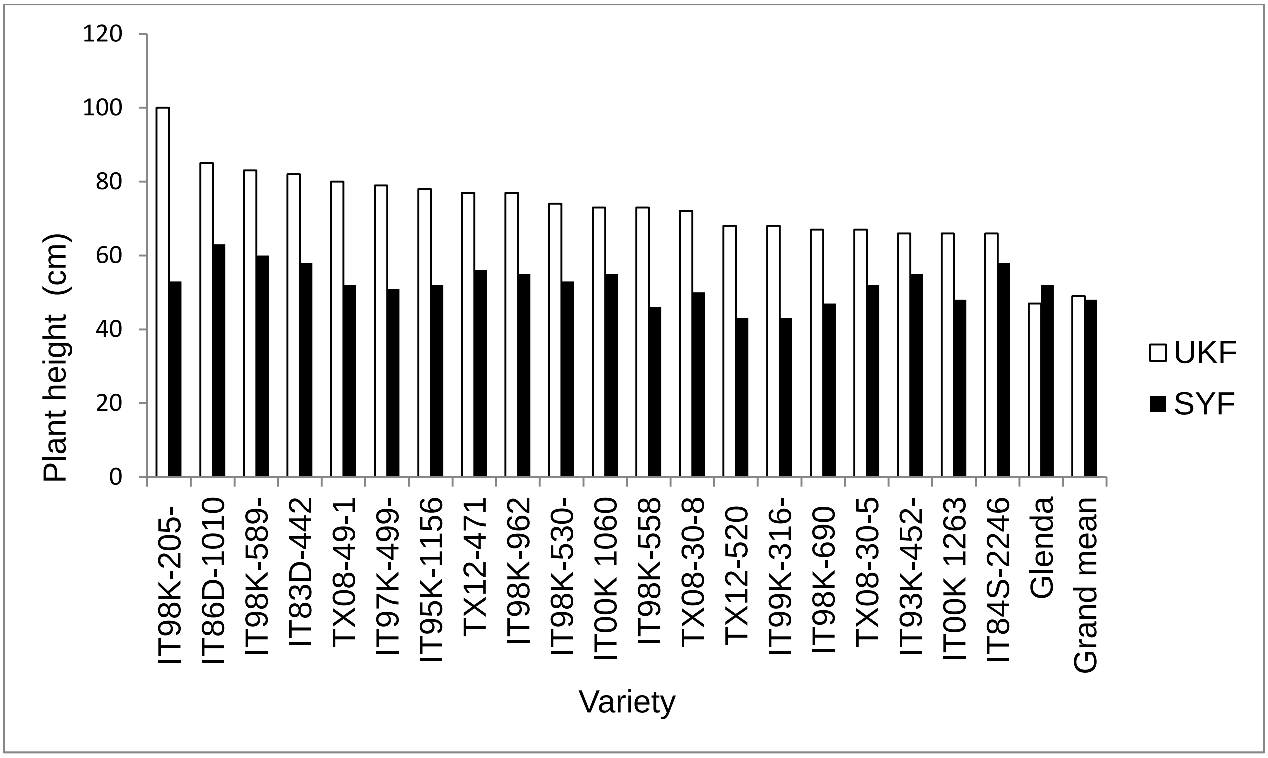

Figure 1: Mean plant height for early maturing cowpea germplasm

4.4 Number of pods per plant

Table 2 shows analysis of variance for number of pods per plant and Figure 2 shows the frequency distribution of the 57 cowpea varieties for number of pods per plant, in both locations. There was significance differences (P≤ 0.05) among number of pods between the two locations. Cowpea varieties planted at UKF were better adaptable than those planted at SYF, with a mean of 13.39 and 11.39 respectively. The mean value ranged from (5.07 to 23.33) in UKF, while at SYF the mean value ranged between (8.87 to 18.43).

The results indicated that of the 57 cowpea varieties planted at UKF, 2 lines had less number of pods per plant than the Glenda and 20 lines had equal number of pods per plant than Glenda, and 35 cowpea varieties had high number of pods per plant than Glenda. However, results for the 57 cowpea germplasm planted at Syferkuil, 1 line had less number of pods per plant than Glenda and 37 lines had equal number of pods per plant than Glenda, and 20 varieties produced high number of pods per plant than Glenda.

The accession which obtained greater number of pods per plant was TX08-4-1 in UKF, with a mean of (23.13). However, at SYF TX08-74-1 obtained the highest number of pods per plant at SYF with a mean of (14.60). TX12-613 had the lowest number of pods per plant in both locations, with a mean of 6.20 in UKF and 6.50 in SYF. TX08-4-1, IT93K-452-1, IT99K-316-2, IT98K-1111 and TX12-445 were the top five varieties at UKF in an increasing order, while TX08-74-1, IT97K-499-35, TX08-74-1, TX123 and TX12-445 were the best five cowpea germplasm in SYF. The results showed that only 1 line (TX12-445) was stable in both locations.

The resulted observed significance difference ($p<0.05$) between the cowpea accessions for counted number of pods per plant between the two locations may be due to genetic variability. These results are supported by the result of Fery (1985), who confirmed in his work that variation in number of pods per plant among varieties is due to genetic factors, and estimated that a heritability of 53.1 percent accounted for the observed differences in the varieties he used and Ali *et al.* (2009) who observed that significant difference in number of branches per plant was as a result of varietal difference in cowpea. Thus, we regard the variation observed for number of pods per plant is attributed to genetic control (Idahosa, 2010).

Table 2: Analysis of variance for number of pods per plant for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	31.96	15.981		
Location	1	341.04	341.04	10.98	0.1893
Error rep*location	2	177.81	88.905		
Variety	56	1304.69	23.298	1.29	0.0013
Location*variety	56	1298.71	23.182	1.19	0.0014
Rep*location*variety	223	2859.52	12.823		
Total	341	6013.73	505.229		

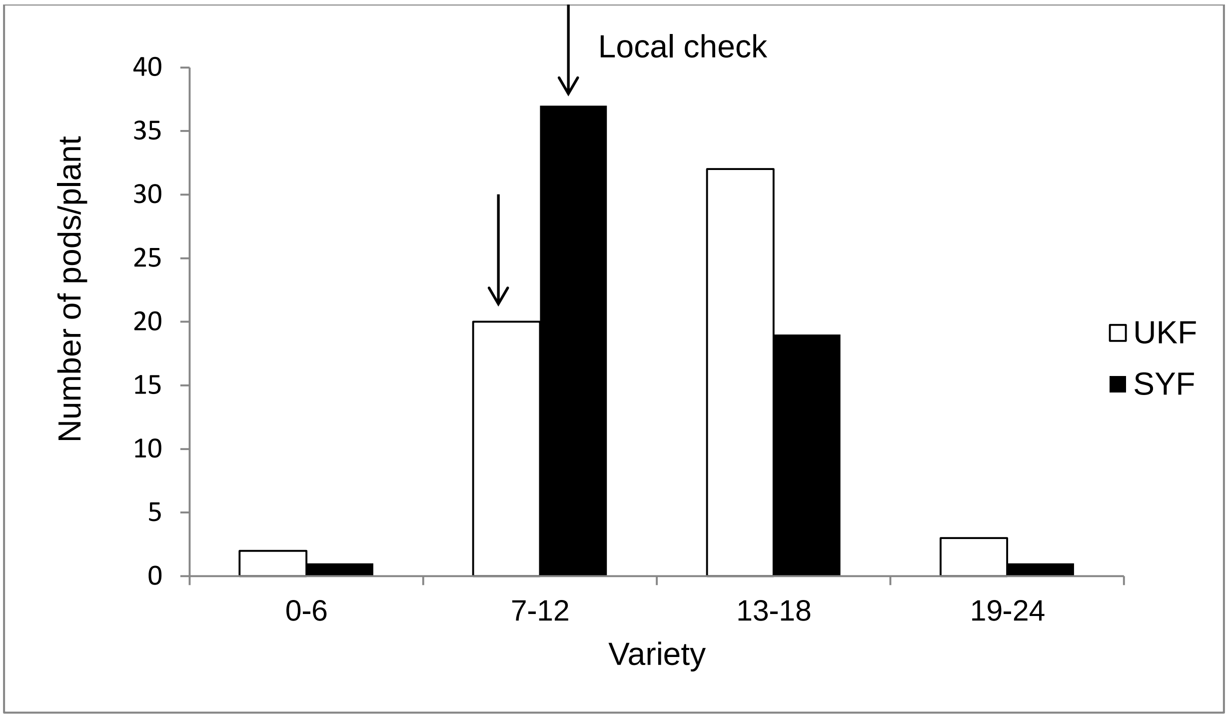

Figure 2: Frequency distribution for number of pods per plant for early maturing germplasm.

4.5 Pod length

There were no significance differences (P≥0.05) between the two locations (Table 3). However, there was significant difference observed among the cowpea varieties. The grand mean between the two locations was nearly the same, with a mean of 17.03 cm in UKF and 17.00 cm in SYF (Figure 3). Mean pod length from UKF farm ranged between (13.17 cm to 23.16 cm) and (12.57 cm to 20.00 cm) in SYF.

ITOOK-1263 had the longest pods in both locations, with a mean value of 23.16 cm in UKF and 20.00 cm in SYF. Glenda had the shortest mean pod length in both locations, with a mean of 13.17 in UKF and 12.57 in SYF. The 57 cowpea varieties in both locations obtained longer mean pod length than Glenda. The top five performing lines at UKF farm in an increasing order were IT00K-1263, IT95K-1156, IT99K-316-2, IT00K-1060 and IT97K-568-1, whereas IT00K-1263, IT95K-1156, TX12-520, IT82D-889, and IT99K-316-2 were the best five in SYF. Three lines (IT00K-1263, IT95K-1156, and IT99K-316-2) showed stability in the two locations.

Grand mean for the measured mean pod length was virtually the same in both locations, these implied that pod length was variety specific and least influenced by the environment. The observed non-significant difference for mean pod length could be under strong genetic control (Khan *et al*., 2010). The inference is that environmental conditions had little or no effect on pod length in cowpeas. Fery (1985) showed that pod length was highly heritable with average heritability estimate of 75.2 percent. Fery (1985) reported that the non-significant effect of plant density on pod length was less effective and that when density stress was induced in a population, various plant parts would be affected or unaffected by their degree of plasticity at different intensities.

Table 3: Analysis of variance for pod length for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	17.03	8.5129		
Location	1	0.57	0.5690	0.19	0.7023
Error rep*location	2	5.84	2.9189		
Variety	56	660.28	11.7908	5.08	0.0000
Location*variety	56	425.89	7.6052	3.27	0.0000
Rep*location*variety	223	520.39	2.3222		
Total	341	1630.00	33.719		

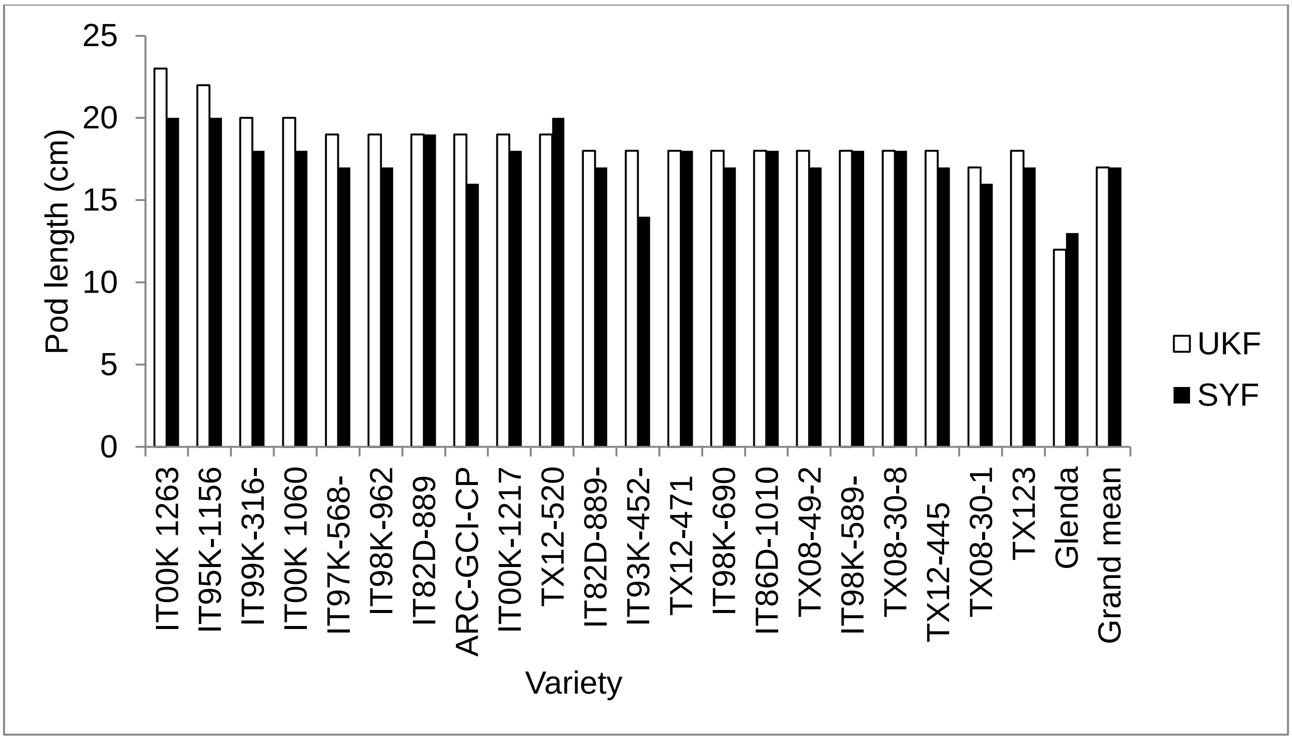

Figure 3: Mean pod length for early maturing cowpea germplasm.

