SCREENING OF COWPEA VARIETIES FOR CERCOSPORA LEAF SPOT (*Cercospora canescens* Ellis and Martin) IN YOLA AND MUBI, NORTH-EASTERN NIGERIA

BY

AYUBA, KUNIHYA

[B. Agric. Tech. (Hons.) Crop production and Horticulture, FUTY, 2008]

(M. TECH./CP/09/0116)

December, 2012

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A Master of Technology Thesis Submitted to the Department of Crop Protection, School of Agriculture and Agricultural Technology, Modibbo Adama University of Technology, Yola in Partial Fulfillment of the Requirements for the Award of Master of Technology (M. Tech.) Degree in Crop Protection

December, 2012

DECLARATION

I hereby declare that this Thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

…….

Ayuba Kunihya

(M. Tech/CP/09/0116)

Date ……

DEDICATION

This thesis is dedicated to my parents, Hon. Ayuba Z. Madi and Mrs. Vura Ayuba.

APPROVAL PAGE

This thesis entitled "Screening of Cowpea Varieties for Cercospora Leaf Spot (*Cercospora canescens* Ellis and Martin*)* in Yola and Mubi, Nigeria" meets the regulations governing the award of Master of Technology (M. Tech.) Degree in Crop Protection, Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

An experiment was carried out at two locations in Yola and Mubi to screen twelve (12) cowpea varieties for their reaction to infection by cercospora leaf spot (*Cercospora canescens* Ellis and Martin) disease on the field during the 2011 cropping season. The cowpea varieties tested in the study were SAMPEA-1, SAMPEA-2, SAMPEA-4, SAMPEA-5, SAMPEA-6, IFE-BROWN, SAMPEA-7, SAMPEA-8, SAMPEA-9, SAMPEA-10, SAMPEA-11 and SAMPEA-12. The experimental design was Randomized Complete Block Design (RCBD), replicated three times. The plot size was 4 x 2 m separated by 0.5 m alley between plots and 1 m between replications, giving a total field size of 43 x 11.5 m. Data collected were percentage establishment, number of vines per plant, vine length (cm), number of pods per plant, disease incidence (%), disease severity (%), number of pods per plant, number of seeds per plant, 100 seed weight and yield per hectare ($kgha^{-1}$). The data collected were analyzed using the Generalized Linear Model (GLM) procedure of SAS (Statistical Analysis System) while the means that were statistically significant were separated using Student-Newman-Kuels-Test. The effect of cercospora leaf spot disease was observed on the; number of primary vines per plant and vine length at Mubi, where SAMPEA-1 and SAMPEA-2 had the highest and the least number of primary vines of 5 and 3 respectively, while SAMPEA-8 had the longest vine (188.60cm). SAMPEA-8 flowered much earlier than the other varieties in both locations and in the combined result. The incidence (%) of cercospora leaf spot was observed in both locations at varying levels with all the varieties having the incidence of 100% at 9 WAS at Yola, while SAMPEA-2, SAMPEA-10 and SAMPEA-12 had the highest incidence of 93.33-100% at 9 WAS in Mubi and in the two location combined. The lowest incidence of 66.67% was recorded on SAMPEA-1 at 9 WAS in Mubi. The severity of the disease was also observed to be higher in Yola than Mubi, where a warm weather coupled with high relative humidity considered favourable for the disease development was recorded. At the peak of the disease severity (12 WAS), SAMPEA-2 gave the highest severity in Yola (83.37%), while IFE-BROWN gave the highest severity in Mubi (76.67%). The lowest severity (48.90%) was observed on SAMPEA-7 in both locations and in the two locations combined. SAMPEA-6 gave the highest number of seeds per pod in Mubi (15), while the 100 seed weight varies between 13 g to 16 g in both Yola and Mubi and in the two locations combined. Mubi gave higher average yield of 2,730 $kgha^{-1}$ than Yola where 1,378.00 $kgha^{-1}$ was recorded. The highest yield in Yola was obtained from SAMPEA-1 (2,060.60 $kgha^{-1}$) and SAMPEA-6 (1999.90 $kgha^{-1}$), while SAMPEA-1 and SAMPEA-11 gave the highest yield in Mubi with yield of 4,104.10 and 4,101.80 $kgha^{-1}$ respectively. From this study, it was observed that all the 12 varieties tested were susceptible to cercospora leaf spot disease with SAMPEA-2, SAMPEA-9 and SAMPEA-11 revealing high susceptibility in Yola and SAMPEA-5, SAMPEA-6, IFE-BROWN and SAMPEA-12 in Mubi. The least susceptible was SAMPEA-7 (48.90% severity at 12 WAS) in both locations, followed by SAMPEA-8 (51.10%) and SAMPEA-4 (51.13%) in Yola and; SAMPEA-9 (53.33%) and SAMPEA-10 (54.43%) in Mubi. Based on the results of this study, it is suggested that the cowpea varieties which were found to be tolerant to the disease should be investigated further to ascertain their levels of tolerance or otherwise. Furthermore, more lines and varieties should be used in future study with a view to identifying resistant ones that will be suitable for these locations.

