EFFECT OF INTER-ROW SPACING ON SOME SELECTED COWPEA (*Vigna unguiculata* (L.) Walp) VARIETIES IN YOLA, ADAMAWA STATE

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DECLARATION

I declare that this work was carried out in its original form by me, Umar, Ishaya Anasunda of the Department of Crop Production and Horticulture, Federal University of Technology, Yola, Nigeria.

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Sign Date

APPPROVAL PAGE

This Thesis entitled "**Effect of Inter-row Spacing on Some Selected Cowpea (*Vigna unguiculata* (L.) Walp) Varieties in Yola, Adamawa State**" by **Umar, Ishaya Anasunda** meets the regulations governing the award of degree in Masters of Technology in Agronomy of Department of Crop Production and Horticulture, Federal University of Technology, Yola, Adamawa state and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

In the name of Almighty God, this work is dedicated to my father Late Anasunda and my mother Late Amairnda of blessed memory.

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ABSTRACT

Recent studies have attributed low grain yield per hectare of cowpea in Nigeria to the cultivation of low yielding varieties and lack of optimum spacing of specific varieties. Field trials were conducted for two years (2009 and 2010) during the rainy season in Yola to examine the effect of inter-row spacing on three varieties of cowpea at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Federal University of Technology, Yola, Adamawa State. There were three (3) inter-row spacing (45 cm x 25 cm, 60 cm x 25cm, 75 cm x 25cm) which were the main plots and the sub-plots consisted of three varieties (IT89KD-288, IT89KD-391, and IT97K-499-35). The field layout was split plot design replicated three (3) times. Data collected were analysed using analysis of variance. The results showed that, spacing had no significant ($p \leq 0.05$) effect on plant establishment count, number of days 50% flowering and number of days 95% maturity in 2009 and 2010 rainy seasons. Increasing inter-row spacing from 45 x 25cm to 75 x 25cm significantly increased the number of pods per plant from 12.77 to 15.74. Similarly, length of pods per plant significantly increased from 13.61cm to 15.73cm and number of seeds per pod increased from 10.91 to 12.74. On the other hand, seed yield per plot and seed yield per hectare were found to be higher in spacing 45 x 25cm with 1314.2Kg/ha followed by 60 x 25cm with 1304.3Kg/ha while 75 x 25cm was the lowest with 1050.6Kg/ha. With respect to the varieties, overall yield result revealed that IT89KD-391 have higher seed yield of 1410.83Kg/ha followed by IT97K-499-35 with 1323.94Kg/ha while IT89KD-288 gave the least with 1031.67Kg/ha. Yield increased with decrease in inter-row spacing and hence closer spacing of 45 x 25cm should be adopted for IT89KD-288, IT89KD-391, and IT97K-499-35 varieties of cowpea in Yola, Adamawa state. Variety IT89KD-391 produced higher seed yield of 1256.03Kg/ha and hence recommended for cultivation in Yola environment.

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CHAPTER ONE

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is a herbaceous short term annual leguminous crop which is grown in many tropical and sub-tropical countries (Singh and Sharma, 1996). It originated in Africa and became an integral part of traditional cropping systems throughout Africa, particularly in the semi-arid region of West African Savanna (Mortimore *et al.,* 1997). Faris (1965) based his evidence on the presence of wild progenitors of cowpea in West and Central Africa and postulated that West Africa was the centre of domestication of cowpea. Cowpea is widely grown throughout Africa, Australia, Asia, low and coastal South America, West Indies and the Southern part of the United State of America (Davis *et al.,* 1991; Singh *et al.,* 1997*;* Boukar, *et al.,* 2004). In Nigeria cowpea is cultivated over a wide range of agro-environments ranging from the forest in the south to the sahel savanna of the north, although the bulk of the production is in the northern drier part of the country (Akande *et al*, 2009). Adamawa state is one of the major cowpea producing State in Nigeria (Adejobi and Ayinde, 2005) as evidenced by the availability of the produce in most market and also the consumption rate by most household. It is called by different names, some of which are beans, black-eye pea, *kafir* pea, southern pea, china pea, marble pea, *lubia*, *niebe*,*coupe* or *frijole* cowpea (Ebong, 1965; Olowe, 1978; Blackhurst and Miller, 1980).

The FAO (2006) estimated that 4.5million tones of cowpea dry grains were produced worldwide in 2005 and 75% of that production was from Africa and Nigeria produced 2.4million tones of this, making it the largest producer, followed by Niger (650,000t), Mali (110,000t). Other producers are South Africa (21%), Europe (1%), Asia (2%), and North America (1%). Total area grown globally was 14.0 million hectares and 9.3 million hectares of these was located in West Africa with about 5.0 million hectares in Nigeria (FAO,2006).

Yield in cowpea have been reported to consist of three primary components, viz: number of pods per plant, number of seeds per pod and 100 seeds weight (Malik and Singh, 1983). In Nigeria, average yield in 2008 and 2009 was about 679.8kg/ha (FAO, 2011) which was far below the yield capacity of the crop. Under recommended practice and good management, yield of 1500 – 2000kg/ha are easily possible (Onwueme and Sinha, 1991) although Blade *et al* (1997) have reported that with sole crop, grain yield potential is 1500-3000kg/ha under good management.

Cowpea is an important food crop in the dry Savannas of West and Central Africa (Kamara *et al;* 2008). It is the major source of dietary protein in many parts of the World, particularly in the countries situated along the tropical and subtropical belt, where availability and consumption of animal protein is rather low because of social and economic constraints (Singh and Singh, 1990). Cowpea dry grains are consumed in several forms (eg. boiled cowpea, *kosai*, *moin moin etc*) (USAID/Nigeria, 2008). Other uses include, seedlings, tender green leaves, immature pods, unripe green seeds are cooked as vegetables whereas immature dry seeds are used in many preparations as pulse. It is also utilized as a fodder plants for hay, silage or pasture and as a quick growing cover crop under wide range of conditions (Rachie, 1985). Increased cowpea yield from intensified cropping system can play a key role in income generation in West Africa because of the multiple uses of cowpea grain and fodder for human and animal diets respectively (Rachie, 1985). According to Adejobi and Ayinde (2005), cowpea is very important for the Federal Government strategic Grain Reserve Programme and Food Aid Programme.

Although Nigeria is a leading producer of cowpea in the world, grain yield per hectares is generally low. Some of the reasons for this low yield could be attributed to cultivation of low yielding varieties, lack of optimum spacing of specific varieties, inadequate fertilizer, high incidence of insect pest, diseases, weed problems and vagaries of weather condition (Tenebe *et al.,* 1995; Katung and Ngu, 2003). In Sub-Sahara Africa, Mortimore *et al*. (1997) reported low cowpea plant population per unit area as a major factor responsible for the low yields obtained from the small holder farming system. They recommended cowpea spacing within such systems to be highly variable (35-90 cm). According to Ndiaga (2000) cowpea varieties with different plant morphology would require different optimum densities to express their full seed yield potential. Rowland (1993) also reported that typical pure plant spacing of cowpea (*Vigna unguiculata* (L.) Walp) is 30cm between plant and 60cm between rows or 5 – 12cm between plant and 70 – 90cm between rows. Cowpea agronomy research (Ezedinma, 1974) had shown that yields increased with increase in plant populations per unit area up to certain limit. At optimal densities, most favourable results were obtained. At narrow spacing between the plants rows, yield was reduced because of the inter plant competition. Other problems of cowpea cultivation are that the local cultivars are photosensitive, indeterminate in growth and possess a prolonged period of pod development. This makes them less suitable for commercial farming when determinate cultivars which utilizes monocropping system is desired (Duke, 1990).

To improve the production and yield of cowpea in Nigeria, a continuous study must be undertaken on the factors affecting the production and yield of cowpea. It is against this background, that a study was conducted on varieties and inter-row spacing with the following objectives:

1. To evaluate the performance of some selected cowpea varieties in Yola, Adamawa State.
2. To determine the inter-row spacing for the varieties.
3. To determine the relationship between the varieties and studied inter-row spacing.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botany of cowpea

Cowpea is a twining annual herbaceous plant. The root system consists of well developed tap root with considerable number of lateral roots. The stem is slightly ridged and almost glabrous. The leaves are trifoliate, alternate and with scattered shoot hairs (Chhidda *et al.*, 2007). The flowers are white, yellow, pink, pearl blue and violet in colour and are self pollinated. The pods are long and cylindrical and constricted between the seeds. The seeds are bean-shaped and many times spotted with different colours such as brown, green, yellow, white and mottled (Chhidda *et al.*, 2007). Germination is epigeal (ICAR, 2006). Many cultivars are known, including climbing, bushy, prostrate and erect forms mostly with indeterminate growth (CFOR, 1981). There are large number of distinct forms of cowpea with their growth habit varying from spreading and bushy to climbing or erect with a high range in plant height of between 20-200cm (ICAR, 2006).

2.2 Climatic and soil requirements

Cowpea grow on most well-drained sandy loam to clay loam soils but do best on medium fertile loams. They are warm weather crop that tolerate high temperature and semi-arid conditions (CFOR, 1981; Dugje *et al.*, 2009). It can be grown under rain fed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season (Dugje *et al.,* 2009). It can perform well even in poor soil of pH 4.5-9.0 (the best pH is 6 – 7) and organic matter content of less than 0.2% (Singh *et al.,* 1997). This may be due to its ability to tolerate drought and the fact that it fixes atmospheric nitrogen to soil which allows it to grow and improve the soil. This makes cowpea an important crop in the savanna region where these constraints restricts other crops growth (IITA, 2004). Cowpea as a warm weather crop cannot tolerate frost. It thrives best at the temperatures of between 27 – 35˚C and the annual rainfall of 500 – 700 mm per annum for its production (Singh *et al,* 1997). Cowpea is a low altitude crop and as a rule, it cannot be grown above 1000 – 1200 m above sea level (Vanderbought and Bandion, 2001). However, with the development of extra-early and early maturing cowpea varieties, the crop can thrive in the Sahel where the rainfall is less than 500 mm/year (Dugje *et al.,* 2009).

2.3 Agronomic practices

Agronomic practices depend on the prevalent growing conditions in the growing area. The current agronomic practices such as date of planting, plant populations, maintenance of soil physical properties and fertility, weeds control and cropping system strongly influence the yield of cowpea (Muleba and Ezuma, 1985).

2.3.1 Site selection

Proper site selection is very important. Select a well-drained sandy loam soil for rain fed cowpea, or inland depressions and along the shores of a lake for dry season cowpea using residual moisture. Cowpea does not tolerate excessively wet conditions or water-logging and should not be grown on poorly drained soil.

2.3.2 Land preparation

Cowpea can be grown with zero, minimum or high tillage. The previous crop grown on the field, soil condition and weeds control measures determine the effectiveness of type of tillage. Clear the site of shrubs and stubble. Plow and harrow the field to provide sufficient tilth for good root growth. Make ridges thereafter if desired. Where the soils are more fragile and prone to erosion, adopt minimum or zero tillage (Dugje *et al.*, 2009). Two harrowing provides sufficient tilt for good cowpea root growth (Onyibe *et al.*, 2006). Land can also be prepared manually with the African hand-hoe.

Zero tillage is also a common practice. It significantly reduces cost of labour and saves energy in land preparation (Pandey *et al*, 1985). Pulverizing and aerating the soil are expensive, time consuming and wasteful of residual moisture and experimental results show that yield at zero or minimal tillage are comparable with those from conventional tillage. Zero tillage significantly reduces the risk of crop failure due to drought and represent savings in labour and energy in land preparation for cowpea production (Oyenuga, 1976, Warag and Hull, 1984). Alternatively, spray the field with Glyphosate (Round-up) at the rate of 4 L/ha (about 2 1/3 milk tins of chemical in a 15L sprayer or 3 milk tins of chemical in a 20L knapsack sprayer) to kill emerged weeds.

2.3.3 Mulching in cowpea

Agricultural land management practices such as mulching and minimum tillage can significantly influence the success of legume and cereal rotations. Mulching can improve soil water supply to crops through reduced runoff and soil evaporation, increased infiltration and water storage. Conservation agriculture, recently introduced in smallholder agriculture a system that encourages minimum soil disturbance and use of mulch cover for moisture and weed management among other benefits. Studies conducted in the higher potential areas of Zimbabwe between 1988 and 1995 indicated that mulching significantly reduced surface runoff and hence soil loss (Erenstein, 2002). The mulching material at the soil−atmosphere interface holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil. Mulch cover shields the soil from solar radiation thereby reducing evaporation from the soil.

2.3.4 Planting of seeds

Cowpea should be planted either on ridges or on flat beds, depending upon the field preparation. Planting is usually manual, since mechanical planters are not readily available (Dugje *et.al.*, 2009). Early planting as soon as rains become well established in mid to late June is associated with high yields (IITA- SAFGRAD, 1982, 1983) but it will mean that in Northern Guinea Savanna and Southern Savanna, photoperiod cultivars will mature in August and early September under humid cloudy weather that favour pod rots. Therefore in these areas, the IITA- SAFGRAD (1982 and 1983) programme recommended planting of cowpea in mid July. Seeds are sown at conventional depth of 2-3 cm and seedlings emerge 2 - 3 days after sowing at favourable temperature (about 28˚C). Germination in cowpea is epigeal (Lush and Wein, 1980). Use about 12–25 kg/ha of cowpea seeds, depending on the variety, seed size, cropping system, and viability of the seeds. More seeds are required when erect varieties are used than when prostrate varieties are adopted, because of the closer spacing of the erect variety. Also, fewer seeds are required when the cowpea is to be grown in mixture with other crops (Dugje *et.al.*, 2009). For all recommended plant spacing, sow 3 seeds/hill and thin to 2 plants/stand at 2 weeks after planting.