4.6 Number of seed per pod

The results indicated that there was no significance difference (P≥0.05) observed among the locations for the counted number of seed per pod, although there was significant differences among the varieties (Table 4). Cowpea lines planted at UKF had grand mean of 11.05 and 11.06 for those planted at SYF. The resulted mean range varied slightly at UKF and SYF, ranging from (7.89 to 15.33) and (7.73 to 14.67) respectively. The highest number of seed per pod was obtained by TX12-468 in UKF with a mean value of (16.00) and IT82D-889 with a mean value of (14.00) in SYF (Figure 4). IT84S-2246-4 had the lowest number of seed per pod in UKF, with a mean of 7.887, while TX12-570 had the lowest number of seed per pod in SYF, with a mean of 7.733.

TX12-468, IT97K-390-2, PAN 311, IT82D-889 and IT82D-889-1 were the top five performing lines at UKF and the best five performing lines at SYF in an increasing order were IT82D-889, IT97K-390-2, IT83D-442, IT86D-1010 and ARC-GCI-CP. Variety IT97K-390-2 was stable in both locations. Fifteen of the 57 cowpea varieties planted at UKF had higher mean number of seed per pod than Glenda and at SYF 23 of the 57 cowpea varieties had higher mean number of seed per pod than Glenda.

The results show that location did not affect the number of seeds per pod. These imply that seed number per pod was genetically controlled and that environmental conditions may have had little or no effect on it (Muli and Saha, 2008). Muhammad *et al*. (1994) attributed that the difference in number of seed between genotypes could be due to an environment which promote early maturity thus minimum time was available for seed setting and development. Table 4 shows analysis of variance for number of seed per pod for early maturing varieties and Figure 4 shows the highest 20 means for number of seed per pod for early maturing germplasm, in both locations.

Table 4: Analysis of variance for number of seed per pod for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	2.93	1.4652		
Location	1	0.01	0.0112	0.00	0.9501
Error rep*location	2	4.50	2.2520	0.00	
Variety	56	614.34	10.9704	3.14	0.0000
Location*variety	56	292.92	5.2306	1.54	0.0218
Rep*location*variety	223	783.53	3.4979	0.00	
Total	341	1698.23	23.4273		

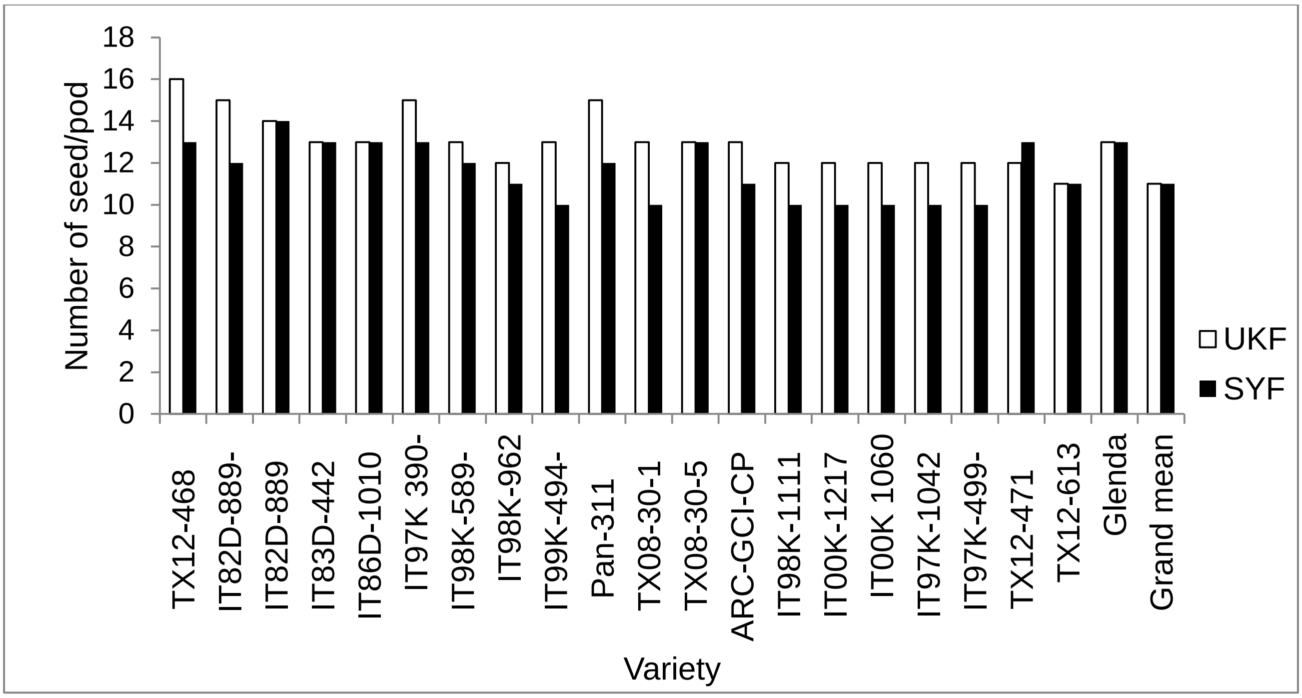

Figure 4: Mean number of seed per pod for early maturing cowpea germplasm

4.7 Number of branches per plant

There was significance differences (P≤ 0.05) among number of branches per plant between the two locations (Table 5). Cowpea breeding lines planted at UKF were found to perform better than those planted at SYF, with a mean value of 8.681 and 7.903 respectively (Figure 5).

TX08-4-1 had higher number of branches per plant than other cowpea accessions in both locations with a mean of 21.00 in UKF and 15.00 in SYF. The best five cowpea varieties at UKF were TX08-4-1, TX08-30-9, TX12-445, IT98K-1111, TX12-520 and TX12-58, whereas the top five cowpea varieties at SYF were TX08-4-1, IT99K-494, IT93K-452-1,ITX98-690 and TX12-471. Variety TX08-4-1 showed stability in the two locations. IT82D-899 had the least number of branches per plant in UKF, which was not the case at SYF, GEC had the least number of branches per plant at SYF.

Ten of the 57 cowpea lines planted at UKF had more number of branches than the Glenda and 24 of the 57 cowpea lines planted at SYF outperformed Glenda. The resulted difference between the cowpea varieties in two locations can be attributed to good environmental conditions in one location than the other. Results showed by

Ali *et al*. (2009) proved that significant difference in number of branches per plant was as results of varietal difference in cowpea. Addo-Quaye *et al*. (2011) also reported that cowpea plants under high moisture regimes produced more branches and pods per plant than those under deficient moisture (Appendix 1).The results of the study suggest that, UKF produced more number of branches and pods per plant than SYF, due to more moisture than in SYF (Appendix 1). We can then suggest that varieties were more adapted to UKF than SYF.

Table 5: Analysis of variance for number of branches for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	7.231	3.6153		
Location	1	51.423	61.4225	6.31	0.1286
Error rep*location	2	16.503	8.1524		
Variety	56	417.456	7.4546	2.38	0.0000
Location*variety	56	415.238	7.4150	2.37	0.0000
Rep*location*variety	223	697.740	3.1289		
Total	340	1605.591	91.1887		

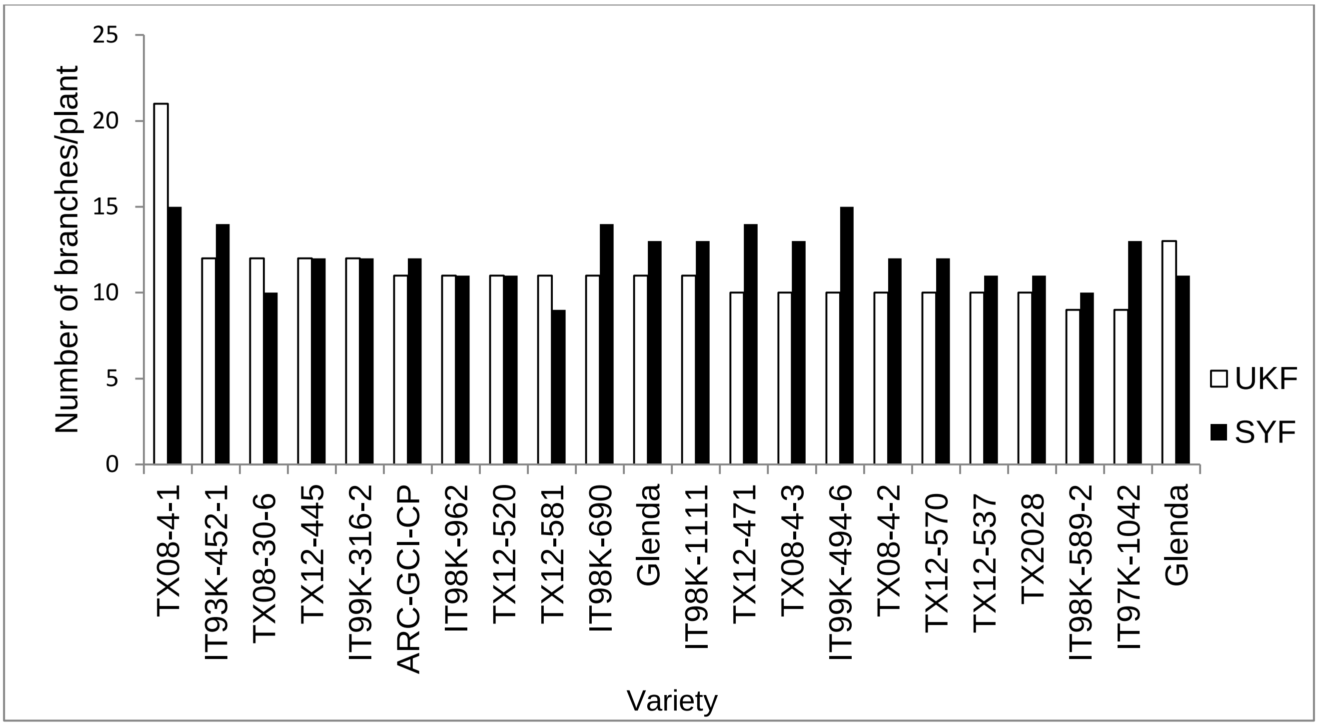

Figure 5: Mean number of branches per plant for early maturing cowpea germplasm

4.8 Pod weight

The results showed there was significance difference (P≤ 0.05) for the measured pod weight taken from five plants per pod, but no significance difference between the two locations (Table 6). Thrity four of the 57 cowpea varieties planted at UKF were found to be superior to Glenda and 33 of the 57 cowpea germplasm planted at SYF had a higher mean pod weight than Glenda.