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ABBREVIATIONS

ANOVA	-	Analysis of Variance
B. Agric. Tech.	-	Bachelor of Agriculture Technology
CLS	-	Cercospora Leaf Spot
CRI	-	Crop Research Institute
CSIR	-	Council for Scientific and Industrial Research
DAS	-	Days After Sowing
DS	-	Disease Severity
FAO	-	Food and Agriculture organization
FOS	-	Federal Office of Statistics
GNA	-	Ghana News Agency
IAR	-	Institute for Agricultural Research
IITA	-	International Institute of Tropical Agriculture
M. Tech.	-	Master of Technology
RCBD	-	Randomized Complete Block Design
SNKT	-	Student-Newman-Kuels-Test

CHAPTER ONE
INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the oldest domesticated crops known to the human race. It is believed to have originated in West Africa between five and six thousand years ago, where it was associated with ancient cereal farming (IITA, 2010). From Africa, it was taken around the world by merchants, travelers, and most notably by slaves. It is cultivated within the approximate latitude range of 35^{o}N to 30^{o}S of the equator, covering Asia, and the Oceania country, the Middle East, Southern Europe, Africa, Southern USA, and Central and South America (Fall *et al.*, 2003; Singh, 2010).

According to FAO (2010), about 7.56 million tonnes of cowpea are produced worldwide annually on about 12.76 million hectares. Nigeria produced 2.1 million tonnes of this, making it the world's largest producer, followed by Niger (650,000 tonnes) and Mali (110,000 tonnes) (IITA, 2004). The annual global cowpea grain production is approximately 4.99 million tons, with Africa producing 70% of the total world production of dried cowpea (FOS, 2005). Nigeria is the world's largest producer, generating 58% of the worldwide yield (FAO, 2010). Cowpea is gradually attaining economic importance in Nigeria, particularly the southern states of Nigeria, even though the bulk of the production is done in the northern parts of the country (Petu-Ibikunle *et al.*, 2008). According to Kormawa (2002), the major crops produced in Adamawa State includes sorghum, rice, maize, cowpea and groundnut, with cowpea occupying the fourth position with respect to average annual area committed to the crops.

Cowpea is a dicotyledonous plant belonging to the order Fabaceae, genus *Vigna* (Cronquist, 1988), and is of major importance to the livelihood of millions of people in the tropics (Quin, 1997; Sanginga *et al.*, 2002). This crop provides food, animal feed and cash for the rural populace in addition to benefits to farmlands via *in situ* decay of roots residues and ground cover from cowpea's spreading habits. Besides, cowpea grain provides a cheap and nutritious food for relatively poor urban communities (Quin, 1997; Adejumo *et al.*, 2001), and the hay is a significant source of income for farmers during the dry season in West Africa (IITA, 2010).

The crop is important in West and Central Africa where it is grown on about 8 million hectares (Kamara *et al.*, 2007). The relatively high protein content of cowpea makes it an important supplement to the diet of many African people (Bressani, 1985; Jaritz, 1991) who consume cereals high in carbohydrate and low in protein. It is a grain

legume grown mainly in the savanna regions of the tropics and subtropics in Africa, Asia, and South America (IITA, 2009). It is mostly grown in the dry savannas of Nigeria, Niger, Burkina Faso, Mali and Senegal, where it is used for both food and forage (Singh, 2002), and is frequently intercropped with cereals where the cowpea crop contributes to the maintenance of soil fertility (Carskey *et al.,* 2001).

According to IITA (2010), cowpea is rich in several vitamins, minerals and especially protein, which makes it a key crop in poverty-stricken areas because it can be used as a replacement for meat. All the plant parts that are used for food are nutritious, providing protein, vitamins and minerals (Abebe *et al.*, 2005). IITA (2009) reported that cowpea grain contains about 25% protein, making it extremely valuable where many people cannot afford protein foods such as meat and fish. More than 4,000,000 tonnes of cowpea are consumed worldwide each year and in Africa alone, 387,000 tonnes are eaten (IITA, 2010). In East Africa, the leaves are often used rather like spinach, in soups and stew; in Asia and Latin America, the green seed pods are eaten as a vegetable. The seeds which are the main food product from the cowpea plant can be dried, used fresh, or cooked, then canned or frozen. The beans are often served with rice or added to other meals. In Nigeria, cowpea is used to make *akara*, a savoury fried donut and *moin-moin*, a steamed bean cake (FAO, 2010). Cowpea grain is consumed directly after cooking, or as a component of meals made from cereals or root crops (Lagoke *et al.*, 1993).

Cowpea is resistant to drought and easily adapts to different soils while growing intercropped with other plants, such as yam, maize, or millet, and as a legume, it acts as a green manure, replenishing the nitrogen in the soil and increasing land fertility (Dugje *et al.*, 2009; IITA, 2010). The crop also maintains the land by growing quickly and covering fields, deflecting the rain with the leaves, and preventing erosion. It is less tolerant to water logging and are short-day, warm-weather plants, sensitive to cold and killed by frost (Duke, 1990).