2.3.5 Plant populations

Optimal plant populations and row spacing vary with plant types and date of planting (Muleba and Ezumah, 1985). Prostrate, photoperiod-sensitive cowpeas show little increase in yield when planted at populations greater than 22,000 plants/ha (IITA- SAFGRAD, 1982) whereas the semi-erect and erect cowpeas respectively, respond positively to intermediate (50,000 – 80,000 plants/ha) and high populations is greater than 100,000 plants/ha (IITA-SAFGRAD, 1983). These plant populations correspond to row spacing of 50 cm x 25 cm, 75 cm x 20 cm for semi- erect intermediate high branching type and 16 cm x 34 cm or 17 cm x 40 cm for erect determinate and low branching types. Two plants per stand are recommended for either erect or prostrate type (Onyibe *et al.*, 2006).

2.3.6 Weeds control

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. Cowpea is not a strong competitor with weed, especially at the early stage of growth. The type of weed control measures adopted should be based on the nature of the problem and the resources available to the farmer.

Significant reduction in cowpea leaf and branch production is caused by delayed weeding. Cowpea can tolerate weeds up to 3 weeks after sowing while delay weeding for more than 4 weeks after sowing may cause significant reduction in yields, i.e. up to 69% yield loss (Tijani-Eniola, 2001). Akobundu (1997) reported that weeds compete with cowpea for above and below ground resources, thus causing losses which range from 50-80%. Crop losses by weeds can be aggravated by delay in weeding or inability to weed throughout the entire crops growth period (Sangakkara, 1999). Weeds also reduce root production, nodule formation of cowpea, harbour insect pests and plant diseases (Gofung, 1987). Ayeni (1982) observed that significant yield reduction occurred when weeds were allowed to infest cowpea for at least six (6) weeks in the early season of the crop and four (4) weeks in the late season crop. Similarly, Fadayomi (1979) found that the highest yield was obtained from the plots maintained weed-free up to six (6) weeks after sowing.

The common traditional weeds control methods in cowpea are hoe-weeding, mulching and intercropping (Robel and Fabro, 1979). Of these methods, hoe-weeding is the most commonly practiced among small scale farmers but it is not suitable for large-scale production because of its high labour requirement. Shebayan *et al.* (1985) reported that hoe weeding is usually done at 3 and 6 weeks after sowing. However in places where weeds pose serious problems, an additional hoe-weeding at 9 weeks after sowing is necessary. Akobundu (1987) suggested that chemical weeds control in cowpea was generally superior to hoe-weeding even though yield was identical. Codal at 2.0kg a.i./ha was recommended for weeds control in Nigeria Savanna (Shebayan, 1986) or metolachlor at 2-3 kg a.i./ha (Olunuga and Akobundu,1980).

2.3.7 Fertilizer application

Soils in humid and semi-arid West Africa have been reported to be deficient in nitrogen and phosphorus and to some extent potassium and

Sulphur (IITA-SAFGRAD, 1983). Prasad (1985) reported that application of starter nitrogen at 20kgN/ha in cowpea is recommended. The amount of applied-N as starter dose is critical as too much of N will decrease nodulation and nodule activity impaired and seed yield reduced (Dart *et al*., 1977).

2.3.8 Maturity and harvesting

Cowpea shows variation in the start and end of the reproductive period some cultivars flowers within 30 days from sowing and ready for dry-seed harvest 25 days later, others take more than 100 days to flower and 210 - 240 days to mature (Summerfield *et al*., 1985). In developing countries, harvesting is done manually. Plants are pulled up and placed in rows or more commonly in piles very early in the morning to avoid pod opening. Climbing type has to be harvested pod by pod as they mature upwards. Moisture content level at harvest should be between 13 - 15% (Jones, 2004). Harvesting of cowpea can also be done using machines especially in large scale mechanized farms (Jones, 2004).

2.3.9 Pests and diseases

Insect pests are major constraints to cowpea production in West Africa. The crop is severely attacked at every stage of its growth by a myriad insects that make the use of tolerant varieties and insecticide sprays imperative. The level of insect attack increases from the Southern Guinea Savanna towards the Sahel Savanna zone of the region. Yields loss in cowpea due to insect pests in Nigeria was estimated to be above 80%. On unsprayed farms with insecticide, serious economic damage is done to farmers (Dike, 1998; Dugje *et al.,* 2009). Major insect pests are: *Aphis Craccivora, Moruca vitrita* and *Megalurathrips Sjostedii* (Oparaeke *et al,* 2003). Oparaeke *et al.* (2003) stated that chemical control remain the most effective method of insect pests in cowpea.

Several diseases caused by bacteria and virus are known to infect cowpea. Blackeye Cowpea Mosaic Potyvirus caused by aphids is reported in different ecological zone of Nigeria (Kashina, 1996). Of the bacterial disease caused by *Xanthomonas compestris* (Burkh) Dye is the mostly widespread (Emechebe and Florini, 1997).

2.4 Effects of variety on yield in cowpea

Cowpea is a single crop species but with different varieties in terms of plant type, seed type, maturity and the use pattern (Singh *et al.*, 1997). The choice of variety is based on maturity period, yield potential, drought tolerance, responsiveness to day length, and pest and disease resistance. However the same variety may be used for more than one purpose e.g. a variety used as a vegetable may be used as fodder (Chhidda *et al.,* 2007). Based on maturity period, some varieties mature early (60-64 days) while others mature late (Rachie, 1985). Therefore, cowpea are classified as early, medium and late maturity type.

To a large extent, majority of the cowpea varieties produced in Adamawa state are still predominantly local cowpea cultivars many of which have potential for high yield. Although, according to Olufajo and Elemo (1991), the acclaimed yield superiority of improved varieties over local varieties ought to be established for cowpea because of the unwillingness of most farmers to adopt cultivation of newly recommended crop varieties due to observed low yields of some of them on their field. Some of the recommended varieties for cultivation in Nigeria include: Ife brown, IAR-48, IAR-49, K59, ITA60, IT84-E, TVX323 and others. These names according to Ogbuinya (1997) are designated by locality or breeder numbers. Currently, improved varieties of cowpea have been developed by the International Institute of Tropical Agriculture (IITA). These varieties are superior to the local cultivars in many respects such as high yielding, resistant to major pest and diseases, earlier maturity, etc (Singh, 1997).

Most cowpea exhibit photoperiods but the sensitivity to day length varies greatly. For practical purposes, the classification by Steele and Mehra (1980) is very useful. They divided the cowpea cultivars into three groups:

i. Type 1A – reproductively day-neutral; determinate genotypes with erect and few branches.

ii. Type 1B – reproductively day-neutral; indeterminate genotypes. These continue to produce new vegetative growth while fruiting.

iii. Type 2 – reproductively photosensitive, indeterminate genotypes, typical of the landraces of the West African Savannas.

The question of determinate versus indeterminate habit is an important issue in the semi-arid agriculture. Admittedly, fast maturity, determinate varieties are suited to certain well defined situations, such as when low rainfall prevails as the crop is planted late in the rains and mature with declining soil moisture. However semi-arid areas are usually characterized by unpredictable rainfall and the determinate habit gives less insurance against pest attack during the reproductive phase. Provided drought begins after first flowering, it does not affect determinate varieties presumably because most of the assimilates used for fruit development are provided before flowering (Rachie and Roberts, 1974). In indeterminate varieties, by contrast, it seems probable that significant amount of assimilates comes from photosynthesis at or after flowering.

2.5 Effects of row spacing on yield and yield components in cowpea

Plant population on the field which depends on inter and intra row spacing influences crop performance (Akobundu, 1987). Albert *et al.* (1984) reported that high planting densities reduce growth, development and yield of individual plants though the production per unit area might increase. Cowpea agronomy research (Ezedinma, 1974) had shown that yields increased with increasing plant population up to certain limit and at optimal densities, most favourable result was obtained. At narrow spacing between plants within rows, yields reduce because of interplant competition. The Institute for Agricultural Research, Zaria recommended 20 - 30 cm intra row spacing for sole cowpea crop depending on the plant type within the Savanna zone of Nigeria (Anon, 1985) and 25cm intra row spacing was recommended by Singh *et al.* (1997) while 60 cm inter-row spacing was recommended by Kayode and Odulaja (1985). The use of appropriate plant population increase yield in arable crop such as maize, soyabean and cowpea (Akobundu, 1987; Johnson and William, 1997, Tijani-Eniola and Akinnifesi, 1998).

Erect cowpea varieties should be planted at a spacing of 50 cm between rows and 20 cm within rows, especially for extra-early maturing varieties (60–70 days). For semi-erect varieties, spacing should be 75 cm between rows and 25–30 cm within rows. For prostrate varieties, plant at a spacing of 75 cm between rows and 50 cm within rows.

2.6 Intercropping cowpea with cereal crops

Cowpea production is mostly found in the savanna ecological zone where it is traditionally grown as a sole crop such as for millet, maize and sorghum (Singh *et al.*, 1997). The beneficial effect of cowpea-cereal mixture is that cowpea can fix up to 240kgN/ha to the soil, hence improves the soil fertility. It provides high proportion of its nitrogen requirements, besides leaving a fixed N-deposit in the soil up to 60-70kgN/ha for succeeding crop (Rachie, 1985). Maize and cowpea are planted on the same row with the population density of cowpea inversely proportional to that of Maize (Muleba and Ezuma, 1985). The outcome of these practices is usually a reduction of cowpea grain yield. The type of cultivars planted, plant population density and planting geometry have been reported to influence crop performance (Olusantan, 1993). IITA (1975) reported that alternate single row of climbing cowpea with maize was superior to planting legumes on the same row with maize. Although Fisher (1977) reported a drastic reduction in bean yields in maize-bean intercrop based on mixing optimum population of maize and beans such that beans were planted with maize on the same row. Where cowpea is to be intercropped or relayed with other crops, such as maize, the spacing should be 75 cm × 50 cm. Also the cowpea should be planted at about 4–6 weeks after planting the first crop, maize, sorghum, or millet. For strip intercropping, adopt 2 rows of cereal to 4 rows of cowpea to improve the productivity of erect and shade-sensitive cowpea varieties.

2.7 Interaction of spacing and variety

Currently, improved varieties of cowpea have been developed by the International Institute of Tropical Agriculture. These varieties are superior to the local cultivars in many respects (high yielding, resistant to major pests and diseases, earlier maturity, etc) (Singh, 1997). However, according to Ndiaga (2000) cowpea varieties with different plant morphology would require different optimum densities to express their full seed yield potential. Grain yields of cowpea in Africa, however, have been reported to be dependent on plant population density, cropping systems, and cultivars (Hegstad et al., 1999). Although Attah *et al.* (2003) reported that there was no significant interaction between cultivars and plant density for grain yield and some components determining yield in L-25 and IAR-48 varieties of cowpea which are erect and of medium height. Investigation carried out to study the effect of different crop population and cultivars on growth and yield of cowpea in West Africa indicated that the main problems limiting production of cowpea is lack of specific spacing for different varieties of cowpea. Several studies in South and South-east Asia revealed that spacing of 50cm between rows with 2 plant/hill at 15cm between stands proved to be the best combination resulting in a yield of 924kg/ha (Braga Paiva *et al* 1971). Mohdnoor (1980) reported a spacing of 75 x 20cm for semi erect indeterminate, high branching types and to 17 x 40cm for erect determinate and low branching type.

2.8 Constraints of cowpea production

Despite the high yield potential of cowpea, throughout the world, the production of cowpea are constrained by many factors, these include: insect pests, diseases, problem of soil, uncertainty of high yielding cultivars, cultural practices which depend on the producing areas, preferences in particular area and management of crop (Rachie, 1985). The crop is also constrained by two obnoxious parasitic weeds *Striga gesneroides* and *Alectra vogelii* causing poor yield in especially late planted cowpea (Anon, 1983). Post-harvest handling and utilization is also a major constraint in cowpea production. Other factors include date of planting, day length, soil nematodes, moisture extremes and temperature (Okigbo, 1978; Hull and Patel, 1985). However, if the effects of these constraints are minimized, high yield can be obtained.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

Field trials were conducted in two successive cropping seasons under rain fed conditions at the Teaching and Research Farm of the Department of Crop Production and Horticulture, School of Agriculture and Agricultural Technology, Federal University of Technology, Yola, Adamawa State. The farm is located at latitude 9° - 10°N and longitude 11° and 14°E at the altitude of 158.5m above sea level (Adebayo, 1999). The annual rainfall in 2009 and 2010 was 577.5mm and 644.1mm and the length of rain fall was 160 – 210 days and mostly from April to October. The annual minimum and maximum temperature of the area were 24.8°C and 38.6°C respectively (See Appendix I).