TX08-4-1 was the top performing line in both locations with a mean of 1413.36 kg/ha in UKF and 1174.29 kg/ha in SYF (Table 1). IT95K-1491 had a lower mean pod weight at UKF than all the other cowpea germplasm, with a mean of 256.03 kg/ha. However, IT95K-1042-3 had a lower mean pod weight at SYF, with a mean of 511.15 kg/ha. The five top cowpea varieties for the weighed mean pod weight at UKF were TX08-4-1, TX12-520, TX08-49-2, TX12-471 and TX12-537, while the best top five cowpea varieties at SYF were TX08-4-1, TX12-520, IT86D-1010, IT98K-1111 and TX12-537. The result shows that three (TX08-4-1, TX12-520 and TX12-537) of the five top cowpea varieties were stable in both locations.

Cowpea breeding lines planted at UKF were found to perform better than those in SYF, with a grand mean of 826.93 kg/ha and 813.66 kg/ha respectively. These result are supported by Egbe *et al*. (2010) who observed difference in cowpea varieties between two locations, where cowpea production been more favorable in Otobi than in Makurdi, influenced by environmental conditions or climate (Appendix 1), as is the case in these study (Bnarda, 2003). Ayaz *et al.* (2004) reported that the variation in cowpea yield components was species dependent, and these are shown in the study with the variation among the genotypes.

Table 6: Analysis of variance for pod weight for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	648.35	324.252		
Location	1	74.0	74.03	3.71	0.1941
Error rep*location	2	39.9	19.973		
Variety	56	9163.7	171.672	4.46	0.0000
Location*variety	56	1341.1	23.948	0.62	0.9820
Rep*location*variety	224	8630.7	38.530		
Total	341	19897.75	652.405		

Table 7: Mean pod weight of best 20 early maturing cowpea lines.

Varieties	Ukulima (kg/ha)	Varieties	Syferkuil (kg/ha)
TX08-4-1	1413.36	TX08-4-1	1174.29
TX12-520	1250.87	TX12-520	1100.67
TX08-49-2	1234.01	IT86D-1010	992.75
TX12-471	1170.4	IT98K-1111	931.43
TX12-537	1138.72	TX12-537	929.94
TX12-445	1125.51	TX12-445	929.94
ITOOK-1060	923.92	IT98K-690	919.13
IT99K-316-2	1031.85	TX12-581	897.85
TX08-30-1	1004.82	TX08-30-6	889.20
TX12-581	1003.05	IT93K-452	889.00
IT86D-1010	999.93	TX12-471	896.42
IT98K-962	995.92	TX08-49-2	895.99
IT93K-452	992..41	TX08-74-1	895.19
TX08-30-6	979.78	PAN 311	892.66
IT98K-690	979.31	IT98K-962	891.33
TX08-4-2	968.67	IT93K-452	891.20
TX08-4-3	962.69	IT99K-316-2	861.20
IT98K-1111	958.93	GEC	829.29
TX123	950.72	TX123	829.02
Glenda (Check)	778.82	Glenda (Check)	772.70

4.9 Seed weight

There were significant differences (P≤ 0.05) among the cowpea varieties for the weighed seed weight between the two locations (Table 8), which were taken from 5 plants. Cowpea breeding lines planted at UKF were found to be superior to those at SYF, with mean of 660.08 kg/ha and 594.01 kg/ha respectively. TX08-4-1 had a higher mean seed weight in UKF, with mean of 1121.62 kg/ha and TX12-445 had the best mean seed weight in SYF, with a mean of 921.26 kg/ha (Table 9).

Thirty three of the 57 cowpea varieties planted at UKF were better performing than Glenda and 30 of the 57 cowpea varieties planted at SYF outperformed Glenda. IT95K-1491 had the lowest mean seed weight than all other cowpea germplasm in both locations, with mean value of 178.5 kg/ha in UKF and 355.0 kg/ha in SYF. The best five cowpea varieties at UKF in an increasing order were TX08-4-1, TX12-520, TX12-471, IT93K-452-2 and TX12-445. However, TX12-445, PAN 311, TX08-30-6 TX08-4-1and TX12-520 were the top five cowpea germplasm at SYF. The result shows three varieties (TX08-4-1, TX12-520 and TX12-445) that were stable in both locations.

The highly significant varietal differences in seed weight across locations obtained in this study agree with the findings of Okafor (1986) as reported by Ekpo *et al*. (2012); Moalafi *et al.* (2010) who found significant differences in seed weight among nine cowpea varieties tested in South Africa and Sekyi (1990) also observed significant differences among three varieties of cowpea in Ghana, the inference is that seed weight was influenced by both genetic and environmental factors (e.g. rainfall) (Appendix 1). The resulted observed difference is due too locational difference.

Table 8: Analysis of variance for seed weight for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	672.6	336.287		
Location	1	337.4	337.42	11.99	0.0743
Error rep*location	2	56.3	28.148		
Variety	56	7040.1	125.716	4.46	0.0000
Location*variety	56	1135.7	20.280	0.72	0.9276
Rep*location*variety	224	6310.0	28.170		
Total	341	15552.1	876.021		

Table 9: Mean seed weight of best 20 early maturing cowpea lines

Varieties	Ukulima (kg/ha)	Varieties	Syferkuil (kg/ha)
TX08-4-1	1121.62	TX12-445	921.26
TX12-520	1077.53	PAN 311	895.49
TX12-471	986.63	TX08-30-6	877.04
IT93K-452-2	945.63	TX08-4-1	814.53
TX12-445	921.26	TX12-520	813.86
TX12-537	894.66	IT86D-1010	777.15
TX08-30-1	893.99	TX12-581	744.47
TX08-4-2	868.26	IT98K-690	738.74
GEC	818.36	IT00K-1060	707.79
TX08-49-2	805.98	IT93K-452	703.80
TX08-30-8	799.33	TX08-49-2	700.91
TX12-570	792.68	TX123	695.02
IT99K-316-2	783.80	IT98K-962	694.69
IT998K-1111	783.14	IT99K-316-2	691.93
TX123	776.95	TX08-30-8	691.92
IT86D-1010	764.52	TX08-30-1	682.53
TX08-74-1	762.99	IT998K-1111	677.40
IT83D-442	756.34	TX08-4-2	668.99
TX08-30-6	729.51	GEC	664.68
GLENDA (Check)	622.87	GLENDA (Check)	620.21

4.10 Hundred seed weight

The results indicate there was no significance difference between the two locations for the measured hundred seed weight, however there was significance difference between the evaluated cowpea varieties (Table 10). Cowpea varieties planted between the two locations nearly performed the same way, UKF had a mean of (19.63 g) and (19.00 g) in SYF. Mean value for hundred seed weight ranged between (11. 920 g to 28.28 g) in UKF and ranged from (10.053 g to 26.887 g) in SYF.

TX123 had the highest mean value hundred seed weight than all other cowpea varieties in both locations, with a mean of 28.283 g in UKF and 26.877 g in SYF (Table 11). IT82D-889-1 had the lowest mean figure hundred seed weight than all other cowpea varieties in both locations. Fifty one of the 57 cowpea varieties planted at UKF out performed Glenda, while 55 of the 57 cowpea varieties planted at SYF were found to be superior to Glenda. TX123, TX12-570, GEC, TX12-520 and TX08-49-2 were the top cowpea varieties at UKF, while the top five cowpea varieties in SYF were TX123, TX12-570, GEC, TX12-520 and IT00K 1263. Four varieties (TX123, TX12-570, GEC and TX12-520) were stable in the two locations.

The results of the study show that there was no significance difference between the two locations. These results are in line with results of Fery, 1985, who reported that since hundred seed weight (which determines the seed size) in both locations was nearly the same with the hundred seed weight, this implies that hundred seed weight was variety specific and least influenced by the environment. The result in this study and other studies suggest that 100 seed weight is under strong genetic control and therefore remains unaffected by density stress (Ekpo *et al*, 2012; Moalafi *et al*., 2010). Futuless and Bake (2010) reported that no single variety of cowpea can be suitable for all conditions, which may explain the variation observed for the measured hundred seed weight.

Table 10: Analysis of variance for hundred seed weight for early maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	30.17	15.087		
Location	1	87.39	87.3903	117.95	0.4840
Error rep*location	2	1.48	0.741		
Variety	56	4802.38	85.7568	56.34	0.0000
Location*variety	56	131.42	2.347	1.34	0.0149
Rep*location*variety	224	340.96	1.5221		
Total	341	5393.80			

Table 11: Mean hundred seed weight of the best 20 early maturing cowpea germplasm

Varieties	Ukulima (g/ha)	Varieties	Syferkuil (g/ha)
TX123	28.283	TX123	26.877
TX12-570	26.810	TX12-570	25.483
GEC	26.557	GEC	24.703
TX12-520	26.210	TX12-520	23.873
TX08-49-2	26.053	IT00K 1263	23.807
IT00K 1263	24.487	TX12-537	23.467
TX08-30-6	23.157	TX08-30-6	22.983
TX08-30-8	23.103	TX08-49-2	22.843
TX12-537	22.987	TX12-494	22.577
TX12-494	22.760	TX08-30-8	22.253
IT95K-1156	22.757	TX2028	21.907
TX08-30-9	22.157	IT97K-499-35	21.707
TX08-74-1	21.880	TX08-4-3	21.560
TX2028	21.687	TX08-74-1	21.557
IT99K-316-2	20.983	TX12-468	21.517
TX08-49-1	20.817	TX12-445	21.153
TX12-451	20.737	IT95K-1156	21.037
IT97K-499-35	20.180	IT99K-316-2	20.983
TX08-49-3	20.153	TX2028	20.967
IT00K 1060	20.097	TX12-473	20.093
GLENDA (Check)	13.300	GLENDA (Check)	12.183

CONCLUSIONS

The results in experiment I showed that most of the early maturing cowpea varieties outperformed the local check (Glenda) for all the measured yield parameters. The result showed that there was significance difference between the two locations, for the following yield parameters, plant height, number of branches and weight of seeds per pod and no significance difference for counted number of seed per pod, pod weight, pod length and hundred seed weight.

The mean plant height, number of branches were respectively (100 cm, 21) greater than the control Glenda (49 cm, 15). Similarly, the mean pod length, total pod weight, weight of seeds per pod, hundred seed weight and number of seed per pod were respectively (23 cm, 1413.4 kg/ha, 1121.62 kg/ha, 28.283g and 16) higher than those from the control check, Glenda (14 cm, 777.82 kg/ha, 622.87 kg/ha, 13.300 g and 13) in experiment I. The cowpea breeding lines at UKF performed better than those evaluated at SYF for most of the measured yield parameters.

The following cowpea lines were stable in the two locations; IT86D-1010, IT98K-589-2 and IT83D-442 were stable for plant height. Variety TX12-445 was stable for number of pods per plant. IT00K-1263, IT95K-1156, and IT99K-316-2 stable for pod length, Variety (IT97K-390-2) was stable for number of seed. TXO8-4-1 stable for number of branches per plant. TX08-4-1, TX12-520 and TX12-537 stable for pod weight. TX08-4-1, TX12-520 and TX12-445 stable for grain yield. TX123, TX12-570, GEC and TX12-520 were stable for large size. Some of the varieties were stable for two or three measured parameters in the two environments.

These stable lines can be recommended for both locations for those traits, while those that performed well in one location will be recommended for that location only. Singh *et al*, (1997) reported that early varieties have opened the possibility of successful sole cropping in areas with short rainy season, double or triple cropping in areas with relatively longer rainfall, in relay cropping after millet, sorghum or maize as well as parallel multiple cropping with cassava and yam. Thus, farmers could grow stable varieties in UKF and SYF to improve their production and to have better productive varieties.

5.1 Experiment II (medium maturity cowpea germplasm) results

There were significant differences (P<0.05) among the cowpea accessions for the following collected yield parameters; plant height, number pods per plant, number of branches, seed weight, pod weight and hundred seed weight and no significance difference (P≥0.05) observed for yield parameters such as number of seed per pod and pod length for the 40 medium maturing cowpea varieties.

5.2 Plant height

The results showed that there was significant difference (P≤ 0.05) among the cowpea varieties for the measured plant height in UKF and SYF (Table 12). Cowpea breeding lines planted at UKF were found to be better performing than those at SYF, having a mean of 70.14 cm and 48.69 cm respectively (Figure 6).

Variety IT98K-1105 was the tallest in both locations, with a mean of 97.00 cm at UKF and 63.00 cm in SYF. Variety IT98K-628 had the shortest height at UKF, with a mean of 46.00 cm, whereas, ITOOK-1060 in SYF, had the shortest mean of 33.33 cm. The top five cowpea varieties in an increasing order at UKF were IT98K-1105, Ife-brown, Mouride, Mounge and IT90K-227-2, whereas the best five cowpea varieties at SYF were Ife-brown, IT98K-1105, ITOOK-1060, IT98K-589-2 and CB-27. Only one line (IT98K-1105) was stable.