According to Dugje *et al.* (2009), cowpea 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, provided that the range of minimum and maximum temperatures is between 28 and 30°C (night and day) during the growing season, and it performs well in agro-ecological zones where the rainfall range is between 500 and 1200 mm/year. 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. It is tolerant of drought and

well adapted to sandy and poor soils. However, best yields are obtained in well-drained sandy loam to clay loam soils with the pH between 6 and 7 (Dugje *et al.,* 2009).

IITA (2009) reported that cowpea is susceptible to a number of fungal, bacterial and viral diseases such as Cercospora leaf spot, ashy stem blight, bacterial blight, blackeye cowpea mosaic potyvirus (BICMV), cowpea aphid-borne mosaic potyvirus (CABMV), and cowpea mosaic comovirus (CPMV). Ajibade and Amusa (2001) reported that brown blotch and Cercospora leaf spot are the most important fungal diseases limiting cowpea production in South-West Nigeria. One of the fungal diseases reported to cause serious yield loss in cowpea is the Cercospora leaf spot caused by two fungi namely *Cercospora canescens* Ellis and Martin and *Mycospharella cruenta* Lanthanus (Akande, 2007).

Cercospora leaf spot (CLS) disease is an important constraint to cowpea (*Vigna unguiculata*) production, particularly in the tropics (Schneider *et al.,* 1976). In 1976, Anon reported that in an evaluation of ecological range of major cowpea pathogens in Africa, *Cercospora* leaf spots (CLS) had the widest range, covering the whole of semi-humid and Guinea savanna and a part of Sudan savanna. The disease is distributed worldwide, including Nigeria and was reported to have caused severe leaf spotting and defoliation in cowpea at Ibadan, Nigeria (Bird and Maramorosch, 1975; Williams 1975).

Pseudocercospora leaf spot produces chlorotic or necrotic appearances on the upper surface of the leaf while the underneath surface, it produces conidiophores and conidia with gray or dark gray appearances whereas Cercospora leaf spot produces a number of circular or irregular spots on both surfaces of leaf and it has cherry red to reddish brown appearances on both surfaces of the leaf (Emechebe and Lagoke, 2003). Yield loss attributed to Cercospora leaf spot (CLS) in susceptible cowpea varieties varies between 36% and 42% (Schneider *et al.*, 1976; Ferry *et al.*, 1977). Out of 75 cowpea lines evaluated in 1999 and 2000, about 40% of the germplasm was found susceptible to Cercospora leaf spot diseases (Ajibade and Amusa, 2001), with Ife brown, a widely adopted and cultivated cowpea cultivars in Southwestern Nigeria having 80% Cercospora incidence on the field. Field observation revealed crop loss of over 40% in Cercospora endemic field (Ajibade and Amusa, 2001). According to Booker and Pathmanathan (2007), Cercospora leaf spot (CLS) is a serious limitation to cowpea production, resulting in yield loss of as much as 42%. According to Akande (2007), for high productivity, a crop variety being considered for recommendation in a particular environment should be resistant or tolerant to the prevailing diseases in that environment. There are little or no reports on the effect of this disease on cowpea in Adamawa State and its environs despite its presence in most cowpea

producing areas of the state. In view of this therefore, this study was carried out in the study areas with the following objectives:

1. to identify the most resistant cowpea variety or varieties to the Cercospora leaf spot disease.
2. to estimate the level of resistance (if any) of each of the cowpea varieties to the Cercospora leaf spot disease in the study areas.
3. to estimate the yield of these varieties under the disease condition in the study areas.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cercospora Leaf Spot of Cowpea

Cercospora leaf spot of cowpea is an important disease of cowpea caused by two fungi namely *Cercospora canescens* Ellis and Martin and *Mycospharella cruenta* Lantham (Akande, 2007). Sinsiri *et al.* (2006) also reported that cowpea crop is facing a lot of problem of diseases such as the problem of Pseudocercospora leaf spot disease caused by *Mycosphaerella cruenta* Lantham and later, this pathogenic disease was known as *Pseudocercospora cruenta* (Sacc.) Deighton, where in many published works, it revealed that this pathogenic disease has its characteristics similar to *Cercospora cruenta* (Sacc.), which causes Cercospora leaf spot disease in cowpea plants (Sinsiri *et al.,* 2006*).*

However, there are distinctive differences found between the two diseases, i.e., Pseudocercospora leaf spot produces chlorotic or necrotic appearances on the upper surface of the leaf while the underneath surface, it produces conidiophores and conidia with gray or dark gray appearances whereas Cercospora leaf spot produces a number of circular or irregular spots on both surfaces of leaf and it has cherry red to reddish brown appearances on both surfaces of the leaf (Emechebe and Lagoke, 2003; Akande, 2007; Adegbite and Amusa, 2008).