3.2 Sources of seed and characteristics of the varieties

The seeds of cowpea varieties IT89KD-288, IT89KD-391 and IT97K-499-35 were obtained from Biu Zonal Office, Borno State Agricultural Development Programme. The characteristics of the varieties are as follows:

3.2.1 Variety - IT89KD-288

The plant is semi-erect and medium size seeds, medium maturity and photo-sensitive. It is excellent for intercropping with cereals and requires 2-3 sprays with insecticide (Onyibe *et.al.,* 2006).

3.2.2 Variety - IT89KD-391

It is improved dan'Ila, early maturing, non-photosensitive, erect, and medium sized brown seeds. It has some level of resistance to aphids, thrips, viruses and several diseases. It requires 2-3 sprays with insecticide for good grain yield (Onyibe *et al.*, 2006).

3.2.3 Variety- IT97K-499-35

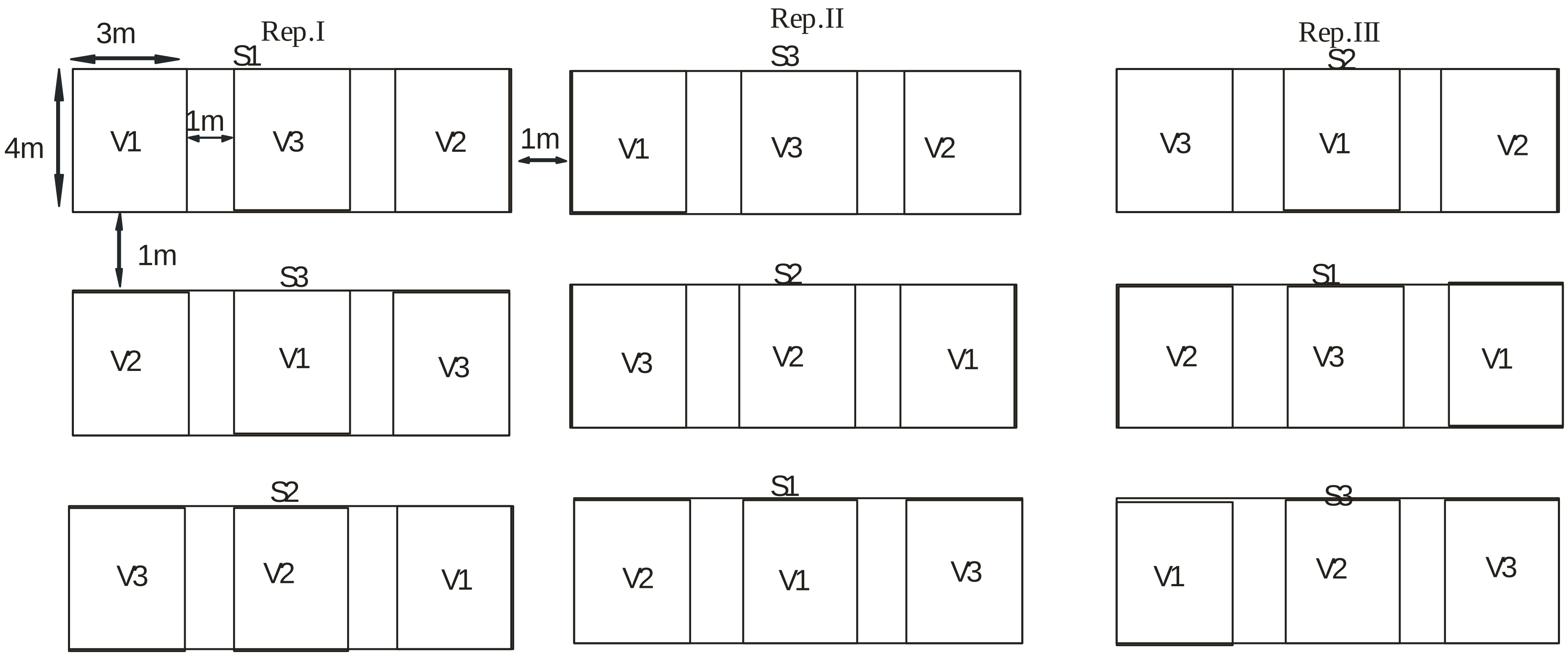
The plant is erect, medium-maturity and photo-insensitive. Medium sized seeds and require at least 2-3 sprays with insecticide (Onyibe *et al.*, 2006).

3.3 Experimental design and treatment

The trial consisted of three inter-row spacings: 45 x 25 cm, 60 x 25cm, 75 x 25cm (designated as S1, S2 and S3) and three varieties of cowpea: IT89KD-288, IT89KD-391 and IT97K-499-35 (designated as V1, V2 and V3). The experimental design used was split plot design. In the experiment, there were 3 replications. Each replication was divided into 3 main plots and each main plot was sub-divided into 3 subplots. Spacing formed the main plot while variety the subplot. There were total of 27 sub-plots of size 4 m x 3m. The treatments were allocated at random.

3.4 Soil test of the experimental site

Soil were randomly sampled by digging three boring of 0 – 15 cm depth. The soil sampled were bulked, air dried and sieved through 2mm mesh before analysis for physical and chemical properties in the Soil Science



Key:

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

Figure 1: Experimental field layout in split plot design

Laboratory of the Department of Soil Science, Federal University of Technology, Yola.

3.5 Cultural practices

3.5.1 Land preparation

The land was cleared to remove thrashes and crop residues. It was then ploughed and harrowed to make fine tilt and leveled.

3.5.2 Sowing and spacing

The seeds were sown at the rate of 3 – 4 seeds per hole and latter thinned to 2 plants per stand. The spacing used for this experiment were 45 x 25cm, 60 x 25cm and 75 x 25cm.

3.5.3 Weeds control

Two hoe weeding were carried out at two weeks after sowing and five weeks after sowing respectively to ensure that weeds competition are kept under control (Onyibe *et al*.,2006). Poor weed control or delay in weeding causes drastic reduction of cowpea yield.

3.5.4 Fertilizer application

Starter dose nitrogen fertilizer was applied at 20kgN/ha as recommended by Prasad (1985). Urea fertilizer was used. The conversion of the commercial quantity of urea to N used is as follows:

$$N = \frac{\text{Quantity of N to be applied}}{\text{Percentage N in urea}} \times 100$$

3.5.5 Insects pests and diseases control

Insects pests and disease attack were the most important constraint in cowpea production. The cowpea plant was severely afflicted at every stage of growth by myriads of insects and diseases that make the use of tolerant varieties and pesticides imperative (Onyibe *et.al,* 2006). To effectively control the insect pests, three (3) sprays were made for good grain yield. The first spray was conducted at 35 days after sowing when flower bud initiation had started. The second and third spray were given at 10 days intervals respectively. Karate 25 EC was used at the rate of one litre per hectare (Onyibe, *et al*., 2006).

3.5.6 Harvesting

Cowpea pods were harvested by hand picking when they were ripe and dry.

3.5.7 Threshing and bagging

The harvested pods were piled up and shelled manually by beating the harvested pods with stick. The shelled beans were winnowed and stored in polythene bags for weighing.

3.6 Data Collection

3.6.1 Establishment Count

This was carried out at 2 weeks after sowing to know the number of cowpea plants that have established on the field.

3.6.2 Plant height

The plant height was measured using a metal sheet measuring tape. The measurement was from the ground level (base) to the tip of the plant. It was taken at 4 weeks after sowing, at 50% flowering and at 95% maturity on 5 sampled plants.

3.6.3 Number of leaves per plant

Five (5) plants were randomly selected per plot and the number of fully expanded leaves were counted at 4 weeks after sowing, at 50% flowering and at 95% maturity.

3.6.4 Number of primary branches per plant

Five (5) plants were sampled and the number branches per plant counted to know the branching ability of the varieties at four weeks after sowing, at 50% flowering and at 95% maturity.

3.6.5 Number of days to 50% flowering

This was done by observing physically when the plants are about 50% flowering and the number of days recorded.

3.6.6 Number of days to 95% maturity

This was taken when the pod set by the plants are observed to be about 95% matured and the number of days recorded.

3.6.7 Length of pods per plant

This was done by measuring length of the five (5) pods randomly picked with centimeter rule or measuring tape and the average length recorded.

3.6.8 Number and weight of pods per plant

At harvesting 5 plants were picked at random from each plot. The pods were counted and weighed and the average recorded.

3.6.9 Number and weight of seeds per pod

At harvesting, five (5) pods were picked at random and the pods opened separately and the seed counted, weighed and averaged.

3.6.10 Weight of 1000 seeds

This was obtained from the threshed seeds per plot at random and 1000 seed were counted and weight recorded for each variety separately.

3.6.11 Shelling percentage

The harvested pods of variety in each plot was shelled manually and the shelling percentage was determined from the following equation:

$$\text{Shelling percentage} = \frac{\text{weight of seeds (g)}}{\text{weight of the pods (g)}} \times 100$$

3.6.12 Grain yield per plot and grain yield per hectare

The grain yield per plot was determined for all the plots and the values were extrapolated to obtain the grain yield in kilogramme per hectare ($kgha^{-1}$).

3.7 Data analysis

Data collected were analyzed using analysis of variance (ANOVA) and the Duncan's Multiple Range Test (DMRT) value at 5% were obtained to separate the means.

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-chemical properties of soil sample of the experimental site

The physico-chemical properties of soil sample of the experimental site are presented in Table 1. The physical properties indicate that the soil of the experimental site is sandy loam soil with 57.2% sand, 29.5% silt and 13.1% clay. The chemical properties also indicate that the soil is relatively a good soil with the pH of 6.5. Electrical conductivity, total nitrogen, organic carbon, other exchangeable bases and exchangeable cation are low in the soil.

4.2 Establishment count, number of days to 50% flowering and number of days to 95% maturity

4.2.1 Plant establishment

Table 2 presents the mean values of the effects of inter-row spacing and variety on plant establishment for 2009 and 2010 rainy seasons and mean of the combined years. The effect of inter-row spacing and variety on plant establishment was not significant ($p \leq 0.05$) in both years. Similarly, the combined years did not show significant ($p \leq 0.05$) variation for the treatments. In 2009, the highest establishment count was recorded in 60 x 25cm spacing having 92.22 while the lowest was in 45 x 25cm with the mean of 89.44 and in 2010 the highest mean of plant establishment count was recorded in 75 x 25cm with the mean of 92.89 while the lowest was in 45 x 25cm with 91.78. The combined mean of the two years also show that

Table 1: Physico-chemical properties of soil sample of the experimental site

Soil properties	Status
Physical properties	
Sand (%)	57.2
Silt (%)	29.5
Clay (%)	13.1
Chemical properties	
pH (H_2O)	6.5
CEC (mmhos/cm)	0.28
Organic carbon (OC)%	1.10
Total nitrogen (%)	0.02
Available P (meq/100g)	2.78
K (meq/100g)	0.74
C (meq/100g)	3.21
Mg (meq/100g)	2.00
Na (meq/100g)	0.14

Soil Texture: sandy loam

Table 2: Mean effects of spacing and variety on plant establishment count, number of days to 50% flowering and number of days 95% maturity in 2009 and 2010 rainy season

	Establishment count (%)			Number of days to 50% flowering			Number of days 95% maturity		
Treatments	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	89.44	91.78	90.61	45.11	47.00	46.06	81.44	83.00	82.22
S_2	92.22	92.00	92.11	45.33	47.11	46.22	81.67	83.00	82.33
S_3	89.67	92.89	91.28	45.33	47.11	46.22	82.22	83.11	82.67
Variety									
V_1	91.78	93.78	92.78	49.44a	51.44a	50.44a	92.56a	92.88a	92.72a
V_2	91.00	89.33	90.17	48.33b	50.89b	49.61b	87.22b	87.78b	87.50b
V_3	88.56	93.56	91.06	38.00 C	38.88c	38.44c	65.56c	68.44c	67.00c
Interaction									
S x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant

60 x 25cm have the highest establishment count of 92.11 while 45 x 25cm maintained the lowest value of 90.61. All these differences in mean were not significant ($p \leq 0.05$).

Among the varieties, IT89KD-288 have the highest establishment count for 2009 which is 91.78 followed by IT89KD-391 while IT97K-499-35 have the lowest establishment count. In 2010, IT89KD-288 has also the highest establishment count of 93.78 while IT89KD-391 has the least (89.33). In the combined years IT89KD- 288 maintained the highest value of establishment count followed by IT97K-499-35 while IT89KD-391 had the lowest establishment count. However the differences in the mean of the varieties is not significant ($p \leq 0.05$). Also there was no significant ($p \leq 0.05$) interaction between inter-row spacing and variety on the establishment count.

4.2.2 Number of days to 50% flowering

Table 2 presents the mean values on number of days to 50% flowering during the 2009 and 2010 rainy seasons and the combined years. In 2009 growing season, 60 x 25cm and 75 x 25cm have the same mean value of 45.33 which was higher than for 45 x 25cm having 45.11. Similar trend was observed in 2010 rainy season, where 60 x 25cm and 75 x 25cm having the highest value of 47.11 while 45 x 25cm the least (47.00). In the combined years, both 60 x 25cm and 75 x 25cm have the same mean value of 46.22 which is the highest while 45 x 25cm having

46.06 the least. The differences in mean values of spacing was not significant ($p \leq 0.05$) for 2009, 2010 season and the combined years.