Thirty eight of the 40 cowpea varieties planted at UKF had higher mean plant height than Glenda and 15 of the 40 accession in SYF performed better than Glenda. The observed significant differences in varietal responses observed in plant height might be due to the genetic factor (Khan *et al*., 2010). However Ichi *et al.* (2013) advised that cowpea height is varietal dependent as certain varieties are taller than others. Basaran *et al*. 2011 attributed that the variation in plant height could be due to the difference in the edaphic factors (amount of rainfall and the distribution of the rain) (Appendix 1).

Table 12: Analysis of variance for plant height for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	3576	1788.2		
Location	1	26944	26944.3	10.98	0.0803
Error rep*location	2	4908	2453.8	0.00	
Variety	38	78459	2064.7	1.29	0.2227
Location*variety	38	77794	2047.2	1.19	0.2331
Rep*location*variety	156	269236	1725.9	0.00	
Total	237	45605.8	37024.1		

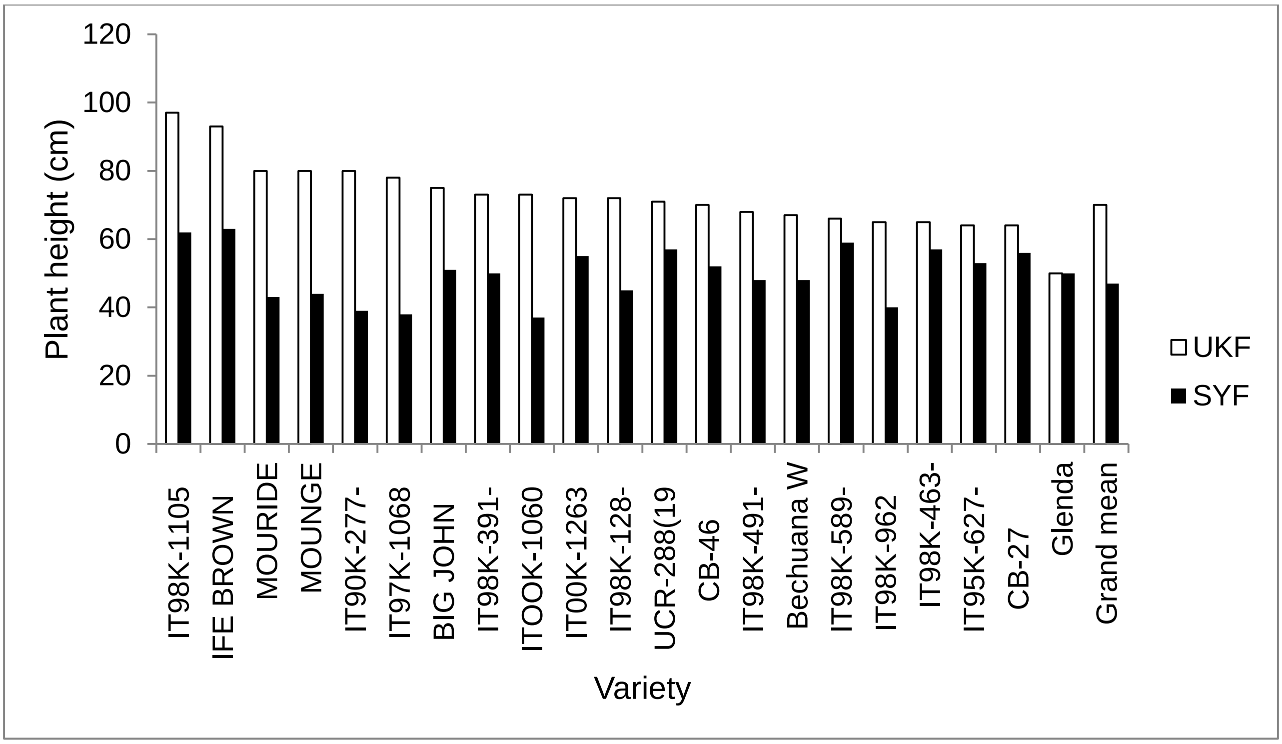

Figure 6: Mean plant height for medium maturing cowpea germplasm

5.3 Number of pods per plant

The results indicated that there was significance difference ($P \leq 0.05$) among number of pods per plant between the two locations (Table 13). Cowpea breeding lines planted at UKF were found to have more number of pods per plant than those at SYF, with a mean of 13.78 and 11.03 respectively. The mean value for number of pods per plant ranged from (9.20 to 23.07) in UKF and (7.20 to 20.80) in SYF.

CB-27 obtained more number of pods per plant than other accessions in UKF, however in SYF IT98K-391-2 had the highest number of pods per plant. IT97K-1068 had the lowest number of pods per plant in UKF, however, Greenpack had the lowest mean for SYF. CB-27, IAR-48, IT98K-491, CB-46 and CB-50 were the top five cowpea varieties at UKF, while at SYF the best five cowpea varieties in an increasing order were IT98K-391-2, UCR-288, CB-46, CB-27, and IT98K-589-2. Two lines (CB-46, and CB-27) had stable performance in the two locations.

The result showed that of the 40 cowpea varieties planted at UKF, 12 lines had least number of pods per plant than Glenda and 8 lines had same number of pods per plant as Glenda, while 10 cowpea germplasm had higher number of pods per plant than Glenda. Only one of the 40 cowpea varieties planted at SYF had lower number of pods per plant than Glenda and 31 lines had same number of pods per plant as Glenda and 8 cowpea lines had higher number of pods per plant than Glenda (Figure 7).

The observed varietal difference for the number of pods per plant could be under genetic control and varied among cowpea varieties and these agrees with Ichi *et al.* (2013), who observed in his study that significant difference in number of pods per plant was as a result of varietal difference in cowpea and also Sekyi (1990), recorded significant varietal difference effect on number of pods per plant. Conducive environmental conditions were more at UKF than at SYF, as supported by Addo-Quaye *et al*. (2011), who postulated that an environment which receives better rain or moisture produced high number of pods (Appendix 1).

Table 13: Analysis of variance for number of pods per plant for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	76.99	38.496		
Location	1	444.71	444.71	6.37	0.1276
Error rep*location	2	139.61	69.804	0.00	
Variety	38	1494.35	39.325	3.53	0.0000
Location*variety	38	1172.81	30.863	2.77	0.0000
Rep*location*variety	156	1737.77	11.140	0.00	
Total	237	5066.24	634.338		

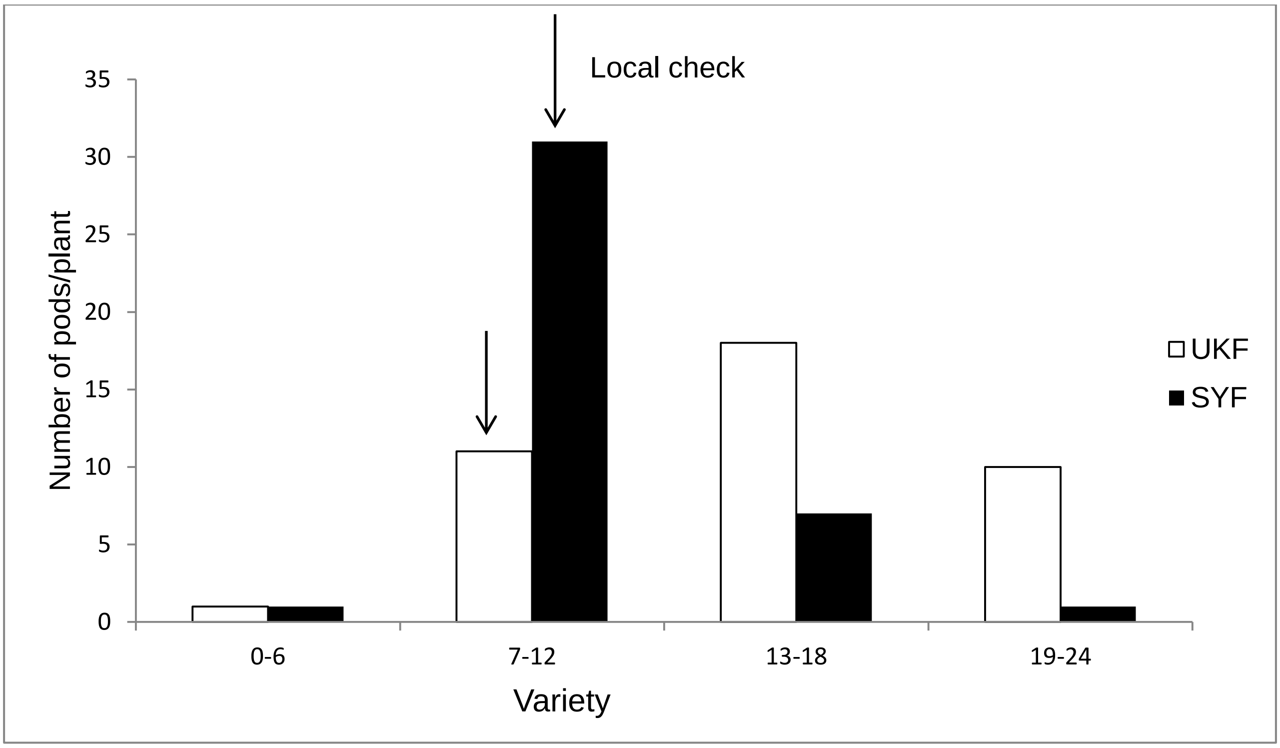

Figure 7: Frequency distribution for number of pods per plant for medium maturing germplasm.

5.4 Pod length

There was no significance difference (P≥0.05) in the two locations for the measured pod length, although there was significant variation observed within cowpea varieties (Table 14). Cowpea varieties planted at UKF were better adapted than those at SYF with a mean of 16.26 and 16.20 in SYF.The mean value for UKF ranged from (11.83 to 21.47) and (10.23 to 20.25) in SYF.

Big john had the longest pod in both locations, with a mean value of 21.467 in UKF and 20.333 in SYF (Figure 8). IT98K-1092 had the shortest pod length in UKF, while IT98K-463-8 had the lowest mean pod length for SYF. In increasing order Big John, IT98K-529-1, ITOOK-1263, Bechauna.W and Green-pack were the best five performing cowpea varieties at UKF and the best five performing cowpea varieties at SYF were Big John, IT98K-1263, Mounge, CB-27 and IT98K-529-1.Two varieties (Big John and IT98K-529-1) constantly performed well in the two locations, showing stability.

Twelve of the 40 cowpea varieties at UKF had longer pods than Glenda and 13 of the 40 cowpea varieties at SYF outperformed Glenda. During the physiological maturity cowpea varieties exhibited no significance difference between the two locations, which shows location did not influence pod length among genotypes. The mean value ranged from 7 cm to 21cm across both locations, the range for this study is also within that which was documented as characteristic for the cowpea crop (Kay, 1979). The variation observed between varieties for the measured pod length was supported by Damarany (1994) who tested 36 genotypes during summer and found significant variation for pod length. That is conformation of genotypic affect. The results in this study suggest that pod length could be under strong genetic control.