It has been advocated that these two types of diseases could manifest its rapid growth on crop residues and in seeds of most leguminous crops throughout the year regardless of the seasons (Allen *et al.*, 1998). It has also been reported that *Pseudocercospora Cruenta* could be found in plant species of *Canavalia ensiformis* (Ram and Mallain, 1992). Although cercospora leaf spot disease occurs mainly on cowpeas and on grain legumes, other minor and major hosts have been identified. The major hosts are *Vigna unguiculata* (cowpea), *Amaranthus* (grain amaranth), *Glycine max* (Soybean), *Lablab purpureus* (hyacinth bean), *Lycopersicon esculentum* (tomato), *Phaseolus* (beans), *Ricinus, Vicia* (vetch), *Vigna* (cowpea), *Voandzeia subterranean* (bambara groundnut). Other hosts obtained from artificial inoculations are *Crotalaria juncea* (sunn hemp), *Psophocarpus tetragonolobus* (winged bean), *Vigna angularis* (adzuki bean), *Vigna mungo* (black gram) and *Vigna radiate* (mung bean) (IITA, 2010). According to Farr *et al.* (1989; IITA, 2010), the disease is widespread in warmer subtropical regions. The fungus has been reported in the Eastern region of USA, Bangladesh, China, India, Indonesia, Thailand, Africa, Brazil and Samoa (IITA, 2010). According Butler (1973), *C. cruenta* was first reported from the United States on a species of *Phaseolus* or *Dolichos* and has been

reported on French beans, rangon beans and cowpea. (Akande, 2007) reported that *C. cruenta* and *C. canescens* caused severe leaf spotting and defoliation in cowpea in Ibadan. *Cercospora cruenta* is the more serious because it occurs severely in susceptible varieties at any time of the year, while *C. canescens* is only occasionally severe. *Cercospora* leaf spot disease of cowpea is worldwide in distribution and has been reported Nigeria (Williams, 1975; IITA, 2010).

2.2 Yield Loss in Cowpea due to Cercospora Leaf Spot

Schneider *et al.* (1976) reported that Cercospora leaf spot is an important constraint to cowpea (*Vigna unguiculata*) production, particularly in the humid tropics. The yield loss in susceptible varieties varies between 36% and 42% (Schneider *et al.,* 1976; Fery *et al.,* 1977; Singh, 1997; Booker and Pathmanathan, 2007). Earlier, Kannaiyan *et al.* (1987) reported that Cercospora leaf spots (*C. canescens* and *C. cruenta*) are severe in the wet season in Zambia and that none of the 336 cowpea entries screened was resistant to the diseases. Similarly, Zhang and Huang (1990) listed Pseudocercospora leaf spot as one of the important diseases of cowpea in China. In Zimbabwe, however, Mariga *et al.* (1985) did not consider Cercospora and Pseudocercospora leaf spots to be economically important. Hartmans and Emechebe (1988) reported that *P. cruenta* has become more prevalent in the Nigerian Sudan savanna, although its effect on cowpea production in this zone is yet to be determined (Singh, 2009).

2.3 Epidemiology of Cercospora Leaf Spot

The development of a disease epidemic on plants depends on several factors relating to the host, the pathogen, the environment and the complex interaction of these factors (Agrios, 1997). Rohan (2011) reported that in some plant pathosystems, which include many *Cercospora* species on various hosts, the pathogen mainly causes discrete lesions on leaves that may remain restricted in size over the life of the host. In contrast, when conditions are favourable, the lesions continue to grow rapidly after their initial appearance, until much of the host is symptomatic (Rohan, 2011). This is known as lesion expansion and is an important component of epidemiology, particularly relevant to the cercospora leaf disease (Berger, 1977; Berger and Roberts, 1990; Berger *et al.,* 1997). Lesion size and development has been used extensively in pathology studies to assess disease severity and in plant breeding to rank germplasm for resistance to various pathogens (Trivoli *et al.,* 2006).

Cercospora leaf spot of cowpea is induced by *Cercospora canescens* Ellis and Martin, while *Pseudocercospora* leaf spot is induced by *Mycosphaerella cruenta* Latham in the form of its anamorph *Pseudocercospora cruenta* (Sacc.) Deighton, formally *C. Cruenta* (Emechebe and Shoyinka, 1985; Adebigte and Amusa, 2008). Before *C. cruenta* was designated as *P. Cruenta,* the diseases induced by what were considered as two species of the genus *Cercospora* were known as *Cercospora* leaf spots. *Pseudocercospora* leaf spot is characterized by chlorotic or necrotic spots on the upper leaf surface and profuse masses of conidiophores and conidia appearing as downy gray to black mats on the lower surface. *Cercospora* leaf spot is characterized mostly by circular to irregular cherry red to reddish-brown lesions on both leaf surfaces (Adebigte and Amusa, 2008).

The mode of penetration of *C. cruenta* into cowpea leaves as revealed by the study carried out by Amadi (1994) is through the stomata. The penetrating structures are the conidiophores. He found that the stomatal concentration was denser on the abaxial than on the adaxial leaf surfaces. Incidentally, *Cercospora* leaf spot symptoms induced sporulation on the abaxial surfaces of infected leaves. This pattern of symptom development might have been conditioned by the stomatal distribution. It could also have been affected by the more humid conditions that exist on the lower (abaxial) leaf surface than on the upper (adaxial) leaf surfaces (Amadi, 1994).