The varieties recorded the mean values of 49.44, 48.33 and 38.00 days for IT89KD-288, IT89KD-391 and IT89K-499-35 respectively in 2009. Similarly, in 2010 the mean values of 51.44, 50.89 and 38.88 days was recorded for IT89KD-288, IT89KD-391 and IT89K-499-35 respectively. The same trend was observed in the combined analysis with IT89KD-288 having the highest mean value of 50.44 followed by IT89KD-391 with 49.61 while IT89K-499-35 is the lowest with the mean value of 38.44. The mean variation for the variety was highly significant ($p \leq 0.01$) for 2009, 2010 and combined years. There was no significant ($p \leq 0.05$) interaction between spacing and variety for 2009, 2010 season and the combined years.

4.2.3 Number of days to 95% maturity

Table 2 presents the mean values of the number of days to 95% maturity for 2009 and 2010 rainy seasons and the combined years. In 2009 season, 75 x 25cm had the highest mean value of 82.22 while 45 x 25cm had the least value of 81.67. In 2010 rainy seasons, similar trend was observed where 75 x 25cm had the highest value of 82.67 while 45 x 25cm had the lowest mean value of 82.22. In the combined years, spacing of 75 x 25cm had the highest mean value of 82.67 while 45 x 25cm had mean value of

82.22. The mean variation in spacing was not significant for the two years and the combined mean in both seasons.

Among the varieties in 2009, IT89KD-288 had the highest number of days which is 92.56 days followed by IT89KD-391with 87.22 while IT89K-499-35 have the least mean number of days. Similar trend was observed in the 2010 where IT89KD-288, IT89KD-391 and IT89K-499-35 recorded 92.88, 87.78 and 68.44 respectively. In the combined analysis, IT89KD-288 have the highest number of days was 92.72 followed by IT89KD-391with 87.78 while IT89K-499-35 had the least number of days which was 67.00. IT89K-499-35 matures significantly ($p \leq 0.01$) higher than IT89KD-288 and IT89KD-391 for 2009, 2010 and the combined seasons. The mean variation in respect of the varieties was significant ($p \leq 0.05$). There was no significant ($p \leq 0.05$) interaction of inter-row spacing and variety in number of days to 95% maturity for 2009, 2010 season and the combined years.

4.3 Growth parameters

4.3.1 Plant height

Table 3 shows the effects of inter-row spacing and variety on plant height at various stages of growth for 2009 and 2010 rainy seasons and the combined mean. In 2009 rainy season, at 4 WAS, 60 x 25cm had the tallest plant with mean value of 16.32cm while the shortest was recorded in 45 x 25cm with the mean height of 15.76cm. In 2010 season, the tallest

Table 3: Mean effects of spacing and variety on plant height at4 weeks after sowing, 50% flowering and 95% maturity in 2009 and 2010 rainy season

	Plant height at 4 WAS (cm)			Plant height at 50% flowering (cm)			Plant height at 95% maturity (cm)		
Treatment	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	15.76	12.58	14.17	21.80	27.51	24.66	34.36	39.22	36.79
S_2	16.32	12.46	14.39	22.03	30.68	26.36	37.10	43.19	39.34
S_3	15.80	12.13	13.97	21.52	27.79	24.66	36.37	40.30	38.33
Variety									
V_1	16.45	13.50a	14.98a	24.48a	46.63a	35.56a	49.39a	59.60a	53.69a
V_2	16.00	11.87b	14.93a	23.88a	23.52b	23.70b	29.94b	35.27b	32.61b
V_3	15.42	11.80b	13.61b	21.00b	15.82c	18.41c	28.49b	27.84c	28.12c
Interaction									
S x V	NS	NS	NS	NS	*	NS	NS	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant   * = significant at 5%
WAS= weeks after sowing

plant was recorded in 45 x 25cm with the mean of 12.58cm while the shortest was in 75 x 25cm with the mean height of 12.13cm. The means of the combined years show that 60 x 25cm spacing had the tallest plant with the mean height of 14.39cm followed by 45 x 25cm spacing which is 14.17cm and the shortest plant was 13.97cm. All the mean variations of height at 4 WAS were not significant ($p \leq 0.05$).

With respect to the varieties, in 2009 season, the tallest plant recorded was IT89KD-288 with 16.45cm while the shortest was IT97K-499-35 with mean height of 15.42cm. Similar trend was observed in 2010 with IT89KD-288 having the tallest plant (13.50cm) while shortest was IT97K-499-35 with the value of 11.80. The mean variation was found to be significant ($p\leq 0.05$). In the combined years, mean of the varieties IT89KD-288 was also the tallest with the height of 14.98cm which was significantly ($p\leq 0.05$) taller than IT97K-499-35 which is 13.61cm. It was observed that at 4 weeks after sowing the interaction between inter-row spacing and varieties was not significant. It was observed that at 4 WAS the interaction between inter-row spacing and varieties is not significant ($p \leq 0.05$).

At 50% flowering, the tallest plant in 2009 with mean height of 22.03cm was recorded in 60 x 25cm while the shortest was in 75 x 25cm with mean height of 21.52cm. In 2010, 60 x 25cm was the tallest plant with 30.68 while the shortest was in 45 x 25cm with 27.51. The combined years shows that 60 x 25cm had the highest mean of 26.44 while 45 x 25cm and 75 x 25cm both follows with the same mean which was 24.66. Variety IT89KD-288 had the tallest plant in 2009 with the mean value of 24.48 while the shortest is IT97K-499-35 with the mean of 21.00. Similarly, in 2010 rainy season, IT89KD-288 was the tallest plant with height of 46.63cm and the shortest is IT97K-499-35 with the mean of 15.82cm. Mean of the combined years followed the same trend where IT89KD-288 was the tallest plant with the mean height of 33.56cm and the shortest was IT97K-499-35 with mean height of 18.41cm. The mean variation of the varieties for 2009 and 2010 was highly significant ($p \leq 0.05$) but not within the spacings.

Mean values of plant height at 95% maturity in 2009 season as showed in Table 3 indicated that, the tallest plant (37.10cm) was recorded in 60 x 25cm while the shortest in 45 x 25cm with mean value of 34.36cm. Similarly, in 2010 season, the tallest plant was recorded in 60 x 25cm while 45 x 25cm had the shortest with the value of 43.19cm and 39.22cm respectively. The combined years also shows that 60 x 25cm had the highest with 39.34 while 45 x 25cm remain the shortest with 36.79. Among the varieties, in 2009 season, IT89KD-288 was the tallest plant (49.39cm) while the shortest was IT97K-499-35 had the mean value of 28.49cm. Similar trend was observed in 2010, the highest mean of 59.60cm was recorded by IT89KD-288 while the shortest (27.84cm) by

IT97K-499-35. The combined years shows that IT89KD-288 was significantly ($p \leq 0.05$) taller than IT97K-499-35 with the mean of 53.69cm and 28.12cm respectively. The mean variation for the varieties was significant ($p \leq 0.05$) for 2009 and highly significant($p \leq 0.01$) for 2010. At 95% maturity, the interaction between spacing and variety for the two growing seasons and the combined seasons were not significant ($p \leq 0.05$).

The mean values of interaction of inter-row spacing and variety at 50% flowering in 2010 is presented in Table 4. The interaction between 60 x 25cm and IT89KD-288 produced significantly tallest plant with mean of 54.27cm followed by 75 x 25cm with 43.63cm while the combination of 60 x 25cm and IT97K-499-35 had the shortest plant with 15.17cm. There was no significant interaction between spacing and variety on plant height in 2009 and the combined years.

Table 4: Interaction effects of inter-row spacing and variety on plant height at 50% flowering in 2010

	Plant height at 50% flowering (cm) 2010		
	S_1	S_2	S_3
V_1	42.00b	54.27a	43.63b
V_2	24.37c	22.60c	23.60c
V_3	16.17d	15.17d	16.13d
SE±	3.09		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

4.3.2 Number of leaves per plant

Table 5: shows the mean values of the effects of inter-row spacing and variety on number of leaves per plant for 2009 and 2010 rainy season. In 2009, at 4 WAS, 60 x 25cm had the highest number of leaves with 11.53 while 45 x 25cm had the least with 10.78, and in 2010, the highest number of leaves was recorded in 60 x 25cm and the least in 75 x 25cm with the values of 7.67 and 7.29 respectively. Similarly, the combined years shows that 60 x 25cm had the highest number of leaves (9.60) while 45 x 25cm was the least with the value of 9.17. The variation of the mean values of number of leaves per plant was not significant ($p \leq 0.05$) at 4 WAS.

In 2009 rainy season, at 4 WAS, variety IT89KD-288 had the highest number of leaves with 11.89 leaves while IT89KD-391 and IT97K-499-35 followed with the same mean values of 10.93. In the 2010 growing season, IT89KD-288 had the mean of 8.17 which is the highest while IT89KD-391 the least (6.92). The combine years shows that IT89KD-288, IT97K-499-35 and IT89KD-391 have 10.03, 9.16 and 8.93 leaves respectively. The variation of the mean result was significant ($p \leq 0.05$) among the varieties for the two seasons. The interaction of inter-row spacing and variety at 4 WAS was not significant ($p \leq 0.05$).

The number of leaves per plant at 50% flowering in 2009 season, 45 x 25cm had the highest number of leaves with 28.36 followed by

Table 5: Mean effects of spacing and variety on number of leaves at 4 weeks after sowing, 50% flowering and 95% maturity in 2009 and 2010 rainy season

	Number of leaves at 4 WAS			Number of leaves at 50% flowering			Number of leaves at 95% maturity		
Treatment	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	10.78	7.56	9.17	28.36	29.98	29.17	20.57	9.36	15.66
S_2	11.53	7.67	9.60	28.21	32.80	30.54	18.31	17.12	17.20
S_3	11.44	7.29	9.37	28.17	33.29	30.73	17.96	10.53	14.42
Variety									
V_1	11.89	8.17a	10.03a	30.49ab	49.47a	40.01a	18.87ab	18.81	15.19a
V_2	10.93	6.92b	8.93b	31.02a	29.93b	30.48b	15.08b	7.20	11.14b
V_3	10.93	7.42b	9.18ab	23.22b	16.67c	19.94c	22.90a	11.01	16.97a
Interaction									
S x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant   WAS= weeks after sowing

spacing of 75 x 25cm which was the least with the mean value of 28.17. Similarly, in 2010 growing season, 75 x 25cm had the highest number of leaves and 45 x 25cm the least with 33.29 and 29.98 leaves respectively. The combined mean of the two seasons showed similar result with 75 x 25cm having the highest number of leaves followed by 60 x 25cm and 45 x 25cm the least with the values of 30.73, 30.54 and 29.17 leaves respectively. The variation of the mean values of number of leaves at 50% flowering for 2009 and 2010 season was not significant ($p \leq 05$).

Among the varieties in 2009 season, IT89KD-288 had the highest number of leaves with 36.49 while IT97K-499-35 was having least value of 23.22. Similar trend was observed in 2010 rainy season where IT89KD-288 have the highest values of 49.47 and the least was IT97K-499-35 with 16.67. The result of the combined seasons showed that IT89KD-288 had 42.98 leaves which is the highest and IT97K-499-35 was the least with 19.94 number of leaves. The mean difference was not significant in 2009 but significant ($p \leq 0.05$) result was obtained in 2010. There was no significant ($p \leq 0.05$) interaction between inter-row spacing and variety on number of leaves per plant at 50% flowering.

In 2009 rainy season at 95% maturity, the mean number of leaves in 75 x 25cm was the highest having 20.57 followed by 60 x 25cm with 18.31 leaves while the least number was in 75 x 25cm with 17.96 number of leaves. In 2010 season, 60 x 25cm was the highest having 17.12 and

45 x 25cm was the least with the mean value of 9.36. The combined seasons showed that 60 x 25cm was the highest while 75 x 25cm the least with mean value of 17.20 and 14.42 leaves respectively. The mean variation was not significant ($p \leq 0.05$).

Variety IT97K-499-35 have the highest number of leaves in 2009 having 18.87 while IT89KD-391 was the least with the mean value of 15.08. However, in 2010 season, IT89KD -288 produced the highest number of leaves (18.81) while IT89KD-391 had the least (7.20). In the combine years, IT97K-499- 35 had the highest of 16.97 while IT89KD-391 have the least number of leaves with 11.14 number of leaves. The mean variation of the variety was significant ($p \leq 0.05$). The observed interaction of inter-row spacing and variety was not significant ($p \leq 0.05$) as indicated in table 5.

4.3.3 Number of Primary branches per plant

Table 6 presents the effects of inter-row spacing and variety on number of primary branches per plant for 2009 and 2010 rainy season. In 2009 rainy season, at 4 WAS, 75 x 25cm recorded 2.51 number of branches which was the highest while 60 x 25cm had the least branches which was 2.42 and in 2010 rainy season, 45 x 25cm had the most number of branches with1.11 while 75 x 25cm recorded the least with 0.67. The combined seasons shows that 45 x 25cm have most number of branches at 4 weeks after sowing (1.79) followed by 60 x 25cm with 1.71 while 75 x 25cm

Table 6: Mean effects of spacing and variety on number of primary branches at 4 weeks after sowing, 50% flowering and 95% maturity in 2009 and 2010 rainy season

	No. of branches at 4 WAS			No. of branches at 50% flowering			No. of branches at 95% maturity		
Treatment	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	2.47	1.11	1.79	4.40	4.66	4.53	4.31	3.66	3.98
S_2	2.42	1.00	1.71	4.27	4.73	4.42	4.30	3.73	4.02
S_3	2.51	0.67	1.59	4.64	4.69	4.67	4.34	3.89	4.11
Variety									
V_1	2.89a	1.51a	2.20a	5.04a	5.54a	5.22a	5.53a	6.68a	5.65a
V_2	2.64ab	0.73b	1.69b	4.33ab	4.87a	4.60b	5.26b	5.09b	5.17b
V_3	1.87b	0.53b	1.20b	3.93a	3.67b	3.80c	5.07b	4.69b	4.88c
Interaction									
S x V	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant WAS= weeks after sowing

recorded the lowest with 1.59. All the mean variation among the inter-row spacing was not significant ($p \leq 0.05$).