Table 14: Analysis of variance for pod length for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	4.01	2.006		
Location	1	272.26	272.264	21.58	0.5433
Error rep*location	2	25.23	12.615		
Variety	38	1165.61	30.674	4.87	0.0000
Location*variety	38	937.85	24.680	3.92	0.0500
Rep*location*variety	156	981.58	6.292		
Total	237	3386.54	348.531		

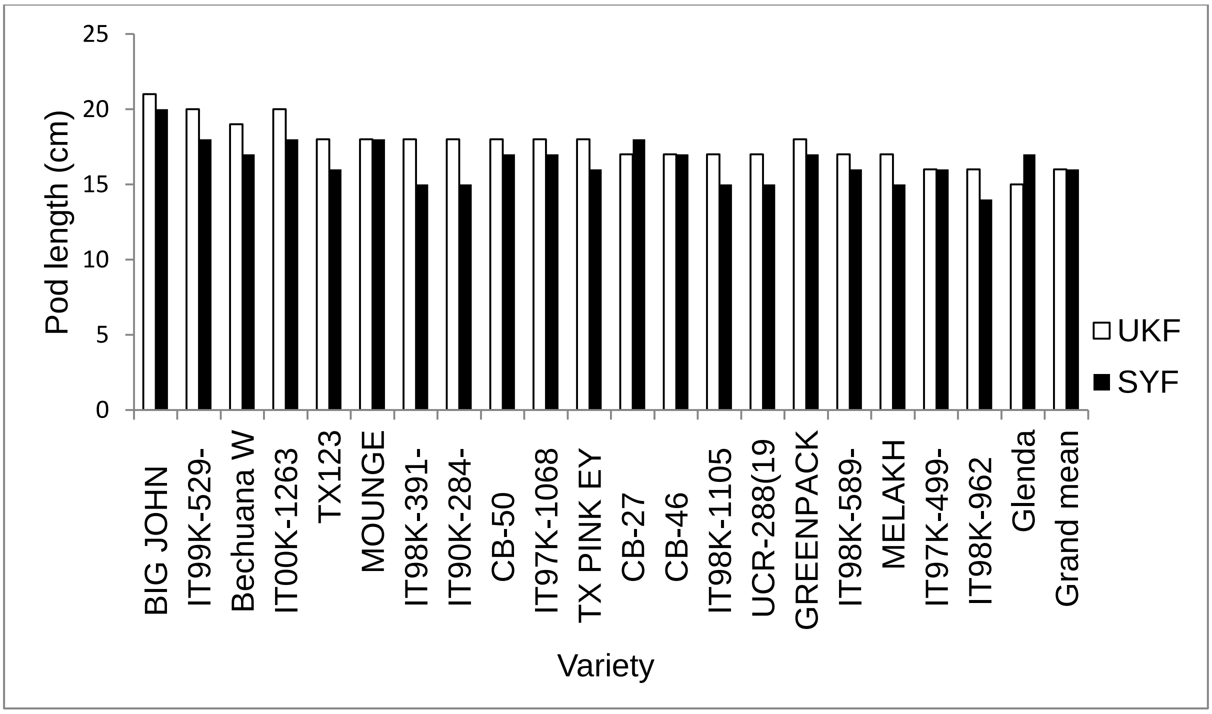

Figure 8: Mean pod length for medium maturing cowpea germplasm

5.5 Number of seed per pod

The results show that there was no significance difference ($P \geq 0.05$) for the counted number of seed per pod between the two locations, however, there was significance difference observed between cowpea varieties (Table 15). The grand mean between the two was nearly the same, with a mean of 12.00 at UKF and 12.77 in SYF. The mean value ranged from (9.13 to 16.43) in UKF and (9.67 to 15.67) in SYF.

The variety with higher number of seed per pod was obtained by Big John in SYF with a mean of 15.67 and IT98K-391-2 was the variety with high number of seed in UKF with a mean of 16.43 (Figure 9). Ife-brown had the lowest mean number of seed per pod at UKF. However, IT97K-567-1 had less number of seed per pod at SYF. IT98K-391-2, Big John, IT98K-589-2, UCR-288, and White acre were top five cowpea lines at UKF and Big John, IT97K-499-3, Melakh, Greenpack and Glenda were the best five cowpea lines for SYF. Only One line (Big John) was stable.

Fifteen of the 40 cowpea varieties planted at UKF had more number of seed per pod than the Glenda and 4 of the 40 cowpea varieties planted at SYF obtained more number of seed than Glenda. The result shows that seed number per pod was genetically controlled and that environmental conditions may have had little or no effect on it. These results were similar to that of Muhammad *et al*. (1994) who observed this variation among cowpea genotypes in number of seed per pod might be due to difference in genotypes and this was also supported by Nwofia *et al*. (2014) who stated that the variation in number of seed per pod may be attributed to inherit transferable parental trait difference in varieties.

Table 15: Analysis of variance for number of seed per pod for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	105.22	52.608		
Location	1	54.02	54.0223	3.67	0.4533
Error rep*location	2	29.47	14.737		
Variety	38	2096.97	55.1833	1.17	0.0000
Location*variety	38	2296.57	60.4361	1.28	0.0500
Rep*location*variety	156	7352.04	47.1285		
Total	237				

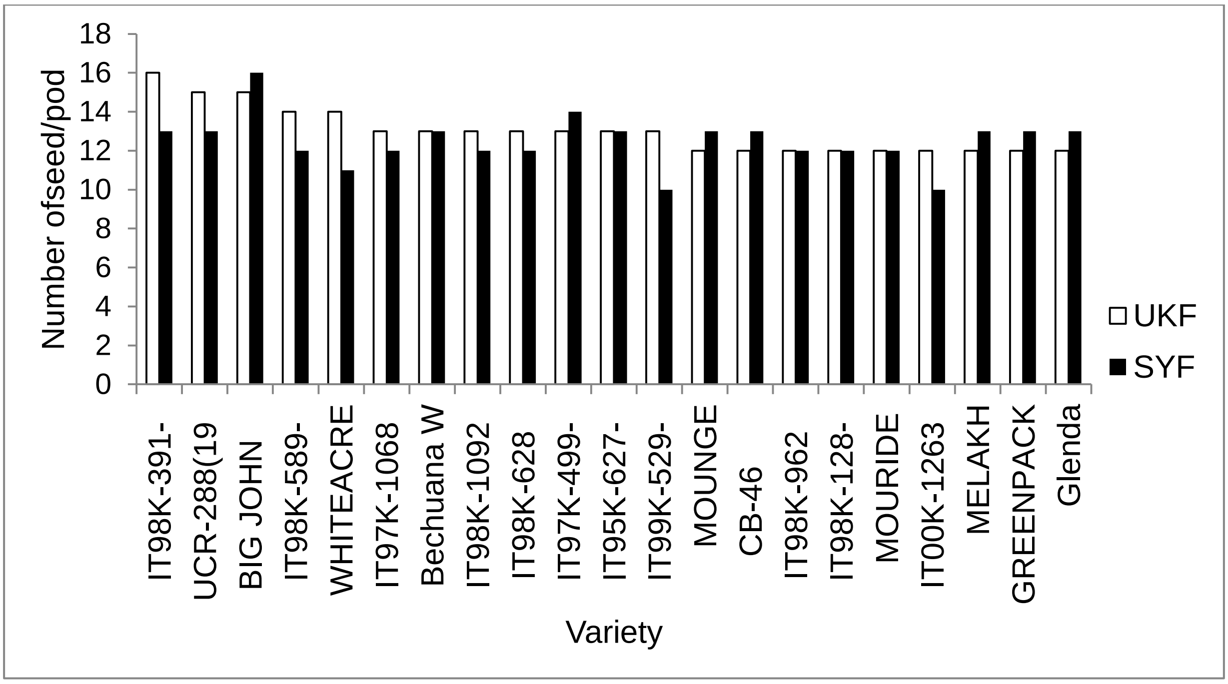

Figure 9: Mean number of seed per pod for medium maturing cowpea germplasm

5.6 Number of branches per plant

There was significance difference (P≤ 0.05) among cowpea varieties for number of branches per plant between UKF and SYF, which was taken from 5 plants (Table 16). The cowpea breeding lines planted at UKF outperformed those planted at SYF, with a mean of 8.946 and 7.632 respectively (Figure 10). CB-27 was the variety with higher number of branches at UKF with a mean of 15.417. However, IT90K-284-2 obtained high number of branches at SYF with a mean of 13.687. The lowest number of branches was obtained by Mounge in both locations, obtaining a mean of 5.933 in UKF and 5.600 in SYF. CB-27, TX123, IAR 48, CB-50, and IT98K-491-4 were top five cowpea lines at UKF and IT90K-284-2, Glenda, IT98K-491-4, CB-27 and IT97K-499-3 were the best five cowpea lines for SYF. Two varieties (CB-27, and IT90K-284-2) were stable in both locations.

The result of the study shows that 6 of the 40 cowpea varieties planted at UKF were more adaptable than Glenda and 8 of the 40 cowpea varieties planted at SYF performed better than Glenda. The observed difference between the cowpea varieties in the two locations for number of pods per plant is due to good environmental conditions in one location than the other, these results are in line with result obtained by Ali *et al*. (2009) who observed that significant difference in number of branches per plant was as results of varietal difference in cowpea. This may be because the varieties were able to utilize edaphic factors such as fertility of the soil for yield maximization and environmental factors such as temperature (Appendix 1) (Akande, 2007).

Table 16: Analysis of variance for number of branches for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	9.583	4.791		
Location	1	101.533	101.533	5.02	0.1544
Error rep*location	2	40.478	20.239	0.00	
Variety	38	463.555	12.99	2.96	0.0000
Location*variety	38	285.170	7.504	1.82	0.0058
Rep*location*variety	156	647.284	4.123	0.00	
Total	237	1598.263	151.18		

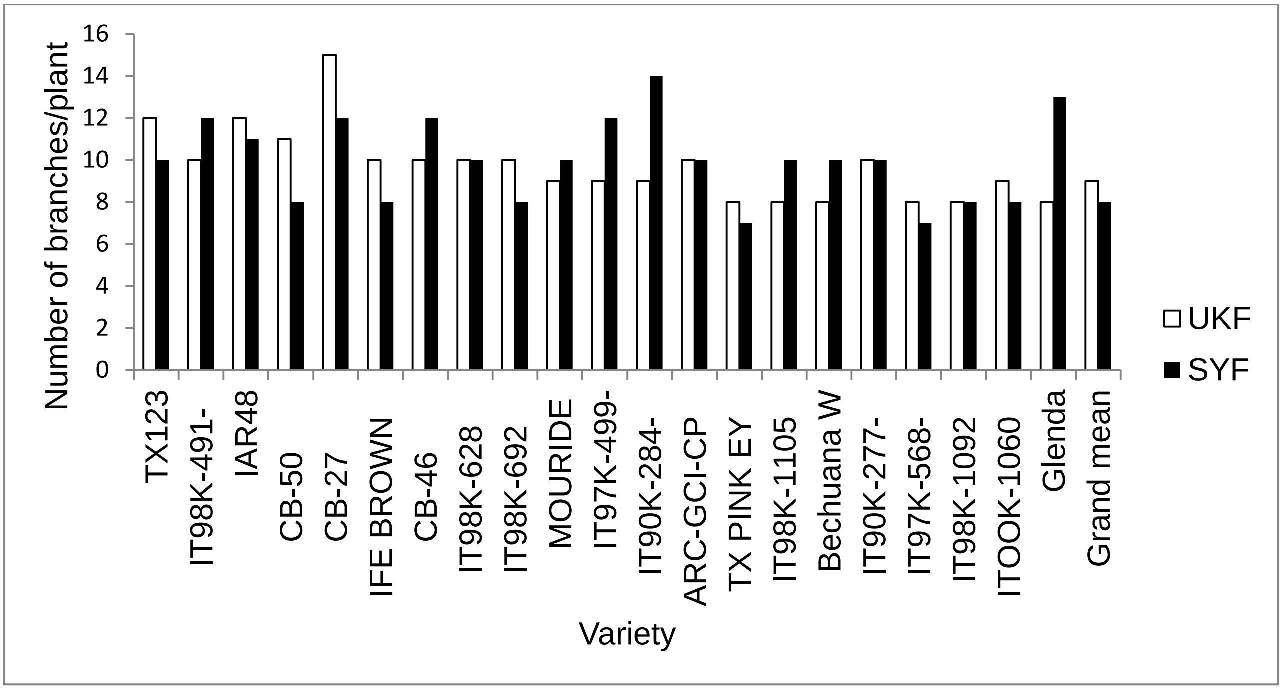

Figure 10: Mean number of branches per plant for medium maturing cowpea germplasm.

5.7 Pod weight

The results indicate there was a significance difference (P≤ 0.05) for the weighed pod weight, which was taken from 5 plants (Table 17). The cowpea breeding lines planted at UKF were better adapted than those at SYF, with a mean of 936.55 kg/ha and 867.92 kg/ha respectively.

CB-27 was the best performing line in both locations, out-weighing all other accessions with a mean value of 1546.19 kg/ha in UKF and 1145.23 kg/ha in SYF (Table 18). The lowest mean pod weight at UKF was obtained for accession White acre, with a mean value of 563.02 kg/ha and Jana Fod had a lower mean pod weight at SYF, with a mean of 667.76 kg/ha. Twenty nine of the 40 lines planted at UKF obtained higher mean pod weight than Glenda and 25 of the 40 lines planted at SYF were better adaptable than Glenda. CB-27, IT98K-491-4, IAR48, IT97K-499-3 and IT98K-1105 were the best five cowpea varieties at UKF, while CB-27, IT98K-1092, CB-50, IT97K-499-3, and IT98K-529 were the top five cowpea varieties in SYF. Two cowpea varieties (CB-27 and IT97K-499-3) were stable in the two locations.