Both pathogens survive the non-crop period on infected crop residue and in infected seed (Williams, 1975; Patel, 1985; Singh, 1997; and Adebigte and Amusa, 2008) although in 1979, it was unable to demonstrate seed-to-plant transmission of *C. canescens* (Singh, 1997). Both leaf spots have been reported from all cowpea growing regions of the world. According to Adebigte and Amusa (2008), *P. cruenta* induces leaf spot on several legumes and *C. canescens* on an even wider range of legumes – the list of suspects of each pathogen is provided by Allen *et al.* (1998). However, *Pseudocercospora* leaf spot is more economically important than *Cercospora* leaf spot (Fatukon, 2001; Adebigte and Amusa, 2008).

According to IITA (2010), the symptoms of Cercospora leaf spot are prominent on the leaves alone. However, the fungus has been isolated from infected seeds which are symptomless. Symptoms found on various plant parts are: On the leaves – subcircular to broadly irregular spots having pale tan to grey centre surrounded by dark brown or reddish margin. The spots coalesce to form round lesions which are brown and necrotic with dark and slightly depressed edges. On pods – the pods are damaged and dry up. On the stem – there are lesions on the stem and cotyledons (Ayodele and Kumar, 2010).

Mulder and Holliday (1975) and Akande (2007) reported that abundant fruiting bodies are produced on the lower surface of the leaf. The conidia are uniform in colour, pale to medium brown, multiseptate, medium to large size, conidial scar present on the rounded apex, thickened hilum. Most conidia are formed at 28^{o}C, while at 24^{o}C and 32^{o}C less no conidia are formed (Charles, 2005). According to Singh (1997), most mycellial growth is at 26^{o}C and most conidial germination at 25^{o}C. The fungus survives in the infected tissue for up to 21 days at 35^{o}C (Singh, 1997). The presence of light increases the number of conidia (Mulder and Holliday, 1975; Singh, 1997). Sporulation is favoured by humid weather, warm temperatures, and dense plant populations. Spores are dispersed by wind and rain splash (Singh, 1997; Singh, 2009).

Schneider *et al.* (1976); Charles (2005) in their work reported that the Cercospora leaf spot of cowpea occurred only after the onset of flowering even though sufficient inoculum was present, and temperature and moisture were favourable for disease development. This was clearly demonstrated in side-by-side comparisons in which older plants were severely diseased and plants in the flowering stages of growth were disease-free (Schneider *et al.*, 1976; Charles, 2005).

2.4 Control of Cercospora Leaf Spot

Crop losses caused by *Cercospora* leaf spot have received far more attention than those caused by any other foliar disease (IITA, 1985). However, Emechebe and Florini (1997) noted that very little work on the two cowpea diseases (Cercospora and Pseudocercospora) had been done between 1985 and 1995, and the situation did not change between 1995 and 2000. The few reports that appeared during this period focused on varietal resistance and fungicide control. In China, 131 cowpea accessories were evaluated for their reaction to *P. cruenta* in the field subsequent to artificial inoculation (Lin *et al.*, 1995). It was shown that 15 accessories were immune and seven were highly resistant. Although only six cowpea cultivars were evaluated in Singapore by Leina *et al.* (1996), one variety was found to be highly resistant to *P. cruenta.* In another experiment, Liena *et al.* (1996) demonstrated a direct correlation between the variation in peroxidase activity in the soluble fraction of inoculated leaves and resistance to infection in cowpea cultivars; they also showed that the soluble fraction of inoculated leaves had higher peroxidase activity than either the mitochondrial or chloroplast extracts.

2.4.1 Chemical Control

Chemical control of some of the major fungal diseases can be effected through application of fungicides to the seeds or through foliar fungicidal sprays (IITA, 1985; Rohan, 2011). Evaluation of fungicides for the control of *Pseudocercospora* leaf spot was also conducted in Bangladesh and Nigeria. A trial by Haque *et al.* (1994) in Bangladesh tested the efficacy of six fungicides against *Pseudocercospora* leaf spot. Their results showed that the best control of the disease and the highest yield were obtained by three to four spray of benomyl after 12 days. In Nigeria, Amadi (1995) evaluated three fungicides (Benomyl, Mancozeb, and Captafol) for the control of *Cercospora* leaf spot in Ilorin. He reported that weekly spraying of benomyl, beginning at three weeks after planting, gave the best control of the disease and the highest grain yield (Adebigte and Amusa, 2008). According to Ayodele and Kumar (2010), seed treatment with mancozeb (Ethylene Bisdithiocarbamate) at the rate of 80g/kg of seeds is recommended, and also fungicidal field sprays in the field during active growth of the plants may be used for the control of cercospora leaf spot in cowpea.

2.4.2 Cultural Control

The cultural practices proposed for control of diseases are based on pathogen survival, inoculum spread for secondary infection and the environmental conditions that enhance disease development (IITA, 1985). All the major diseases survive the dry season on infected crop residues in the form of vegetative bacterial cells, fungal mycelia or resistant structures such as chlamydospores, oospores, sclerotia, and teliospores (IITA, 1985; Arunee *et al.*, 1999). Palti and Rotem (1983) reported that these primary sources of inoculum could be reduced if plant residues were collected and burned at the end of the crop season.