With respect to the varieties in 2009 season, IT89KD-288 had highest number branches, followed by IT89KD-391 while IT97K-499-35 the least with the values of 2.89, 2.64 and 1.87 primary branches respectively. Similar observation was recorded in 2010 season where IT89KD-288, IT89KD-391 and IT97K-499-35 recorded 1.51, 0.73 and 0.53 number of primary branches per plant. The combined seasons also showed similar results with IT89KD-288 having the highest number of branches which was 2.20 while IT97K-499-35 having the least value of 1.20. The mean variation among the varieties was significant ($p \leq 0.05$). There was no significant($p \leq 0.05$) interaction between inter-row spacing and variety on number of primary branches per plant.

The number of primary branches at 50% flowering showed no significant difference ($p \leq 0.05$) in 2009 planting season, plant spacing 75 x 25cm produced the highest number of branches followed by 45 x 25cm and 60 x 25cm with mean values of 4.40 and 4.27 respectively. In 2010 cropping season, the highest mean value of 4.73 branches was recorded in 60 x 25cm and the least mean value of 4.44 was recorded in 45 x 25cm plant spacing, while the combined analysis for both the seasons were 4.67, 4.53 and 4.42 primary branches recorded for spacing 75 x 25cm, 45 x 25cm and 60 x 25cm, respectively.

Among varieties in 2009 at 50% flowering, IT89KD-288 had the highest number of primary branches with 5.04 while IT97K-499-35 had the least number with 3.93. In 2010 season, IT89KD-288 again had the highest number of primary branches with 5.54 while IT97K-499-35 was the least with 3.67. The trends was maintained in the combined years where IT89KD-288 had the highest number of primary branches followed by IT89KD-391 while IT97K-499-35 had the least with the mean value of 5.22, 4.60 and 3.80 primary branches respectively. The variation in the mean with respect to varieties was significant ($p \leq 0.05$). There was also no significant ($p \leq 0.05$) interaction between spacing and variety.

At 95% maturity, in 2009 rainy season 45 x 25cm had the highest number of primary branches while 60 x 25cm had the least with values of 5.31 and 5.24 respectively. The observed values in 2010 season shows that 75 x 25cm had the highest mean value of 3.69 while 45 x 25cm the least with 3.66. In the combined seasons, 45 x 25cm had the highest number of primary branches (5.65) followed by 60 x 25cm with 5.17 while 75 x 25cm had the lowest with the mean value of 4.88.

Variety IT89KD-288 was significantly ($p \leq 0.05$) higher than varieties IT89KD-391 and IT97K-499-35. In both 2009 and 2010 rainy season, IT89KD-288 had the highest number of primary branches and IT97K-499-35 was the lowest. In the combined seasons, similar trend was noticed where IT89KD-288 had maintained its highest branches followed by IT89KD-391 while IT97K-499-35 was the least with 5.65, 5.17 and 4.88 respectively. There was no significant interaction of inter-row spacing and variety on number of primary branches at 95% maturity as shown in table 6.

4.4 Yield parameters

4.4.1 Number of pods per plant

Table 7 shows the mean values of number of pods per plant for 2009 and 2010 rainy season. In 2009, the highest number of pods per plants in spacing 75 x 25cm was 17.04 followed by 60 x 25cm with 16.11 while 45 x 25cm was the least 12.81 pods per plant. In 2010 season, higher mean values was recorded in 75 x 25cm which was 14.43 and the lowest in 60 x 25cm with 11.27. Similarly 15.74, 14.18 and 12.77 pods per plant were recorded for spacing 75 x 25cm, 60 x 25cm while 45 x 25cm respectively. The mean variation in respect of inter-row spacing was not significant ($p \leq 0.05$).

In 2009 rainy season, variety IT89KD-391 recorded the highest with 18.73 number of pods per plant followed by IT97K-499-35 and IT89KD-288 with 14.11 and 13.12 pods per plant, respectively. In 2010 rainy season, IT89KD-391 had the highest number of pods with 15.20 while IT89KD- 288 the lowest having 11.29. In the combined analysis of both years, IT89KD- 391 had 16.97 pods which was the highest while the lowest of 12.21 pods was recorded in IT89KD-288. The mean difference

Table 7: Mean effects of spacing and variety on number of pod per plant and length of pod per plant in 2009 and 2010 rainy season

	Number of pods per plant			Length of pods per plant (cm)		
Treatment	2009	2010	Combined	2009	2010	Combined
Spacing						
S_1	12.81b	12.72	12.77b	13.33c	13.88	13.61b
S_2	16.11ab	11.26	14.18ab	14.68b	16.24	15.44a
S_3	17.04a	14.43	15.74a	15.82a	15.63	15.73a
Variety						
V_1	13.12b	11.29b	12.21b	13.26b	13.96	13.63b
V_2	18.73a	15.20a	16.97a	15.10a	17.06	16.08a
V_3	14.11b	12.92ab	13.52b	15.48a	14.70	15.09ab
Interaction						
S x V	NS	NS	NS	**	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant ** = significant at 1%

among the varieties was significant ($p \leq 0.05$). The interaction between inter-row spacing and variety was not significant ($p \leq 0.05$) as shown in table 7.

4.4.2 Length of pods per plant

Table 7: shows the effects of inter-row spacing and variety on length of pods per plant for 2009 and 2010 rainy season and the combined years. In 2009 season, the mean values of the length of pods per plant was significantly ($P \leq 0.01$) higher in spacing 75 x 25cm with 15.83cm than in spacing 45 x 25cm which was the lowest with value of 13.61cm. In 2010 season, 60 x 25cm had the highest mean followed by 75 x 25cm and then 45 x 25cm with 16.20cm, 15.63cm and 13.88cm respectively. These mean variation of spacing was not significant ($P \leq 0.05$).

In combined mean of the years, pod length in 75 x 25cm was the longest recording 15.73cm followed by 60 x 25cm with 15.46 while 45 x 25cm was the least (13.61cm). The mean variation was significant ($P \leq 0.05$). There was significant difference ($P \leq 0.05$) in 2009 with respect to the variety, IT97K-499-35 recorded the highest mean value of 15.48cm followed by IT89KD-391 (15.10cm) while IT89KD-288 was the least with the mean values of 13.26cm. Similarly in 2010 season, IT89KD-391 had 17.06cm which had the longest pods while IT89KD-288 the shortest pod length of 13.96cm. In the combined years, IT89KD-391 mean value was the highest with 16.08cm while IT89KD-288 was the least in terms

Table 8: Mean interaction effects of spacing and variety on length of pods per plant in 2009

	Length of pods per plant (cm) 2009		
	S_1	S_2	S_3
V_1	10.53d	13.03c	16.20a
V_2	13.97b	15.50a	15.83a
V_3	15.50a	15.50a	15.43a
SE±	0.90		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

of pod length with the mean value of 13.63cm.

Interaction between inter-row spacing and variety was highly significant($p \leq 0.01$) in 2009 (Table 8). Treatment 75 x 25cm by IT97K-499-35 had the highest mean value of 16.20cm in 2009 which was significantly ($p \leq 0.01$) higher than the combination of spacing 45 x 25cm and variety IT89KD-288 with mean value of 10.53cm. In 2010 season and the combined years, the interaction effect was not significant.

4.4.3 Number of seeds per pod

The mean effects of inter-row spacing and variety on number of seeds per pod for 2009 and 2010 rainy seasons and the combined years are presented in Table 9. In 2009 season, spacing 75 x 25cm had the highest number of seeds per pod recording 12.69 while 45 x 25cm was the least having 10.58 number of seeds per pods. Similarly, in 2010 rainy season, spacing 75 x 25cm had the highest number of seeds per pod with the mean value of 12.80 followed by 60 x 25cm with 12.61 and 45 x 25cm being the least with the mean value of 11.24. In the combined years, 75 x 25cm was also the highest with 12.74 number of seeds per pod while 45 x 25cm had 10.91seeds per pod. The difference in inter-row spacing was significant($p \leq 0.05$) in 2009. In 2010 season and the combined years, no significant difference was observed.

With respect to the varieties, in 2009 season, IT97K-499-35 had the highest mean value of number of seeds per pod with 13.38 while IT89KD-288 had the least with the mean value of 10.38. And in 2010

Table 9: Mean effects of inter-row spacing and variety on number of seeds per pod in 2009 and 2010 rainy season

	Number of seeds per pod		
Treatment	2009	2010	Combined
Spacing			
S_1	10.58b	11.24b	10.91b
S_2	11.82ab	12.61a	12.02a
S_3	12.69a	12.80a	12.74a
Variety			
V_1	10.38b	11.59b	10.79c
V_2	11.33b	12.53b	11.93b
V_3	13.38a	12.53a	12.96a
Interaction			
S x V	*	NS	**

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant * = significant at 5%
** = significant at 1%

Table 10: Interaction effects of inter-row spacing and variety on number of seeds per pod in 2009 and the combined years

	Number of seeds per pod					
	2009			Combined		
	S_1	S_2	S_3	S_1	S_2	S_3
V_1	8.07f	10.00e	13.07abc	9.17d	10.40c	12.80a
V_2	10.87de	11.27d	11.87cd	11.20bc	12.40a	12.20ab
V_3	12.80bc	14.20a	13.13ab	12.37a	13.27a	13.23a
SE±	1.21			1.08		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

growing season, IT89KD-391 and IT97K-499-35 had the same mean value of 12.53 followed by IT89KD-288 with the mean value of 11.53. Similarly, in the combined mean of the two years, IT97K-499-35 had the highest number of seeds per pod with 12.96 while IT89KD-288 had the least with 10.79. The mean variation with respect to the varieties in 2009 and combined years was significant ($p \leq 0.05$) and not significant ($p \leq 0.05$) for 2010.

Table 10 shows the interaction of inter-row spacing and variety on number of seeds per pod. Combination of 60 x 25cm with IT97K-499-35 had the highest mean value of 14.20 in 2009 while combination of 45 x 25cm with IT89KD-288 was the least with 8.07 number of seeds per pod. Similarly, in combined years, combination between 60 x 25cm with IT97K-499-35 had the highest mean value of 13.27 while 45 x 25cm with IT89KD-288 recorded 9.17. The interaction of inter-row spacing and variety was significant ($p \leq 0.05$) for 2009 season and highly significant ($p \leq 0.01$) in the combined seasons. In 2010 session, interaction was not significant.

4.4.4 Weight of seeds per pod

Table 11: shows the mean values of weight of seeds per pod for 2009 and 2010 rainy season and the combined seasons. In 2009 season, the mean seeds weight per pod was highest in 75 x 25cm with 8.66g and lowest in 60 x 25cm with 7.58g. In 2010 growing season, 75 x 25cm had the highest mean value followed by 60 x 25cm and then 45 x 25cm with

Table 11: Mean effects of spacing and variety on weight of seeds per pod, weight of pod per plant and seed weight of 1000 seeds in 2009 and 2010 rainy season

	Weight of seeds per pod (g)			Weight of pods per plant (g)			1000 seed weight (g)		
Treatment	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	8.28	8.39c	8.33b	15.07b	28.17ab	21.62b	137.49b	157.76	147.62b
S_2	7.58	9.29b	8.47b	18.63ab	27.28b	23.68b	145.02a	142.58	151.74ab
S_3	8.66	10.55a	9.60a	23.97a	32.61a	28.29a	149.22a	165.01	157.12a
SE±	0.27	0.65	0.77	4.33	4.22	3.90	5.51	25.10	8.65
Variety									
V_1	7.46b	9.47	8.50b	14.14b	26.29b	20.95c	144.93	153.81	149.37a
V_2	8.18ab	9.19	8.69ab	23.94a	32.67a	28.31a	141.96	153.97	147.96b
V_3	8.87a	9.56	9.21a	19.58ab	29.09ab	24.33b	144.84	157.57	151.21ab
SE±	0.27	0.65	0.77	4.33	4.22	3.90	5.51	25.10	8.65
Interaction									
S x V	NS	NS	NS	NS	NS	NS	**	NS	NS

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key:

S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant   ** = significant at 1%

weight of seeds per pod of 10.55g, 9.29g and 8.39g, respectively. The combined seasons similarly had 75 x 25cm as the highest with 9.60g while 45 x 25cm recorded the least mean value of 8.33g. The mean variation was significant ($p \leq 0.05$) for the year 2009 and the combined analysis for the two seasons. In 2010 growing season, the mean variation was not significant ($p \leq 0.05$).