The observed difference among the cowpea accessions in the two locations is due to influence by environmental factors such as rainfall (Appendix 1), which could also influence the yield potential and genetic constitution of genotypes (Nwofia *et al*., 2014). The result of this trial is in agreement with that of Nielsen and Hall (1985) as reported by Kamai (2014) that yield parameters such as seed weight and pod weight of cowpea varies widely when grown at different locations.

Table 17: Analysis of variance for pod weight for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	395.81	197.907		
Location	1	66.67	66.669	1.31	0.3706
Error rep*location	2	101.64	50.820	0.00	
Variety	38	7650.97	201.341	3.93	0.0000
Location*variety	38	2420.02	63.685	1.24	0.1785
Rep*location*variety	156	8038.95	51.204	0.00	
Total	237	18674.1	631.626		

Table 18: Mean pod weight of the best 20 medium maturing cowpea germplasm

Varieties	Ukulima (kg/ha)	Varieties	Syferkuil (kg/ha)
CB-27	1546.19	CB-27	1145.32
IT98K-491-	1341.74	IT98K-1092	1089.27
IAR48	1285.45	CB-50	1083.62
IT97K-499-	1209.57	IT97K-499-3	1057.75
IT99K-1105	1150.68	IT98K-529	1013.36
CB-50	1120.53	IAR48	1007.91
IT98K-391	1115.87	IT98K-491-	1001.92
ARC-GCI-CP	1067.09	IT98K-391	986.76
IT97K-1068	1053.36	ARC-GCI-CP	976.45
IT98K-692	1032.31	IT97K-1068	967.34
IFEBROWN	994.18	IT99K-1105	948.06
IT98K-529	967.61	IT98K-692	947.06
BIG JOHN	950.05	IT98K-628	935.99
GREEN PACK	938.32	MOURIDE	929.67
MOURIDE	931.00	IT00K-1060	922.21
IT98K-1092	925.25	TX-PINK EY	922.21
TX-PINK EY	912.48	IFEBROWN	910.82
IT98K-628	901.74	IT98K-962	892.43
IT90K-277-	864.93	UCR-288	879.23
GLENDA (Check)	761.86	GLENDA (Check)	761.86

5.8 Seed weight

Table 19 shows analysis of variance for weighed seed weighed and Table 20 shows 20 best varieties of the 57 cowpea varieties in both locations.The analyses indicate that there was a significance difference (P≤ 0.05) between the cowpea varieties for seed weight in the two locations (Table 19). Cowpea breeding lines at UKF had better grain yield than those at SYF, obtaining a mean of 725.35 kg/ha, and 20.436, respectively. CB-27 had a high mean value for the weighed seed weight in both locations, with a mean value of 1245.11 kg/ha at UKF and 898.65 kg/ha for SYF (Table 20).

Twenty five of the 40 cowpea varieties planted at UKF had higher mean seed weight than Glenda and 31 of the 40 cowpea varieties planted at SYF outperformed Glenda. IT98K-463-8 had the lowest grain yield in both locations, with a mean of 446.81 kg/ha at UKF and 533.76 for SYF. CB-27, IT98K-491-4, CB-50, CB-46 and Ife Brown were the best five cowpea varieties in increasing order at UKF, while the top five cowpea varieties at SYF were CB-27, IT99K-529-1, IT97K-499-, IT98K-692, and IT98K-628.

One line (CB-27) of the 5 cowpea lines that performed well at UKF did well in SYF too. The observed difference among the cowpea accessions in the two locations may also be influenced by edaphic factors and genetic variability, this in line with a report by Nwofia *et al*. (2014), who suggested that the wide difference in seed yield observed in a study, could due to genetic constituents of the cowpea varieties as well as variations in their population densities. Also Kamai (2014) reported that yield parameters such as seed weight and pod weight of cowpea vary widely when grown at different locations. This is confirmed in this study, which shows variation between the two locations and in between the two varieties.

Table 19: Analysis of variance for seed weight for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	175.21	87.622		
Location	1	112.03	112.026	14.58	0.0622
Error rep*location	2	15.36	7.682	0.00	
Variety	38	4996.57	118.31	3.64	0.0000
Location*variety	38	1822.51	47.961	1.47	0.05
Rep*location*variety	156	5106.73	32.527	0.00	
Total	237	18674.1	406.128		

Table 20: Mean seed weight of the best 20 medium maturing cowpea germplasm

Varieties	Ukulima (kg/ha)	Varieties	Syferkuil (kg/ha)
CB-27	1145.11	CB-27	898.65
IT98K-491-	1052.70	IT99K-529-	896.09
CB-50	936.09	IT97K-499-	868.26
CB-46	928.09	IT98K-692	875.90
IFE BROWN	920.13	IT98K-628	866.83
IT97K-499-	915.80	IT98K-491-	815.29
IT98K-1105	859.61	IT98K-568	814.53
IT98K-1092	842.32	IT98K-1105	794.11
IAR48	819.05	MOURIDE	772.63
BIG JOHN	810.20	BIG JOHN	754.01
ARC-GCI-CP	793.35	IT98K-1092	750.55
MOURIDE	768.50	IAR48	728.61
IT98K-692	765.85	IFE BROWN	724.62
IT99K-529-	734.83	IT97K-1068	723.62
IT97K-1068	728.61	CB-50	708.13
IT98K-284-	669.42	IT98K-128	703.67
IT98K-568	668.09	IT98K-284-	669.75
IT98K-628	667.43	ARC-GCI-CP	661.01
GLENDA	585.63 (Check)	GLENDA (Check)	637.74

5.9 Hundred seed weight

The results indicated that there was significance difference between the cowpea breeding lines for hundred seed weight at UKF and SYF (Table 21). Mean value ranged from (13.29 to 27.36) for cowpea lines planted at UKF and (12.763 to 25.03) for cowpea lines planted at SYF. Cowpea varieties planted at UKF were superior than those had a grand mean of 19.48, while those in UKF had a mean of 19.00 (Table 22).

TX123 had the best mean hundred seed weight in both locations, with a mean value of 27.36 for UKF and 25.03 was obtained in SYF. UCR-288 had the lowest mean hundred seed weight in both locations, with mean value of 13.293 for UKF and 11.570 for SFY. TX123, IT90K-284-2, CB-50, Big John and IT98K-1105 were the top five cowpea varieties in UKF. However the top five at SYF were TX123, IT90K-284-2, CB-50, Big John and IT98K-1105. 32 of the 40 cowpea varieties planted at UKF out performed Glenda and 15 of the 40 cowpea varieties at SYF had a higher mean hundred seed weight than Glenda.

Five varieties (TX123, IT90K-284-2, CB-50, Big John and IT98K-1105) that performed well in Ukulima farm did well also in Syferkuil farm. The observed variation for hundred seed weight is due to environmental difference between the two locations and genetic diversity among the varieties (Khan *et al.,* 2014), this result are confirmed also by Addo-Quaye et al. (2011) who observed results at Cape Coast where the environment was relatively dryer than Twifo Hemang, where there was enough moisture (Appendix 1). Similarly, Kamara (1976) reported and cited by Fery (1985) that seed weight was significantly reduced when cowpea plants were under deficient moisture.

Table 21: Analysis of variance for hundred seed weight for medium maturing cowpea germplasm

Source of variation	DF	SS	MS	F	P
Rep	2	15.19	7.594		
Location	1	573.80	573.798	559.46	0.0018
Error rep*location	2	2.05	1.026		
Variety	38	2678.44	70.485	23.00	0.0000
Location*variety	38	888.80	23.389	7.63	0.0000
Rep*location*variety	156	478.11	3.065		
Total	237	4636.39	679.357		

Table 22: Mean hundred seed weight of the best 20 medium maturing cowpea germplasm

Varieties	Ukulima (g/ha)	Varieties	Syferkuil (g/ha)
TX123	27.363	TX123	25.030
IT90K-284-	25.333	CB-50	24.517
CB-50	25.017	BIG JOHN	22.940
BIG JOHN	24.860	IT90K-284-	22.567
IT98K-1105	24.810	IT98K-1105	22.010
IT98K-476-	23.980	IT00K-1263	21.777
IT99K-529	22.663	IT99K-529	21.413
IT00K-1263	22.367	IT90K-277	21.303
IT90K-277	22.190	IT98K-476-	20.403
ITOOK-1060	20.837	CB-46	20.093
IT98K-962	20.834	IT98K-491	19.993
IT98K-491-	20.367	ARC-GCI-CP	19.970
CB-46	20.117	IT98K-692	19.650
IAR-46	20.017	IT00K-1060	19.383
IT97K-499-	20.010	IT97K-1068	18.950
ARC-GCI-CP	19.870	IAR48	18.607
IT97K-1068	19.760	GRRENPACK	18.543
TX-PINK EY	19.133	IT98K-962	18.130
IT97K-568	18.730	TX-PINK EYE	18.037
GREENPACK	18.580	IT97K-499	17.942
GLENDA	18.393 (Check)	GLENDA (Check)	17.060

CONCLUSIONS

The results of the second experiment showed that most of the medium maturing cowpea accessions outperformed the local check Glenda in most of yield parameters. The result showed that there was significance difference between UKF and SYF, for the following yield parameters, plant height, number of branches, total pod weight, and weight of seeds per pod and no significance difference for counted number of seed per pod and measured pod length.

Experiment II result showed the mean plant height, number of branches were respectively (97 cm, 21) greater than the control Glenda (50 cm, 15). Similarly mean pod length, total pod weight, weight of seed per pod, hundred seed weight and number of seed per pod were respectively (20 cm, 1546.19 kg/ha, 1245.11 kg/ha, 27.363 g and 16) high than those from local check, Glenda (17 cm, 795.11kg/ha, 661.01 kg/ha, 18.393 g and 13). The results shows that cowpea varieties evaluated in Ukulima performed well than those in Syferkuil farm. This indicates that Ukulima station is better for cowpea production with favourable environmental factors than in Syferkuil which is drier.

The following cowpea lines were stable in the two locations for different traits; IT98K-1105 was the stable line for plant height. CB-46 and CB-27 were stable for number of pods per plant. Big John and IT98K-529-1 were stable for pod length. Big John stable for number of seed per pod. CB-27 and IT90K-284-2 were stable for number of branches per plant. CB-27 and IT97K-499-3 stable for pod weight. CB-27 was stable for grain yield. TX123, IT90K-284-2, CB-50, Big John and IT98K-1105 were stable for large size. Some lines were stable in both locations for the different measured parameters. Varietal requirements in terms of plant type, seed type, maturity, yield for cowpea varies from region to region thus the importance of selection of varieties, hence varieties that performed well in the two locations are recommend for the this locations based on their adaptability (Futuless and Bake, 2010).

CHAPTER 5

GENERAL CONCLUSIONS, SUMMARY AND RECOMMENDATION

The wide range in the data observed for most of the traits and the significant mean square obtained have shown the presence of genetic variability for the traits studied. This indicates that these traits can be improved through breeding. High genetic variation was obtained for plant height, number of pods per plant and seed weight and pod weight. Number of seed per pod, pod length and 100 seed weight showed less genetic variation in experiment one. In experiment two high genetic variations was obtained for plant height, number of pods per plant, seed weight, pod weight and 100 seed weight. Number seed per pod, pod length showed less genetic variation in experiment two.

The hypothesis of the study outlined that yield components and characteristics of introduced cowpea breeding lines do not differ. The evaluated cowpea germplasm were compared with a local check Glenda which is commonly grown and mostly planted by commercial farmers, introduced cowpea germplasm varied in the traits and performed better than the local check (Glenda). Therefore is enough significance (evidence) to reject the Null hypothesis.

Early maturing varieties performed well with added advantage of being suitable in areas with unreliable rainfall in terms of total amount, distribution and duration where crop failure is often attributed to early cessation of rains and thereby making it adaptive to different agroecological environments. This preference for extra early and early-maturing crop varieties, particularly cowpea has been well documented (Singh *et al.*, 2007).