It was reported that the usual practice of igniting heaps of collected stubble when winds are favourable often leaves parts of the infected tissues untouched and is, therefore, of doubtful value (Palti and Rotem, 1983). According to IITA (1985) and Singh *et al.* (2002), four diseases are enhanced by high plant populations – '*Cercospora'* leaf spots, *Pythium* stem rot, *Sclerotium* wilt and web blight and their infection rates can be reduced in moderate plant populations. Crop rotation, tillage and other practices which hasten decay on infected leaves will reduce initial inoculum and initial infection, and the disease development each year is dependent on inoculum that survives the winter in infected leaves and petioles of the previous year crop (Barry *et al.*, 2006).

2.4.3 Use of Resistant Varieties

In 1985, IITA reported that until then there was virtually no popular cowpea variety with acceptable levels of resistance to the major fungal diseases prevalent in cowpea-production areas in Africa. Thus, one of the most popular, high yielding varieties of cowpea in Nigeria, Ife Brown, is susceptible to diseases in both the rain forest and the savanna zones (IITA, 1985). However, Singh (1993) reported that IITA have developed cultivars which combine resistance to several major diseases. According to Charles (2005), resistance to *Cercospora canescens* has been reported in mung bean and cowpea. According to Singh (2010), over 15,000 germplasm of cowpea lines have been collected by IITA and a range improved varieties with diverse maturity, plant type combined with high protein, iron, zinc, and resistance to major biotic and abiotic stress stresses have been developed, including resistance to cercospora leaf spot. Some of the cowpea varieties reported to be resistant to *Cercospora* leaf spot in Nigeria includes IT-86D-719, IT-87D-939-1, IT-87D792, IT-87D-400 and IT-83S-899, developed at the International Institute for Tropical Agriculture, Nigeria (Booker and Pathmanathan, 2007). Singh (2005) reported that using a combination of field and laboratory screening, a number of cowpea breeding lines have been developed with combined resistance to many biotic factors, including Cercospora leaf spot. Among these, IT82D- 889, IT83S-818, IT86D-880, IT86D-1010, IT84S-2246-4, IT89KD-889, IT90K-59, IT90K-76, and IT90K- 277-2, IT90K-284-2, IT97K-207-15, IT97K-499-35 and IT98K-205-8 are very promising (Van Boxtel *et al.*, 2000; Singh *et al.*, 2002).

Castro *et al.* (2003) studied the inheritance of resistance to cercospora leaf spot in cowpea, utilizing the L101000-1 line and the cultivar IPA 206 as parents, the two being considered resistant and susceptible, respectively. Parent plants were crossed using the flower emasculation technique to obtain F_1, F_2 and F_3 populations. The plants of the L101000-1 line and F_1 populations showed resistance while the cultivar IPA 206 showed typical symptoms of Cercospora leaf spot. In the F_2 generation, from the 132 plants observed, 105 were resistant and 27 susceptible; in the F_3 generation, from the 90 plants evaluated, 70 were resistant and 20 susceptible. Therefore, it was concluded that the inheritance of resistance to *Cercospora cruenta*, in the L101000-1 line, is the monogenic and dominant type (Castro *et al.*, 2003).

GNA (2008) reported that the Crop Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) has developed two varieties of cowpea, IT87D-611-3 named "Nhyira" meaning Blessing in Akan and IT87D-2075 with the name "Tona"

meaning Profit in Dagarti. Nhyira had an early maturing period (65-68 days), high yielding (2.3 tons per hectare), moderately resistant to virus, resistant to Anthracnose and Cercospora leaf spot, high in iron, energy and phosphorus contents, protein, tolerant to leaf hoppers, bold, white seed with brown eye and drought tolerant, while Tona variety has high energy, phosphorus and iron, resistant to Cercospora leaf spot and viruses, resistant to leaf hoppers, medium maturing age of 71-80 days and drought tolerant (GNA, 2008).

2.4.4 Integrated Control

Integrated pest management uses all suitable techniques that complement each other with the aim of keeping pest or pathogen populations below the threshold at which economic damage occurs. In integrated pest management, resistant crop varieties might be used in conjunction with chemical treatment, crop rotation and manipulation of the environment (University of Sydney, 2003).

Enikuomehin (2005) reported that the use of chemicals may pose ecological problems. This in turn, necessitates the search for alternatives in plant products, many of which have been reported to be effective in the control of several plant diseases (Enikuomehin and Peters, 2002; Okigbo and Emoghene, 2003). According to IITA (1985), only complementary use of the three methods (chemical, cultural and resistant varieties) will ensure effective control of diseases, especially as several diseases attack cowpea in each of the ecological zones. For example, all the cultural practices recommended for the control of the major diseases should be adhered to, whether or not resistant variety. Also, improved varieties may be protected against several other diseases, to which they are susceptible, if seeds are treated with appropriate fungicides; where economic, fungicidal sprays should also be used to control diseases (IITA, 1985, Singh, 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out in the 2011 cropping season at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola and the FAO Experimental Farm of the Department of Crop Sciences, Adamawa State University Mubi. Yola is located in the Northern Guinea Savanna of Nigeria, between latitudes 9^{o} and 10^{o} N and longitude 11^{o} and 14^{o} E, at an altitude of 158.5m above sea level. The annual rainfall ranges from 700-1000mm, and the temperature ranges from 15.2-39^{o}C (Adebayo, 1999). Mubi is located between latitude 9^{o} $30^{'}$ and 11^{o} N and longitude 13^{o} and 13^{o} $45^{'}$ E (Adebayo, 2004), at an altitude of 696m. The mean annual rainfall for Mubi is about 1016mm (Rayar, 1986).