With respect to varieties in 2009 season, IT97K-499-35 recorded the highest seed weight per pod followed by IT89KD-391 and then IT89KD-288 with mean values of 8.87g, 8.18g and 7.46g, respectively. Similarly, in 2010 season, variety IT97K-499-35 had the highest weight of seeds per pod followed by IT89KD-288 and IT89KD-391 the least recorded with the mean values of 9.56g, 9.47g and 9.19g respectively. The combined seasons followed similar trend with IT97K-499-35 having the highest value of 9.21g while IT89KD-288 the lowest with 8.50g. The mean variation was significant ($p \leq 0.05$) for 2009, however there was no significant difference in 2010 among the varieties. The interaction of inter-row spacing and variety on weight of seeds per pod for 2009, 2010 season and the combined years was not significant ($p \leq 0.05$).

4.4.5 Weight of pods per plant

Table 11 shows the mean effects of inter-row spacing and variety on weight of pods per plant for 2009 and 2010 rainy season and the combined seasons. In 2009 season, the mean weight of pods was highest in 75 x 25cm followed by 60 x 25cm and least in 45 x 25cm with the values of 23.97g, 18.63g and 15.07g respectively. Similarly in 2010, the highest mean was recorded in spacing 75 x 25cm which is 32.61g and the least is 60 x 25cm with 8.39g. The combined seasons showed that 75 x 25cmwas the highest followed by 60 x 25cm while 45 x 25cm was the least with 9.60g,8.47g and 8.33g respectively. The mean variation was highly significant ($p \leq 0.01$) in 2009 and combined seasons while in 2010 mean result was not significant ($p \leq 0.05$).

In 2009 season, varieties IT89KD-391 had the highest mean with 23.94g while IT89KD-288 was the least with 14.14g and in 2010 season, the similar trend was observed with IT89KD-391 have the highest mean value of 32.67g followed by IT97K-499-35 with 29.09g while IT89KD-288 had the least (26.29g). In the combine seasons, variety IT89KD-391 recorded the highest weight of 28.31g followed by variety IT97K-499-35 with 24.33g while variety IT89KD-288 had the least weight with value of 20.95g. The mean variation was significant ($p \leq 0.05$) in 2009, the difference however was not statistically significant in 2010. In the combined seasons, the weight of pod per plant was highly significant ($p \leq 0.01$). The interaction of inter-row spacing and variety was not significant ($p \leq 0.05$).

4.4.6 1000 seed weight

The mean weight of 1000 seeds for 2009 and 2010 rainy season and combined season is presented in Table 11. In 2009 season, the mean weight of 1000 seeds is highest in 75 x 25cm followed by 60 x 25cm while 45 x 25cm is the lowest with the value of 149.22g, 145.02g and 137.49g respectively. In the 2010 rainy season, similar result was obtained with 75 x 25cm having the highest mean weight of 165.01g while 60 x 25cm the lowest with 142.58g. In the combined seasons, 75 x 25cm similarly had the highest 1000-seed weight followed by 60 x 25cm while 45 x 25cm had the lowest with the value of 157.62g, 151.74g and 147.62g. The means for 2009 rainy season was highly significant ($p \leq 0.01$) and not significant for 2010 rainy season and combined seasons.

With respect to the varieties, in 2009 season, IT89KD-288 had the highest weight of mean value of 144.93g while IT89KD-391 had the lowest value of 141.96g. In 2010 rainy season, IT97K-499-35 had the highest followed by IT89KD-391 and IT89KD-288 the lowest with the values of 157.57g, 153.97g and 153.81g respectively. In the combined years, IT97K-499-35 had the highest mean value of 151.21g and IT89KD-391 had the lowest with 147.96g. The mean variation for 2009 and 2010 seasons was not significant ($p \leq 0.05$) in respect of the varieties but the combined seasons was significant ($p \leq 0.05$).

Table 12 presents mean interaction of inter-row spacing and variety

Table 12: Mean interaction effects of spacing and variety on 1000 seed weight in 2009

	1000 seed weight 2009		
	S_1	S_2	S_3
V_1	134.07d	140.90c	159.88a
V_2	141.10c	133.27d	151.20b
V_3	137.00cd	160.90a	136.63cd
SE±	5.51		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

on 1000 seed weight in 2009. Interaction between 60 x 25cm and variety IT97K-499-35 had the mean value of 160.90g which was significantly ($p \leq 0.01$) higher than interaction between 45 x 25cm and IT89KD-288 which was the least with the mean value of 143.07g. There was no interaction between spacing and variety in 2010 growing season and the combined years.

4.4.7 Shelling percentage

Table 13 shows the mean values shelling for percentage for 2009 and 2010 rainy seasons. In 2009 season, 75 x 25cm spacing gave the highest shelling percentage of 80.06% followed by 45 x 25cm with 78.32% while 60 x 25cm was the least with 77.93%. In 2010 season, similar trend was observed with 75 x 25cm having the highest mean value and 45 x 25cm the least which was 77.83% and 75.50% respectively. In the combined analysis, 75 x 25cm spacing had higher value of 78.94% followed by 60 x 25cm which had 77.21% then 45 x 25cm with the least mean value of 76.72%. The mean variation for 2009 and 2010 was not significant ($p \leq 0.05$). With respect to the varieties in 2009, the mean shelling percentage of IT97K-499-35 gave the highest with 79.53% while IT89KD-288 the least with 77.91%. In 2010, IT89KD-391 was the highest with the value of 77.73% and IT89KD-288 the lowest with 74.33%. The observation in combined years shows that IT97K-499-35 was the highest (78.44%) followed by IT89KD-391 with 78.31% while the mean of IT89KD-288

Table 13: Mean effects of spacing and variety on shelling percentage, seed yield plot and seed yield hectare in 2009 and 2010 rainy season

	Shelling percentage(%)			Seeds Yield per plot(kg)			Seeds Yield per hectare (Kg)		
Treatment	2009	2010	Combined	2009	2010	Combined	2009	2010	Combined
Spacing									
S_1	78.32b	75.5	76.72b	1.576	1.370	1.473	1314.2	1141.6	1227.92a
S_2	77.93b	76.39	77.21b	1.565	9.970	1.423	1304.3	972.9	1194.81a
S_3	80.06a	77.83	78.94a	1.433	1.274	1.353	1160.5	950.6	1055.56b
Variety									
V_1	77.91b	74.26	76.12b	1.252b	1.710	1.23b	1044.3b	906.7	1031.67b
V_2	78.88ab	77.73	78.31a	1.733a	1.321	1.53a	1410.8a	1101.2	1256.03a
V_3	79.53a	77.36	78.44a	1.589a	1.402	1.50a	1323.9a	1057.2	1190.58a
Interaction									
S x V	*	NS	*	NS	NS	NS	*	NS	*

Means in a column followed by the same letter(s) are not significantly different at 5% probability level of the Duncan's Multiple Range Test (DMRT)

Key: S_1 = 45 x 25cm V_1 = IT89KD-288
S_2 = 60 x 25cm V_2 = IT89KD-391
S_3 = 75 x 25cm V_3 = IT97K-499-35
NS = Not Significant   * = significant at 5%

Table 14: Interaction effects of spacing and variety on shelling percentage in2009 and the combined years

	Shelling percentage (%)					
	2009			Combined		
	S_1	S_2	S_3	S_1	S_2	S_3
V_1	76.57e	77.17de	80.00ab	73.92d	75.30c	79.15a
V_2	78.53c	77.83cd	80.27a	77.58b	78.30ab	79.20a
V_3	79.87ab	78.83bc	79.90ab	78.67ab	78.00ab	78.67ab
SE±	1.17			1.52		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

was the least with the mean value of 76.12%. The mean difference for combined result was significant ($p \leq 0.05$) but not significant for the individual years. The mean interaction effect of spacing and variety on shelling percentage showed no significant difference in both seasons as well as the combined seasons.

Interaction of inter-row spacing and variety on shelling percentage is presented in table 14. In 2009, interaction between 75 x 25cm and variety IT89KD-391 had the shelling percentage of 80.27% which was significantly ($p \leq 0.05$) higher than interaction between 45 x 25cm and IT89KD-288 with the mean value of 76.57%. In combined years, interaction between 75 x 25cm and IT89KD-391 had significantly higher mean value of 79.20% than 45 x 25cm and IT89KD-288 which was the least with 73.92%. There was no significant interaction in 2010 season.

4.4.8 Seed yield per plot

Table 13 presents the mean value of the effect of inter-row spacing and variety on seed yield per plot for 2009 and 2010 rainy season and the combined years. In 2009 rainy season, 45 x 25cm had the highest mean value of seed yield per plot followed by 60 x 25cm while 45 x 25cm had the least with the mean values of 1.576g, 1.565g and 1.433g, respectively. The mean value of 1.370g, 1.280g and 1.274g were obtained in plant spacing of 45 x 25cm, 60 x 25cm and 75 x 25cm respectively in 2010 cropping season. Similarly, the combined years gave the mean values of

1.473g, 1.423g and 1.353g seed yield per plot for 45 x 25cm, 60 x 25cm and 75 x 25cm respectively which was significantly higher than both 2009 and 2010 cropping seasons.

Analysis of mean values among the varieties showed that IT89KD-391 had the highest yield of 1.73g compared to IT97K-499-35 with 1.59g while IT89KD-288 having the least with 1.25g 1n 2009. Similarly in 2010 season IT97K-499-35 had the highest yield of 1.40g while IT89KD-288 is the least with 1.21g. In combined seasons of the two years, IT89KD-391, IT97K-499-35 and IT89KD-288 varieties had mean values of 1.53g, 1.50g and 1.23g respectively. The mean difference for 2009 and the combined seasons were highly significant ($p \leq 0.01$) in terms of seed yield per plot. There was no significant interaction between spacing and variety for 2009, 2010 season and the combined years (table 13).

4.4.9 Seed yield per hectare

Table 13 shows the mean value of the effect of inter-row spacing and variety on seed yield per hectare for 2009 and 2010 rainy season and combined years. In 2009 growing season, spacing 45 x 25cm , 60 x 25cm and 75 x 25cm had the mean values of 1314.2kg, 1304.3kg and 1160.5kg seed yield per hectare respectively. In 2010 rainy season, it was observed that 45 x 25cm had the highest mean value of 1141.2kg while 75 x 25cm was the least mean value of 950.6kg. The similar observation was made in the combined seasons, where 45 x 25cm had the highest mean with

1227.9Kg, followed by 60 x 25cm with 1194.8Kg while 75 x 25cm the least with value of 1055.6Kg. The mean variation was not significant in 2009, 2010 growing seasons and the combined mean of the years among the grain yield per hectare. With respect to the varieties, in 2009 season, IT89KD-391 had the highest yield of 1410.8Kg followed by IT97K-499-35 with 1323.9Kg while IT89KD-288 is the lowest with 1044.3Kg. Similarly in 2010 season, IT89KD-391 had the highest yield of 1101.2Kg while IT89KD-288 the least with 906.7Kg. In combined years, IT89KD-391 had the highest mean value of 1256.6Kg followed by IT97K-499-35 with1190.6Kg while IT89KD-288 was the least 1031.7Kg. The mean difference in seed yield per hectare for 2009 was significant ($p \leq 0.05$) and not significant in the 2010 and the combined years.

Mean interaction effects of spacing and variety on grain yield per hectare for 2009 and the combined years is presented in Table 15. In 2009 season, interaction between 60 x 25cm with IT89KD-391 had 1528.6kg/ha followed by 75cm x 25cm and IT97K-499-35 with 1526.57kg/ha were significantly ($p \leq 0.05$) higher than variety IT89KD-288 spaced 45 x 25cm which had the mean value of 973.6kg/ha. In the combined seasons, interaction of 45 x 25cm and IT97K-499-35 had 1399.82kg/ha was followed by60 x 25cm combined with IT89KD-391 with 1342.08kg/ha which were significantly ($p \leq 0.05$) higher than 60 x 25cm with IT89KD-288 with 985.68kg/ha. In 2010 season, the interaction was not significant($p \leq 0.05$).

Table 14. Mean interaction effects of spacing and variety on grain yield per hectare for 2009 and the combined years

	Seed yield per hectare (Kg)					
	2009			Combined		
	S_1	S_2	S_3	S_1	S_2	S_3
V_1	973.63e	1023.87de	1135.30d	1015.98e	985.68e	1093.33de
V_2	1442.53ab	1528.60a	1261.37c	1267.95abc	1342.08ab	1158.05cd
V_3	1526.57a	1360.53bc	1084.73de	1399.82a	1256.65bc	1065.28de
SE±	121.23			135.21		

S_1 = 45 x 25cm V_1 = IT89KD-288

S_2 = 60 x 25cm V_2 = IT89KD-391

S_3 = 75 x 25cm V_3 = IT97K-499-35

SE= standard error

CHAPTER FIVE

5.0 DISCUSSION

The result of the experiment showed that the highest establishment count was recorded in 60 x 25cm with the mean of 92.22 in 2009 and 75 x 25cm with 92.89 in 2010, but the mean variation was not significant ($p \leq 0.05$). The lack of significant effect may be because the plant had not establish ground coverage and therefore inter-plant competition for environment and growth resources and development had not yet set in. Bello (1997) reported that spacing had no significant effect on establishment count in cowpea in Yola. According to Ikeorgu *et al.* (1984), the reduction of establishment percentage could be due to the modification of the soil microenvironment at full cover of cowpea.