The results shows that cowpea varieties evaluated in Ukulima farm performed better than Syferkuil farm, inferring that the environment was more conducive to production of cowpea in UK than UL. Cowpea germplasm such as Big John and IT97K-390-2 were observed to be more productive in term of seed weight and TXO8-4-1 and CB-27 were found to be more productive in term of grain yield. Varieties found to be stable for both environment, are recommended for immediate releases for commercial production after due process of registration at DAFF, Pretoria. Further evaluations or on farmer trials can lead to increase the scope of these results, and lead to more release of these introduced cowpea germplasm. And their use can benefit small-holder farmers in South Africa by planting varieties that are high yielding and well adapted to South African environment.

In conclusion we can say the data generated from the studies will contribute useful information to the data base of the characteristics of these cowpea lines. The above results indicate the superiority of the introduced breeding over the local check (Glenda) as well as the potentials of using these promising lines for the development of better adapted germplasm in South Africa.

REFFERENCE

ABDOU RAZAKOU, I. B. Y., MENSAH, B., KIARI, S. and AKROMAH R. 2013. Research paper using morpho-physiological parameters to evaluate cowpea varieties for drought tolerance. *International Journal of Agricultural Science Research.* Vol. 2, pp. 153-162.

ADDO-QUAYE, A., DARKWA, A. and AMPIAH. M. K. P. 2011. Performance of three cowpea (*Vigna unguiculata (L.)* walp) varieties in two agro-ecological zones of the central region of Ghana ii: grain yield and its components. *Journal of Agricultural and Biological Science.* Vol. 6, no. 2.

ADEBOWALE, A.S. 2011. Evaluation of the possible application of cowpea genotypes in the farming systems of the Eastern Cape Province South Africa. Submitted in fulfilment of the requirements for the degree of Master of Science in Biochemistry.

ADENIJI, T.O. 2007. Studies on grain yield stability in cowpea (*Vigna unguiculata (L.)* Walp). In: OLUFAJA, O.O., OMOKORE, D.F., AKPA, G.N and SANNI, S.A. (eds.). Proceedings of the 41st Annual Conference of the Agricultural Society of Nigeria (ASN) held at the Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria between 22nd and 26th October, Pp 25 – 28.

ADIPALA, E., AMPALA, P., KARUNGI, J. and ISUBIKALU, P. 2000. A review on options for management of cowpea pest: Experience from Uganda integrated pest management reviews.

AGBOGIDI, O. M. and EGHO, E.O. 2012. Evaluation of eight varieties of cowpea (*Vigna unguiculata (L.)* Walp) in Asaba agro-ecological environment, Delta State, Nigeria. *Basic Research Journal of Agricultural Science and Review*,1: 63-68.

AHMED, B. I. and YUSUF, A. U. 2007. Host–plant resistance: A viable non – chemical and environmentally friendly strategy of controlling stored products pests-a review. *Emir. Journal of Food Agricultural Science* 19: 01-12.

AJEIGBE, H.A., MOHAMMED, S.G. and SINGH, S.S. 2006. Comparative Assessment of yield potentials of improved cowpea breeding lines using performance index and ranking methods. *Journal of Food, Agriculture and Environment*, Vol.4: 95-98.

AKANDE, S. R. 2007. Biplot analysis of genotype by environment interaction of cowpea grain yield in Forest and Southern Guinea Savanna Agro-ecologies of Nigeria. *Journal of Food, Agriculture and Environment.* 5: 464-467.

AKYAW, M.O., BAIDOO, P.K. and MOCHIAH, M.B. 2014. The effect of time harvest on the damage caused to cowpea by storage bettle, *Callosobruchus maculatus* (FAB.) (*Coleoptera: Bruchidae*). *Global advanced research journal of agricultural science*, Vol. 3(11) pp. 351-355.

ALI, B., IZGE, A.U., ODO, P.E. and AMINU, D. 2009. "Varietal performance of dual purpose dry season cowpea (*Vigna unguiculata (L.)* Walp) under Varying Plant Spacing in the Fadama in North Eastern Nigeria". *Am.-Eurasian Journal of Sustainable. Agriculture*. 3:13-18.

ALIYU, T.H., BALOGUN, O.S. and KUMAR, L. 2012. Survey of the symptoms and viruses associated with cowpea (*Vigna unguiculata (L.)* Walp) in the Agroecological Zones of Kwara State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*. Vol. 5 no.4 (Suppl.2)

ASANTE, S.K., TAMÒ, M. and JACKAI, L.E.N. 2001. Integrated management of cowpea insect pests using elite cultivars, date of planting and minimum insecticide application. *African Crop Science Journal.* 9: 655-665.

ASIWE, J.A.N. 2007. Baseline survey on the production practices, constraints and utilization of cowpea in South Africa: implications for cowpea improvement. *Acta Hort (ISHS)* 752:381-385*.*

ASIWE, J. A. N. 2009. Needs assessment of cowpea production practices, constraints and utilization in South Africa. *African Journal of Biotechnology,* 8: 5383-5388.

ASIWE, J.A.N., NOKOE, S., JACKAIC, L.E.N. and EWETE. F.K. 2005. Does varying cowpea spacing provide better protection against cowpea pests? *Crop Protection* 24: 465–471*.*

ASIWE, J.A.N., TOLMAY, V.L. and JANKIELSOHN, A. 2012. Evaluation of wheat germplasm for Russian Wheat Aphid (*Diuraphis noxia*) resistance in South Africa. Book of Abstracts, Plant Breeders Association Symposium, Kruger National Park, Nelspruit, South Africa, 12-15 March, 2012.

AYAZ, S. B., MACKENZIE, A., HILL, G.D. and MCNEILL. D.L. 2004. “Variability in yield of four grain legume species in a Sub humid temperate environment. II yield components”. *Journal of Agricultural Science*. 142: 21–28.

BASARAN, U., AYAN, I., ACAR, Z., MUT, H. and ASCI, O. 2011. Journals full length research paper seed yield and agronomic parameters of cowpea *(Vigna unguiculata (L.)* Walp) genotypes grown in the Black Sea region of Turkey. *African Journal of Biotechnology,* Vol. 10, pp. 13461-13464.

BNARDA. 2003. Benue State Agricultural and Rural Development Authority: Annual Report, 2003, Makurdi, Nigeria.

BAZZANO, L.A., HE, J., OGDEN, L.G., LORIA, C., VUPPUTURI, S., MYERS, L. and WHELTON, P.K. 2001. Legume consumption and risk of coronary heart disease in US men and women: NHANES I Epidemiologic Follow-up Study. *Archives Internal Med*, 161: 2573-2578.

CHIULELE, R.M. 2010. Breeding Cowpea (*Vigna unguiculata (L.)* Walp) for Improved drought tolerance in Mozambique. A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy (PhD) in Plant Breeding.

CORK, A., DOBSON, H., GRZYWACZ, D., HODGES, R., ORR, A and STEVENSON, P. 2009. Review of pre- and post-harvest pest management for pulses with special reference to East and Southern Africa.

DAMARANY, A.M. 1994. Testing and screening of some cowpea genotypes under Assiut conditions. *Assiut J. of Agric. Sci*., 25: 9-19.

DAVIS, D.W., OELKE, E.A., OPLINGER, E.S., DOLL, J.D., HANSON, C.V. and PUTNAM, D.H. 1992. Cowpea alternative field crop manual. University of Wisconsin of Minnesota. Available from: http://www.hort.produce.edu/new crop. Date accesed: 21 march 2015.

DUGJE, I.Y., OMOIGUI, L.O., EKELEME, F., KAMARA, A.Y. and AJEIGBE. H. 2009. Farmers' guide to cowpea production in West Africa. IITA, Ibadan, Nigeria. 20 pages.

DEGRI, M.M., MAINA, Y.T. and RICHARD, B.I. 2012. Effect of plant extracts on post flowering insect pests and grain yield of cowpea (*Vigna unguiculata) (L.)* Walp) in Maiduguri, Semi-arid Zone of Nigeria. *Journal of Biol. Agric. Healthcare* 2:46-56.

EGBE, O.M, ALIBO, S.E. and NWUEZE, I. 2010. Evaluation of some extra-early- and early-maturing cowpea varieties for intercropping with maize in southern Guinea Savanna of Nigeria. *Agriculture and Biology Journal of North America.* 1: 845-858.

EGHO, E.O. and ENUJEKE, E.C. 2012. Effect of native soap on insect pests and grain yield of cowpea (*Vigna unguiculata (L.)* Walp) in Asaba and Abraka during the Late Cropping Season in Delta State, Nigeria. *Sustainable Agriculture Research. Vol. 1, No. 2.*

EKPO, I.A., AGBOR, R.B., OSUAGWU, A.N., OKPAKO, E.C. and EKANEM, B.E. 2012. Evaluation of eight cowpea (*Vigna unguiculata (L.)* Walp) species for yield and associated traits. *Int. J. Pure Appl. Sci. Technol.*, 12, pp. 1-7.

EMECHEBE, A.M. and LAGOKE, S.T.O. 2002. Recent advances in research on cowpea diseases. In: FATOKUN, C.A., TARAWALI, S.A., SINGH, B.B., KORMAWA, P.M, TAMO M (eds) Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the World Cowpea Conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 4-8 September 200. IITA, Ibadan Nigeria. pp 94-123.

FATOKUN, C. 2009. Designer (Cowpea) plants. http://r4dreview.org/2009/03/ Christian-a-Fatokun-the-guardian-of-biosafety Accessed on 04/02/2015.

FERY, R.L. 1985. The genetics of cowpeas: A review of the world literature. In: Singh, S.R. and Rachie, K.O. (Eds). Cowpea research, production and utilization. Chichester: John Wiley and Sons. pp. 25-62.

FUTULESS, K.N. and BAKE, K.I.D. 2010. Evaluation of yield and yield attributes of some cowpea *(Vigna Unguiculata (L.)* Walp) varieties in Northern Guinea Savanna. *Journal of American Science* 6 :(8).

GOMEZ, C. 2004. COWPEA: Post-harvest operations. Food and Agriculture organization of the United Nations (FAO). *Last reviewed: 15/06/2004*.

ICHI, J.O., IGBADUN, H.E., MIKO, S. and SAMNDI, A.M. 2013. Growth and yield response of selected cowpea *(Vigna unguiculata (L.)* Walp) varieties to irrigation interval and sowing date. *The Pacific Journal of Science and Technology*: Volume 14:1.

IDAHOSA, D.O., ALIKA, J.E. and OMOREGIE, A.U. 2010. Genetic variability, heritability and expected genetic advance as Indices for yield and yield components selection in cowpea (*Vigna unguiculata (L.)* Walp). Academia Arena 2010:2.

IMRAN, M., HUSSAIN, S., KHAN, S., BAKHSH, A., ZAHID, M.S and BAIG, D. 2010. Character association and evaluation of cowpea germplasm for green fodder and grain yield under rain-fed conditions of Islamabad. *Sarhad Journal Agriculture 26, No 3.*

HALL, A.E., CISSE, N., THIAW, S., ELAWAD, O.H.A., EHLERS, J.D., ISMAIL, A.M., FERY, R.L., ROBERTS, P.A., KITCH, L.W., MURDOCKH, L.L., OUSMANE BOUKARI, R.D., PHILLIPS, K.H. and WATTERS, M.C. 2003. Development of cowpea cultivars and germplasm by the Bean/Cowpea CRSP. *Field Crops Research* 82: 103-134.

HALL, A.E. and EHLERS, J.D. 1997. Cowpea (*Vigna unguiculata (L.)* Walp). *Field Crops Research* 53: 187-204.

HAYATU, M., and MUKHTAR, F. B. 2010. Physiological responses of some drought resistant cowpea genotypes (*Vigna unguiculata (L.)* Walp) to water stress. *Bayero Journal of Pure and Applied Sciences*, 3: 69-75.

KABULULU, M.S. 2008. Cowpea (*Vigna unguiculata (L.)* Walp) variety mixtures for stable and optimal leaf and seed yields when intercropped with maize in Central Tanzania. MSc thesis at Georg-August-Universität, Göttingen, Germany. 75 pp.

KHAN, A., BARI, A., KHAN, S., HUSSAIN SHAH, N. and ZADA, I. 2010. Performance of cowpea genotypes at higher altitude of NWFP. Pak. J. Bot., 42: 2291-2296.

KAMAI, N., GWORGWOR, N.A. and SODANGI, I.A. 2014. Morphological basis for yield differences among cowpea varieties in the Sudan Savanna Zone of Nigeria. *IOSR Journal of Agriculture and Veterinary Science.* Volume 7, Issue 12.