3.2 Experimental Materials

Twelve (12) cowpea varieties obtained from the Institute for Agricultural Research (IAR) Samaru, Zaria, Kaduna State, Nigeria were used for the experiment (Plates 1a- l). The names, source, outstanding characteristics and yield potential of the varieties are as shown in Table 1.

3.3 Experimental Design

The twelve (12) cowpea varieties were evaluated for resistance to Cercospora leaf spot disease of cowpea in a Randomized Complete Block Design (RCBD) with three replications, under natural field conditions attained through the use of spreader rows (TVX-3236 - a cowpea variety susceptible the *Cercospora* leaf spot). Each block (treatment) had an area of 4 x 2 metres, with a length of 4 metres while the breadth was 2 metres. The space between plots was 0.5 metres, and the space between replications was 1 metre (Figure 1).

Table 1: The Names, Source, Outstanding Characteristics and Yield Potential of the Cowpea Varieties used for the Experiment

Name of Variety	Source	Outstanding Characteristics	Yield Potential (Kg/ha)
SAMPEA 1	IAR, Zaria	Consistent & stable in yield, good palatability	1700-2400
SAMPEA 2	IAR, Zaria	Good palatability	1500
SAMPEA 4	IAR, Zaria	Good palatability	1200-2400
SAMPEA 5	IAR, Zaria	Early maturity and good palatability	1200-2400
SAMPEA 6	IAR, Zaria	Long pods, extra long seed, high yielding & good palatability	1000-1500
SAMPEA 7	IAR, Zaria	Consistent and stable, high yielding & good palatability	1500-2500
Ife-Brown	IAR, Zaria	Semi erect & uniform maturity, pods held above the canopy	1200-2400
SAMPEA 8	IAR, Zaria	Extra-early maturity, good seed quality, field tolerance to major insect-pests	1300-2000
SAMPEA 9	IAR, Zaria	Dual purpose (good grain &fodder yields), acceptable seeds quality & good fodder quality	2500
SAMPEA 10	IAR, Zaria	Early maturing, white seeded striga resistant, white seeded alectra resistant, good seed quality, field tolerance to major insect-pests	2500
SAMPEA 11	IAR, Zaria	Aphid resistant, good quality seed and tolerant to major insect pests.	1300-2000
SAMPEA 12	IAR, Zaria	Tolerant to aphids, good quality seed, large brown seeds.	2500

Source: ***National Centre for Genetic Research and Biotechnology (2009).***

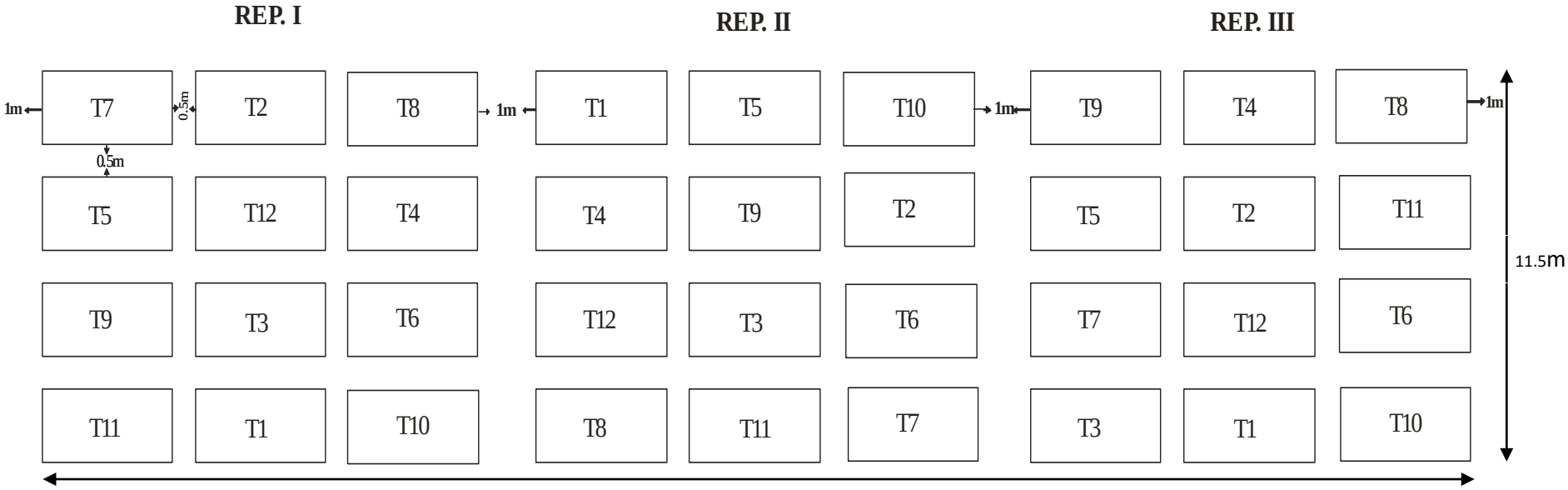

Figure 1: Experimental Design and Field Layout.