The effect spacing on number of days to 50% flowering and 95% maturity showed little difference and the variation was not significant ($p \leq 0.05$) in 2009 and 2010 rainy seasons. This may probably be because the varieties used were erect and semi-erect varieties which could adjust to decrease in inter-row spacing as low as 45cm if planted at 25 – 30cm intra-row spacing. The observation is in line with Sajo *et al.* (2000) who reported that the three spacing used (60 x 30cm, 50 x 25 and 75 x 25cm) showed little difference in number of days to 50% flowering and 95% maturity. The observation also agreed with the report of Mohdnoor (1980) that semi-erect and erect cowpeas respectively responded positively to plant population of 50,000 – 80,000 plant/ha and high population of 100,000 plants/ha which correspond to a row spacing of 50 x 25cm or 75 x 20cm for semi erect indeterminate, high branching types and to 16 x 34cm or 17 x 40cm for erect determinate and low branching type. Similarly, Ali (2004) reported that plant spacing had no significant ($p \leq 0.05$) effect on number of days to flowering in okra. However, 45 x 25cm have shorter mean number of days to flowering and maturity than 75 x 25cm. This slight variation may be due to high competition for growth resources which shorten their life cycle.

Number of days to 50% flowering and 95% maturity is significantly ($p \leq 0.05$) higher in IT89KD-288 than in IT89KD-391 and IT97K-499-35 while IT97K-499-35 had significantly ($p \leq 0.05$) shorter number of days to 50% flowering and 95% maturity. The interaction between spacing and variety did not show significant ($p \leq 0.05$) effect. This is because the erect, determinate and photo-insensitive variety of cowpea had shorter days to flowering and maturity compared to the semi-erect, photo-sensitive variety and the prostrate type. This finding is in line with Summerfield *et al.* (1985) and Rachie (1985) that cowpea varieties show variation in the start and end of the reproductive period. Some cultivars flowers within 30 days from sowing and ready for dry-seed harvest 25 days later, while others take more than 100 days to flower and 210 - 240 days to mature. Also Steele and Mehra (1980) stated that erect and determinate varieties are early maturing.

The Growth and growth components include plant height, number of leaves per plant and number branches per plant among others. All the mean values of these growth characters for the two seasons and the combined seasons were not significantly affected by spacing. This observation agrees with the report of Mohamed (2002) that plant spacing had no significant effect on cowpea plant height. However, these findings are contrary to similar reports by Weber *et al.* (1966) who found that plants produced at highest densities were taller and more sparsely branched. Also, Ahmed *et al.* (2010) reported that increasing plant density decreased plant height at all sampling occasions. Although 60 x 25cm seems to have better growth performance on plant height and number of leaves. The higher mean number of branches was recorded in 75 x 25cm. The variation in the mean values of spacing was not significant ($p \leq 0.05$). In like manners, most of the improved varieties are erect and semi-erect and spread less, which is also responsible for the non-significant variation in number of branches recorded among the varieties. Similar observation was made by Mortimore *et al.* (1997) who recommended highly variable spacing (35 – 95cm) between rows. Similarly, Rowland (1993) reported that typical pure stand spacing of cowpea (*Vigna unguiculata* (L.) Walp) is 30cm between plant and 60cm between rows or 5 – 12cm between plant and 70 – 90cm between rows. Ezedinma (1974) suggested decreased spacing between rows and increased spacing within rows for better performance.

Although, the effect of variety on all growth components was not significant ($p \leq 0.05$) at 4 WAS in 2009, it was highly significant ($p \leq 0.01$) at flowering and at 95% maturity for 2009, 2010 and the combined mean values of the two years. Variety IT89KD-288 was significantly ($p \leq 0.05$) taller, had more number of leaves and more number of branches than IT97K-499-35. These differences in plant height, number of leaves and number of branches per plant may be due to the varietal differences of the plant since IT89KD-288 was semi-erect and photo-sensitive while IT89KD-391 and IT97K-499- 35 were erect and photo-insensitive varieties. Ahmed *et al.* (2010) also reported that difference in growth attributes observed among cultivars may be due to the growth habit and the genetic potential of each genotype. Similarly, according to Steele and Mehra (1980) erect and determinate varieties are early maturing.

Yield in cowpea have been reported to consist of three primary components viz: number of pods per plant, number of seeds per pod and 100 seeds weight (Malik and Singh, 1983). Other components includes length of pods per plant, weight of pods per plant and weight of seeds per pod. The response of the three varieties of cowpea to spacing indicated that the number of pods per plant were not significantly ($p \leq 0.05$)

affected by spacing in 2010 but were significant ($p \leq 0.05$) in 2009 and the combined seasons. In the combined seasons, increasing spacing from 45 x25cm to 75 x 25cm significantly increased the number of pods per plant from 12.77 to 15.74. Similarly, length of pods per plant significantly increased from 13.61cm to 15.73cm and number of seeds per pod increased from 10.91 to 12.74. Similarly, Ahmed *et al.* (2010) reported that increasing population density decreased number of pods per plant and the seed yield per plant. They further stated that plant population had a significant effect on most yield components. With respect to the varieties, IT89KD-391 had significantly higher number of pods per plant, length of pods per plant and number of seed per pod followed by IT97K-499-35 while IT89KD-288 recorded the lowest numbers. Ahmed *et al.* (2010) also reported that difference in growth attributes observed among cultivars may be due to the growth habit and the genetic potential of each genotype.

Weight of seeds per pod, weight of pods per plant and 1000 seed weight all increased significantly with increase in spacing or decrease population density. Plant spaced 75 x 25cm (165.01g) gave the highest 1000 seed weight in 2010 on individual plant while 45 x 25cm had the least with 137.49g in 2009. Furthermore, Ahmed *et al.* (2010) reported that decreased plant population had a significant increase on most yield components and increased 100-seed weight. This may be due to better availability of nutrients and better translocation of photosynthates from source to sink and may be due to higher accumulation of photosynthates in the seeds. With respect to varieties, IT97K-499-35 was found to have higher weight of seed per pod and 1000 seed weight while IT89KD-391 higher weight of pod per plant. This was because IT89KD-391produce more number of pods per plant. IT89KD-288 was found to have lower values for weight of seed per pod, weight of pod per plant and 1000 seed weight. The variation among varieties might be due to genotype. However, the overall seed yield per plot and seed yield per hectare was found to be higher in spacing 45 x 25cm with 1227.9Kg/ha followed by 60 x 25cm had 1194.8Kg/ha while 75 x 25cm had the least with 1055.6Kg/ha. This observation is in line with the findings of Albert *et al.* (1984) that high planting densities reduce yield of individual plants though the production per unit area might increase. The findings of Mohdnoor (1980) also stated that, semi-erect and erect cowpeas respectively responded positively to plant population of 50,000 – 80,000 plant/ha and high population of 100,000 plants/ha which correspond to a row spacing of 50 x 25cm or 75 x 20cm for semi erect indeterminate, high branching types and to 16 x 34cm or 17 x 40cm for erect determinate and low branching type. Ezedinma (1974) had shown that yields are increased with increase in plant population per hectare up to certain limit.

The interactions of treatments 60 x 25cm and IT89KD-391 and of 45 x 25cm and IT97K-499-35 recorded significantly ($P \leq 0.05$) higher mean values with 1528.60kg/ha and 1526.57kg/ha respectively in 2009. Similarly, in the combined season, 45 x 25cm and IT97K-499-35 recorded 1399.82kg/ha significantly higher than the mean yield of the three varieties in 75 x 25cm. Since the three varieties used were erect and semi-erect varieties, yield reduction due to increase in the spacing from 45 x 25cm to 75 x 25cm cannot be compensated by yield increase of the varieties due to increase in the availability of growth resources. This observation is in line with Alao *et al* (2003) that on successive grain yield trials, there was a consistent increase in yield per hectare as the spacing decreases. Ezedinma (1974) also reported that yields of cowpea cultivars in spacing trials increase with increase in plant density.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The effect of inter-row spacing and variety on growth and yield of cowpea (*Vigna unguiculata* (L.) Walp) in Yola Adamawa state was studied during the 2009 and 2010 cropping seasons. The field trials were conducted at the teaching and research farm of the Department of Crop Production and Horticulture, Federal University of Technology, Yola, Adamawa State. The area is located at latitude 9° - 10°N and longitude

11° and 14°E at the altitude of 158.5m above sea level and lies in the Northern Guinea savanna of Nigeria.

The experimental design used was split plot design with three (3) replications. There were three (3) inter-row spacing (45 cm x 25 cm, 60 cm x 25cm, 75 cm x 25cm) which were the main plots and the sub-plots consisted of three varieties (IT89KD-288, IT89KD-391, and IT97K-499-35). A total number of 27 sub-plots measuring 4 m x 3m were used. The treatments were allocated at random. Characters measured included: establishment count, plant height, number of leaves per plant, number of branches per plant, number of days to 50% flowering, number of days to 95% maturity, length of pods per plant, number and weight of pods per plant, number and weight of seeds per pods, number and weight of seeds per pods, shelling percentage, 1000 seed weight, grain yield per plot and grain yield per hectare. Data collected were subjected to analysis of variance and means separated using Duncan's Multiple Range Test (DMRT) method.

The results from the experiment revealed that the mean variation of plant establishment count was not significant ($p \leq 0.05$) in 2009 and 2010. The effect of spacing on number of days 50% flowering and 95% maturity showed little difference and the variation was not significant ($p \leq 0.05$) but was significantly ($p \leq 0.05$) higher in IT89KD-288 than IT97K-499-35 which was shorter in 2009 and 2010 rainy season. All the mean values of the results for the two seasons and the combined seasons were not significantly affected by spacing for all growth characters. At 50% flowering and at 95% maturity, growth components was highly significant ($p \leq 0.01$) for the two years in respect of the spacing and variety. IT89KD – 288 was significantly ($p \leq 0.05$) taller, had more number of leaves and more number of branches than IT89KD-391 and IT97K-499-35.

In cowpea plant, decreasing plant population or increasing spacing from 45 x25cm to 75 x 25cm significantly increased the number of pods per plant from 12.77 to 15.74. Similarly, length of pods per plant significantly increased from 13.61cm to 15.73cm and number of seeds per pod increased from 10.91 to 12.74. However, the overall results revealed that seed yield per plot and seed yield per hectare were found to be higher in spacing 45 x 25cm with 1227.9Kg/ha followed by 60 x 25cm with 1194.8Kg/ha while 75 x 25cm was the least with 1055.6Kg/ha.

With respect to the varieties, IT89KD-391 had significantly higher number of pods per plant, length of pods per plant and number of seed per pod followed by IT97K-499-35 while IT89KD-288 recorded the lowest values. Variety IT97K-499-35 was found to have higher weight of seed per pod and 1000 seed weight while IT89KD-391 had higher weight of pod per plant and IT89KD-288 was found to have the lowest in weight of seed per pod weight of pod per plant and 1000 seed weight. Overall yield result revealed that IT89KD-391 had higher of 1240.54Kg/ha followed by IT97K-499-35 with 1190.58Kg/ha while IT89KD-288 had the least with 1031.67Kg/ha.

The effect of the interaction between inter-row spacing and varieties was significant ($P \leq 0.05$) on grain yield per hectare in 2009 and combined season. The combination of treatments 60 x 25cm and IT89KD-391 and of treatments 45 x 25cm and IT97K-499-35 recorded significantly higher mean values with 1528.60kg/ha and 1526.57kg/ha respectively. Similarly, in the combined season, 45 x 25cm and IT97K-499-35 recorded 1399.82kg/ha significantly higher than the mean yield of the three varieties in 75 x 25cm. This observation is in line with Alao *et al* (2003) that on successive grain yield trials, there was a consistent increase in yield per hectare as the spacing decreases.

6.2 Conclusion

From the results of the study, decreasing plant population or increasing spacing from 45 x25cm to 75 x 25cm significantly increase the number of pods per plant from 12.77 to 15.74. Similarly, length of pods per plant significantly increased from 13.61cm to 15.73cm and number of seeds per pod increased from 10.91 to 12.74. However, on the overall, seed yield per plot and seed yield per hectare was found to be higher in spacing 45 x 25cm with 1227.9Kg/ha followed by 60 x 25cm have 1194.8Kg/ha while 75 x 25cm was the least with 1055.6Kg/ha. With respect to the varieties, overall yield results revealed that IT89KD-391 had higher seed yield of 1240.54Kg/ha followed by IT97K-499-35 with 1190.58Kg/ha while IT89KD-288 the least with 1031.67Kg/ha.

The interaction of treatments 60 x 25cm and IT89KD-391 and of treatments 45 x 25cm and IT97K-499-35 recorded significantly higher mean values with 1528.60kg/ha and 1526.57kg/ha respectively. Similarly, in the combined season, 45 x 25cm and IT97K-499-35 recorded 1399.82kg/ha significantly higher than the mean yield of the three varieties in 75 x 25cm.

6.3 Recommendations

It is therefore suggested that:

i. Variety IT89KD-391 which produced higher seed yield of 1256.03Kg/ha, than IT89KD-288 and IT97K-499-35 with 1190.58Kg/ha and 1031.67Kg/ha respectively, could be recommended for cultivation in Yola environment.

ii. Yield per hectare was found to increase with a decrease in inter-row spacing in this experiment. In the combined years, yield per hectare of spacing 45 x 25cm was 1227.92Kg/ha followed by 60 x 25cm with 1194.81Kg/ha while 75 x 25cm was the least with 1055.56Kg/ha. Hence spacing of 45 x 25cm should be adopted by farmers for these varieties of cowpea in Yola, Adamawa state.

iii. Further investigations will however, still need to be carried out in other Yola environment to evaluate the suitability of the varieties using the same plant spacing.