KAMARA, C.S. 1976. The effects of excess and deficient soil moisture on growth and yield of cowpea. Tropical Grain Legume Bulletin. p. 6, 4.

KARUNGI, J., ADIPALA, E., NAMPALA, P., OGENGA-LATIGO, M.W. and KYAMANYWA, S. 2000. Pest management in cowpea. part 3. Quantifying the elect of cowpea"eld pests on grain yields in eastern Uganda. *Crop Protection* 19: 343-347.

KAWUKI, R.S., AGONA, A., NAMPALA, P. and ADIPALA, E. 2005. A comparison of effectiveness of plant-based and synthetic insecticides in the field management of pod and storage pests of cowpea. *Crop Protection* 24:473–478.

KAY, D.E. 1979. Crop and product digest No. 3 – Food legumes. London: Tropical Products Institute. Pp.86-101.

KELECHUKWU, N.E., ADEWALE, M.O. and EZEKIEL. A.A. 2007. "Aluminum Influence on performance of some cowpea (*Vigna uniguculata (L)* Walp) varieties on a Nigerian Alfisol". *Word Journal of Agrc*. Sci. 3:512-522. 2007. IDOS. Publication

LAMBOT, C. 2002. Industrial potential of cowpea, in C.A. Fatokun, S.A. Tarawali, P.M. Singh, P.M. Kormawa and M. Tarmo (ed.) Challenges and opportunities for enhancing sustainable cowpea production : 367-75. Ibadan: International Institute of Tropical Agriculture.

LUKA, G. Y., ABDULLAHI, G. and SHEHU, A. 2015. Differential Susceptibility of Some cowpea varieties to field infestation by insect pests in Mubi Region of Sudan

Savannah Ecological Zone of Nigeria. *American Journal of Experimental Agriculture, 5: 366-373.*

MAGLOIRE, N.S. 2005. The genetic, morphological and physiological evaluation of African Cowpea Genotypes. Thesis presented in accordance with the requirements for the degree *Magister scientiae Agriculturae* in the faculty of natural and Agricultural Sciences. Department of Plant Sciences (Plant breeding) at the University of the Free State, 131 p.

MISHILI, F.J., SHEHU, J.F.M., KUSHWAHA, S., MARFO, K., JAMAL, M., CHERGNA, A. and DEBOER, J.L. 2007. Consumer preferences for quality characteristics along the cowpea value chain in Nigeria, Ghana and Mali. Working Paper #06-17.

MOALAFI, A.I., ASIWE, J.A.N. and FUNNAH, S.M. 2010. Germplasm evaluation and enhancement for the development of cowpea (*Vigna unguiculata (L.) Walp*) dual-purpose F2 genotypes: Afr. J. Agri. Res. 5(7): 573-579.

MOSHIA, M.E., MASHATOLA, M.B. and SHAKER, P. 2008. Prospects for irrigated Maize-Soybean intercropping in Syferkuil experimental farm using Geospatial Information Technology*. Journal Home > vol, 8, no 2.*

MOSES, R.T. 2006. Biological and chemical control of fungal seedling diseases of cowpea. Submitted in partial fulfilment of the requirements for the degree of M.Inst. Agrar. (Plant Protection) In the Faculty of Natural and Agricultural Sciences Department of Microbiology and Plant Pathology University of Pretoria.

MOUSAVI, S.R AND ESKANDARI, H. 2011. A general review on intercropping and its advantages in sustainable agriculture. *J. Appl. Environ. Biol. Sci*.1: 482-486.

MUHAMMAD, G., RAMAZAN, C.M., ASLAM, M. and CHAUDHRY. G.A.1994. Performance of cowpea cultivars under rainfed conditions. *J. of Agric. Res*. 32: 119-122.

MULI, M. B. and SAHA, H. M. 2008. Participatory evaluation of cowpea cultivars for adaptation and yield performance in coastal Kenya. Kenya Agricultural Research Institute, Regional Research Centre, Mtwapa P.O Box 16, Kikambala.

NATIONAL DEPARTMENT OF AGRICULTURE. 2009. Production guidelines for Cowpeas. http:// www.nda.agic.za/docs/Infopark-cowpea booklet.pdf. (Accessed 2015 /04/10).

NDONG, A., KEBE, K.H., THIAW, C.H., DIOME, T. and SEMBENE, M. 2012. Genetic distribution of the cowpea (*Vigna Unguiculata (L.)* Walp) Bruchid (*Callosobruchus Maculatus F., Coleoptera, Bruchidae*) populations in different Agro-Ecological Areas of West Africa. *J Anim Sci Adv: 2*: 616-630.

NIELSEN, C.L. and HALL. A. 1985. Responses of cowpea (*Vigna unguiculata (L.)* Walp) in the field to high night air temperature during flowering. II. Plant responses. *Field Crops research.* 10: 181-196.

NWOFIA, G.E., NWANEBU, M.C. and MBAH, E.U. 2014. Yield and yield component responses of some cowpea varieties to population density structures under rainfed conditions in Lowland Tropics of Southeast Nigeria. *World Journal of Agricultural Sciences* 10: 68-75.

OKAFOR, L.I. 1986. Adapting improved cowpea cultivars to the Nigeria and arid zone. *Tropical Grain Legume Bulletin*. 33: 20-23.

OKE, O.A. and AKINTUNDE, E.M. 2013. Reduction of the nutritional values of cowpea infested with *Callosobruchus Maculatus (Coloeptera: Bruchidae. International Journal of Agricultural Science* Vol. 3: 30-36.

OPOLOTA, H.N., AGONAB, A., KYAMANYWA, S., MBATAC, G.N. and ADIPALA, E. 2006. Integrated field management of cowpea pests using selected synthetic and botanical pesticides. *Crop Protection* 25:1145–1152.

ORAWU, M., MELIS, R., DE MILLIANO, W., LAING, M. and ADIPALA, M. 2005. African crop science society occurrence and prevalence of cowpea virus diseases in Uganda. Vol. 7. pp. 1279-1283.

ORUONYE, E. D. and OKRIKATA, E. 2010. Sustainable use of plant protection products in Nigeria and challenges. *Journal of Plant Breeding and Crop Science* Vol. 2. pp. 267-272.

OYEWALE, R.O. and BAMAIYI, L. J. 2013. Management of cowpea insect pests. *Sch. Acad. J. Biosci*., 1:217-226.

PADULOSI, S. and NG, N.Q. 1997. Origin, taxonomy, and morphology of *Vigna unguiculata (L.)* Walp. In: SINGH, B.B., MOHAN, R.A.J., DASHIELL, D.R., JACKAI, L.E.N., (eds) Advances in Cowpea Research. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Sayce, Devon, UK, pp 1–12.

QUIN, F.M. 1997. Introduction. p. ix–xv. In: Singh, B.B., Mohan Raj, D.R., Dashiell, I.E. and Jackai, L.E.N. (eds.), Advances in cowpea research. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS), IITA, Ibadan, Nigeria.

SARIAH, J. E. 2010. Enhancing cowpea (*Vigna unguiculata (L.)* Walp) production through insect pest resistant line in east Africa. Department of Agriculture and Ecology, University of Copenhagen.

SEKYI, E.A. 1990. Effect of plant density on the performance of three varieties of cowpea [*Vigna unguiculata (L.)* Walp] in the Coastal Savannah of Ghana. Unpublished B.Sc. dissertation, School of Agriculture., University of Cape Coast, Ghana.

SHELEY, R. L. and PETROFF, J. K. 1999. Biology and management of Noxious Rangeland Weeds. Oregon State University Press, pp.4-15. pp. 44-84.

SINGH, B.B. and AJEIGBE, H.A. 2001. Breeding improved cowpea varieties for different cropping systems and Agro-ecologies in West Africa. *Afr. Crop Sci. Conf. Proc*. 5: 35-41.

SINGH, B.B. and AJEIGBE, H.A. 2002. Improving cowpea-cereal based systems in the dry Savannas of West Africa. In: Fatokun C.A., Tarawali S.A., Singh B.B., Kormawa P.M., Tamo M (eds). Proceedings, the World Cowpea Conference III, Challenges and opportunities for enhancing sustainable cowpea production*, Int. Inst. Trop. Agriculture (IITA), Ibadan, Nigeria,* pp. 278-286.

SINGH, B.B., AJEIGBE, H.A., TARAWALI, S.A., FERNANDEZ-RIVERA, S. and ABUBAKAR, M. 2003. Improving the production and utilization of cowpea as food and fodder. *Field Crops Research* 84: 169–177.

SINGH, B.B., ASANTE, S.K., FLORINI, D., JACKAI, L.E.N., FATOKUN, C. and WYDRA. K. 1997. Breeding for multiple disease and insect resistance. *IITA Annual Report Project* 11. Page 22.

SINGH, S.S., BAOULE, A. L., AHMED, H. G., DIKKO, A. U., ALIYU, U., SOKOTO, M. B., ALHASSAN, J., MUSA, M.,N. and HALIRU, B. 2011. Influence of phosphorus on the performance of cowpea (*Vigna unguiculata (L.)* Walp) varieties in the Sudan savanna of Nigeria. Vol.2, No.3: 313-317.

SINGH, B.B, EHLERS, J.D., SHARMA, B. and FREIREFILHO, F.R. 2002. Recent progress in cowpea breeding. In: FATOKUN, C.A., TARAWALI, S.A., SINGH, B.B., KORMAWA, P.M., TAMO, M., (eds). Proceedings, the World Cowpea Conference III, Challenges and opportunities for enhancing sustainable cowpea production*, Int. Inst. Trop. Agric. (IITA), Ibadan, Nigeria*, pp. 22-40.

SINGH, S.R., SINGH, B.B. and JACKAI, L.E.N. 1983. Ntare, Ibadan, Grain legume program, IITA, 20p. (Information series No: 14).

SINGH, B.B. and SHARMA, B. 1996. Restructuring cowpea for higher yield. *Indian Journal of genetics*. 56: 389-405.

SINGH, N., SUVEDI, M. and MATHURA, R. 2008. Varietal evaluation of cowpea in Eastern Uttar Pradesh. I*ndian Journal of Extension Education.* 43 (1&2).

SINGH, B.B. (2007). Potential and constraints of improved cowpea varieties in increasing the productivity of cowpea-cereal systems in the dry Savannas of West Africa. Pages 14-26 in MAJIWA, P., ODERA, M., MUCHIRI, N., OMANYA, G. and WEREHIRE, P. (eds). A plan to apply technology in the improvement of cowpea productivity and utilisation for the benefit of farmers and consumers in Africa: Proceedings of cowpea stakeholders workshop. Nairobi Kenya: African Agricultural Technology Foundation

TAKIM, F.O. and UDDIN, R.O. 2010. Effect of weed removal on insect populations and yield of cowpea (*Vigna unguiculata (L.) Walp)*. *Aust. J. Agric. Eng*., 1: 194- 199.

TAMÒ, M., SRINIVASAN, R., DANNON, E., AGBOTON, C., DATINON, B., DABIRE, C., BAOUA, I., BA, M., HARUNA, B. and PITTENDRIGH, B.R. 2010. Biological control: a major component for the long-term cowpea pest Management strategy. In Enhancing cowpea value chains through research advances, edited by BOUKAR, O., COULIBALY, O., FATOKUN, C., LOPEZ, K. and TAMÒ. M. Proceedings of the 5th World Cowpea Research Conference, 26 September–1 October 2010 Saly, Senegal.

TIMKO, M.P. and SINGH, B.B. 2008. Cowpea, a multifunctional legume. *Genomics of Tropical Crop Plants.* Chapter 10.

VALENZUELA, H. and SMITH, J*.* 2002*.*Green manure crops: Cowpea. *SA-GM-6.*

VINCENT, C., HALLMAN, G., PANNETON, B. and FLEURAT-LESSARD, F. 2003. Management of Agricultural insects with physical control methods. *Annual Review of Entomology*. Vol. 48: 261-281.

ZYL, E.V. and SADI, A.M. 2005*.* Cowpeas as fodder crop for lactating ewes*.* Grassroots: *Newsletter of the Grassland Society of Southern Africa*. Vol 5: No. 1.

LIST OF APPENDICES

Summarised rainfall data from Syferkuil farm and Ukulima farm

Appendix 1: rainfall data from Syferkuil farm and Ukulima farm