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Appendix I: Meteorological data at Yola in 2009 and 2010, season

Months	Rainfall (mm)		Temperature (°C)		Relative humidity (%)	
	2009	2010	2009	2010	2009	2010
January	NA	NA	NA	28.00	NA	49
February	NA	NA	NA	32.50	NA	62
March	NA	1.6	NA	32.25	NA	57
April	69.8	4.0	38.56	34.25	44.32	69
May	18.95	48.5	35.75	31.50	76.00	73
June	31.8	157.9	33.6	28.00	78.06	84
July	80.4	88.0	30.9	28.50	79.60	78
August	161.7	151.0	30.95	26.75	78.00	89
September	176.6	116.0	30.85	27.50	76.60	90
October	38.2	77.1	31.0	28.75	82’32	89
November	NA	NA	NA	26.50	NA	54
December	NA	NA	NA	24.75	NA	42
Total	577.45	644.10	231.61	349.25	514.90	794.00
Mean	82.49	80.51	33.09	29.10	73.56	72.18

Source: Geography Department, Federal University of Technology, Yola

Appendix II: Analysis of variance showing the effect of inter-row spacing and variety on Plant Establishment Count, number of days to 50% flowering and number of days to 95% maturity

		Establishment count		Days to 50% flowering		Days to 95% maturity	
Source of variation	DF	2009	2010	2009	2010	2009	2010
Rep.	2	10.778	23.111	0.037	86.873	0.333	59.259
Spacing	2	21.444 NS	3.111 NS	0.148 NS	81.495 NS	1.444 NS	63.815 NS
Error (a)	4	45.389	32.889	0.204	0.204	1.111	0.370
Variety	2	25.444NS	56.444 NS	358.481**	328.984*	1840.333**	1154.481**
Int.(Spacing x variety)	4	32.889 NS	3.056 NS	0.148 NS	78.973 NS	1.611 NS	59.370 NS
Error (b)	12	63.417	21.333	0.204	0.231	0.444	0.481

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix III: Analysis of variance showing the effect of inter-row spacing and variety on plant height

		Plant height 4WAS		Plant height at 50% flowering		Plant height at 95% maturity	
Source of variation	DF	2009	2010	2009	2010	2009	2010
Rep.	2	3.505	0.108	12.758	25.005	72.873	109.610
Spacing	2	0.894 NS	0.474 NS	0.589 NS	27.676 NS	18.171 NS	37.863 NS
Error (a)	4	2.224	1.541	2.346	15.079	48.804	9.008
Variety	2	2.414 NS	8.343*	30.171**	2314.107**	1225.523*	2483.424**
Int.(Spacing x variety)	4	2.083 NS	1.938 NS	4.011 NS	54.375*	52.753 NS	84.169 NS
Error (b)	12	1.684	1.255	3.515	13.978	75.879	26.751

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix IV: Analysis of variance showing the effect of inter-row spacing and variety on number of leaves

		Number of leaves 4WAS		Number of leaves at 50% flowering		Number of leaves at 95% maturity	
Source of var.	DF	2009	2010	2009	2010	2009	2010
Rep.	2	4.593	1.166	0.480	20.401	10.908	136.318
Spacing	2	1.535 NS	0.339 NS	0.878 NS	28.751 NS	18.210 NS	157.385 NS
Error (a)	4	3.601	0.175	95.784	35.649	137.716	4.161
Variety	2	2.739 NS	3.529**	170.893 NS	2450.093**	137.716*	315.274 NS
Int.(Spacing x variety)	4	2.775 NS	0.315 NS	32.068 NS	38.918 NS	16.207 NS	182.702 NS
Error (b)	12	2.561	0.525	32.651	23.936	17.119	2.804

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix V: Analysis of variance showing the effect of inter-row spacing and variety on number of branches

		Number of branches at 4WAS		Number of branches at 50% flowering		Number of branches at 95% maturity	
Source of var.	DF	2009	2010	2009	2010	2009	2010
Rep.	2	0.653	0.024	0.184	1.045	0.169	3.483
Spacing	2	0.018 NS	0.481 NS	0.330 NS	0.014 NS	0.011 NS	2.678 NS
Error (a)	4	0.370	1.564	1.684	0.538	0.051	0.205
Variety	2	2.564*	2.401*	2.850 NS	8.138**	0.496**	9.960*
Int.(Spacing x variety)	4	0.489 NS	0.361 NS	0.670 NS	0.247 NS	0.078 NS	2.296 NS
Error (b)	12	0.444	0.199	0.487	0.430	0.031	0.082

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix VI: Analysis of variance showing the effect of inter-row spacing and variety on number of pod per plant, length pod per plant and number of seed per pod

Source of var.	DF	Number of pods per plant		Length of pods per plant		Number of seeds per pod	
		2009	2010	2009	2010	2009	2010
Rep.	2	9.724	3.294	0.163	11.947	2.062	0.727
Spacing	2	44.523 NS	22.611 NS	13.968**	13.194 NS	10.135*	6.125 NS
Error (a)	4	27.251	14.889	1.866	10.000	4.348	2.084
Variety	2	80.741*	54.111*	12.724**	23.569 NS	21.139**	2.676 NS
Int.(Spacing x variety)	4	2.012 NS	6.370 NS	6.602**	10.563 NS	5.650 NS	1.125 NS
Error (b)	12	6.438	6.548	0.874	9.626	1.107	0.878

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix VII: Analysis of variance showing the effect of inter-row spacing and variety on weight of seeds per pod, weight of pods per plant and weight of 1000 seeds

Source of var.	DF	Weight of seeds per plant		Weight of pods per plant		1000 seeds weight	
		2009	2010	2009	2010	2009	2010
Rep.	2	1.827	2.210	50.573	65.137	193.548	315.883
Spacing	2	2.675 NS	10.567 NS	180.563*	73.668 NS	318.093**	1179.394 NS
Error (a)	4	1.433	0.716	34.232	10.129	46.526	250.954
Variety	2	4.460*	0.338 NS	216.943**	91.944 NS	25.831 NS	40.633 NS
Int.(Spacing x variety)	4	0.946 NS	0.880 NS	10.683 NS	18.575 NS	519.228 NS	838.819 NS
Error (b)	12	0.982	0.652	25.048	21.385	45.038	142.543

NS = not significant
*   = significant at 5%
** = significant at 1%

Appendix VIII: Analysis of variance showing the effect of inter-row spacing and variety on number of shelling percentage, seed yield per plot and seed yield per hectare

		Shelling percentage		Seed yield per plot		Seed yield per hectare	
Source of var.	DF	2009	2010	2009	2010	2009	2010
Rep.	2	2.383	3.347	0.121	0.014	90649.463	13568.250
Spacing	2	11.406*	16.538*	0.057 NS	0.026 NS	66665.179 NS	18961.951 NS
Error (a)	4	4.570	3.307	0.036	0.053	24044.579	26646.275
Variety	2	5.994*	31.255 NS	0.548**	0.092*	330210.689**	43458.739 NS
Int.(Spacing x variety)	4	2.246*	12.995 NS	0.109 NS	0.032 NS	79559.604*	19566.874 NS
Error (b)	12	0.793	5.621	0.034	0.032	21046.313	17127.147

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix IX: Combine analysis of variance showing the effect of inter-row spacing and variety on plant establishment count, number of days to 50% flowering and number of days 95% maturity

Source of var.	DF	Establishment Count	Days to 50% flowering	Days to 95% maturity
Year	1	42.667 NS	44.463**	21.407*
Rep. (Year)	4	16.944	0.167	0.241
Spacing	2	10.167 NS	0.167 NS	0.963 NS
Spacing x Year	2	50.167 NS	3.241**	9.019**
Error (a)	8	15.722	100.323	0.574
Variety	2	31.722 NS	808.167**	3327.463**
Spacing x Variety	4	13.806 NS	0.000 NS	1.130 NS
Int.(Spacing x Variety x Year)	6	19.556 NS	1.222 NS	0.593 NS
Error (b)	24	41.296	0.227	0.602

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix X: Combine analysis of variance showing the effect of inter-row spacing and variety on plant height at 4weeks after sowing, at 50% flowering and at 95% maturity

Source of var.	DF	Plant height 4WAS	Plant height at 50% flowering	Plant height at 95% maturity
Year	1	172.092**	637.914*	264.449*
Rep. (Year)	4	1.806	24.114	66.081
Spacing	2	0.803 NS	17.340	29.697
Spacing x Year	2	1.570 NS	1280.903**	98.854
Error (a)	8	0.012	10.813	41.969
Variety	2	9.187**	1063.376**	3346.784**
Spacing x Variety	4	1.299 NS	21.299	50.040
Int.(Spacing x Variety x Year)	6	2.003 NS	28.367	29.538
Error (b)	24	1.045	6.973	33.154

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix XI: Combine analysis of variance showing the effect of inter-row spacing and variety on number of leaves at 4 weeks after sowing, at 50% flowering and at 95% maturity

Source of var.	DF	Number of leaves 4WAS	Number of leaves at 50% flowering	Number of leaves at 95% maturity
Year	1	189.656**	194.940*	1103.422**
Rep. (Year)	4	2.879	10.767	5.966
Spacing	2	0.847 NS	13.067 NS	10.657 NS
Spacing x Year	2	0.284 NS	817.947**	27.685 NS
Error (a)	8	1.782	100.323	19.099
Variety	2	5.985*	9.334**	160.072**
Spacing x Variety	4	1.270 NS	9.334 NS	7.945 NS
Int.(Spacing x Variety x Year)	6	1.556 NS	47.332 NS	11.712 NS
Error (b)	24	0.742	13.159	12.925

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix XII: Combine analysis of variance showing the effect of inter-row spacing and variety on number of branches at 4 weeks after sowing, at 50% flowering and at 95% maturity

Source of var.	DF	Number of branches at 4WAS	Number of branches at 50% flowering	Number of branches at 95% maturity
Year	1	32.047**	0.560 NS	0.145 NS
Rep. (Year)	4	0.339	0.575	0.140
Spacing	2	0.183 NS	0.271 NS	0.016 NS
Spacing x Year	2	0.465 NS	0.787 NS	0.434*
Error (a)	8	0.091	1.942	0.228
Variety	2	4.501*	9.082**	2.734**
Spacing x Variety	4	0.396 NS	0.449 NS	0.049 NS
Int.(Spacing x Variety x Year)	6	0.408 NS	0.228 NS	0.042 NS
Error (b)	24	0.537	0.342	0.069

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix XIII: Combine analysis of variance showing the effect of inter-row spacing and variety on number of pod per plant, length of pod per plant and number of seeds per pod

Source of var.	DF	Number of Pods per plant	Length of Pods per plant	Number of Seeds per pod
Year	1	64.460*	5.542 NS	2.081 NS
Rep. (Year)	4	7.399	5.933	1.052
Spacing	2	39.784*	24.054*	15.352*
Spacing x Year	2	6.601 NS	8.441 NS	5.325*
Error (a)	8	34.873	4.714	2.301
Variety	2	108.869**	27.346*	21.147**
Spacing x Variety	4	1.672 NS	10.415 NS	4.586 NS
Int.(Spacing x Variety x Year)	6	9.504 NS	5.521 NS	1.895 NS
Error (b)	24	6.502	5.949	1.734

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix XIV: Combine analysis of variance showing the effect of inter-row spacing and variety on weight of seeds per pod, weight of pod per plant and 1000 seed weight

Source of var.	DF	Weight of seeds per pod	Weight of pods plant	1000 seed weght
Year	1	21.395*	1521.103**	3673.725**
Rep. (Year)	4	2.156	44.863	146.746
Spacing	2	8.753**	210.002**	408.036 NS
Spacing x Year	2	2.392 NS	31.000 NS	230.796 NS
Error (a)	8	1.611	23.224	157.292
Variety	2	2.460 NS	243.989**	406.660*
Spacing x Variety	4	0.734 NS	2.742 NS	241.120*
Int.(Spacing x Variety x Year)	6	2.299*	19.431 NS	229.727 NS
Error (b)	24	0.903	22.871	93.064

NS = not significant
* = significant at 5%
** = significant at 1%

Appendix XV: Combine analysis of variance showing the effect of inter-row spacing and variety on shelling percentage, seed yield per plot and seed yield per hectare

Source of var.	DF	Shelling percentage	Seed Yield per plot	Seed yield per hectare
Year	1	71.415**	0.633**	377303.527**
Rep. (Year)	4	2.865	0.068	49951.301
Spacing	2	24.587**	0.065 NS	72102.449 NS
Spacing x Year	2	6.712**	0.149*	13524.682*
Error (a)	8	1.459	0.027	8793.922
Variety	2	30.537*	0.492**	282667.839**
Spacing x Variety	4	11.754*	0.117 NS	83429.831*
Int.(Spacing x Variety x Year)	6	3.444 NS	0.023*	15696.647**
Error (b)	24	3.537	0.021	16958.445

NS = not significant
* = significant at 5%

** = significant at 1%