KEY:

T1 = SAMPEA 1
T2 = SAMPEA 2
T3 = SAMPEA 4
T4 = SAMPEA 5
T5 = SAMPEA 6
T6 = SAMPEA 7
T7 = Ife Brown
T8 = SAMPEA 8
T9 = SAMPEA 9
T10 = SAMPEA 10
T11 = SAMPEA 11 and;
T12 = SAMPEA 12.

Plate 1a: SAMPEA-1 variety

Plate 1b: SAMPEA-2 variety

Plate 1c: SAMPEA-4 variety

Plate 1d: SAMPEA-5 variety

Plate 1e: SAMPEA-6 variety

Plate 1f: SAMPEA-7 variety

Plate 1g: IFE-BROWN

Plate 1h: SAMPEA-8 variety

Plate 1i: SAMPEA-9 variety

Plate 1j: SAMPEA-10 variety

Plate 1k: SAMPEA-11 variety

Plate1l: SAMPEA-12 variety

Plate 1a– l: Names and physical appearance of the different seeds of cowpea varieties used in the study

3.4 Cultural Practices

The cultural practices that were carried out during the experiment included land preparation, seed treatment, sowing, weeds control, and insect pests control.

3.4.1 Land Preparation

The land was cleared of shrubs and stubbles, and ploughed with tractor. The beds were then prepared manually with the use of hoe in accordance with the experimental design. The soil was prepared to provide sufficient tilth for good root growth and the seeds were sown on flat beds, not ridges.

3.4.2 Seed Treatment

The seeds were treated with Apron Plus at the rate of 10g/5 kg of seeds to enhance good germination and protect the seedlings from insect and fungal infection (Dugje *et al.,* 2009).

3.4.3 Sowing

Sowing was carried out manually using hoe on the prepared beds consisting of a single test row, 4m long, guarded on either side by spreader rows. The seeds were sown at an inter-row spacing of 60cm and intra-row spacing of 25cm, at the rate of 3 seeds per hill which were thinned to 2 plants per stand at 2 weeks after planting. The seeds were sown at a depth of 2.5-5 cm.

3.4.4 Fertilizer Application

Fertilizer application was done in small quantity of 15 kg/ha nitrogen as a starter dose for a good crop, and phosphorus in the form of single super phosphate, at the rate of 30 kg of P/ha recommended for cowpea production to help the crop nodulate well and fix its own nitrogen from the air (Dugje *et al.,* 2009).

3.4.5 Weed Control

Weed control was carried out manually using hoe, first at 2 weeks after planting, and second at 5 weeks after planting to ensure clean field as recommended by Dugje *et al.,* 2009.

3.4.6 Application of Insecticides

The trials were protected from insect attack by the application of Cypermethrine + Dimethoate (Sherpa plus) insecticide applied at the rate of 50g a.i/ha at 3 weeks after seedling emergence and twice after anthesis to control insect attack (Akande, 2007).

3.5 Preparation and Application of Inoculum on the Field

In the field, each plot was surrounded by a spreader row of a cercospora leaf spot susceptible cowpea variety (TVX-3236), planted 2 weeks in advance of the test varieties. The plants were inoculated at the flower initiation stage of the spreader rows with prepared pure culture of the pathogen at the rate of 4×10^5 conidia ml^{-1} between 6 – 7pm to further boost the chances of infection and avoid disease escape. The prepared inoculum was applied to the plants with a Knapsack sprayer until runoff. In addition, diseased leaf debris was placed at the base of the spreader plants according to the method of Booker and Pathmanathan (2007), all with the aim of increasing the chances of infection.

3.6 Isolation of *Cercospora cruenta* from Infected Cowpea Leaves

The method of isolation as described by Roger and Dean (2005) was used to isolate the pathogen and the following steps were followed:

Leaves with young lesions were chosen, because the fungus was at its most active. Small pieces of the tissue were cut from the edge of the lesion using a sterile scalpel and the pieces were surface sterilized using 10% sodium hypochloride and then rinsed in sterile water.

The leaf pieces were then plated onto potato dextrose agar surface. The petri dish lids were carefully lifted and replaced when plating the leaf pieces onto the agar to avoid entry of airborne contaminants, and the isolation plates were then incubated in inverted position to prevent condensation of water vapour on the agar surface. A pure culture of the pathogen was obtained from the primary isolation plates after 7 days from hyphal tips. The plates were then examined under a stereo microscope.

3.7 Pathogenecity Test

The twelve cowpea varieties were planted in plastic pods in the screen house of the Department of Crop Production and Horticulture, Modibbo Adama University of Technology,

Yola. The varieties sown were SAMPEA-1, SAMPEA-2, SAMPEA-4, SAMPEA-5, SAMPEA-6, IFE-BOWN, SAMPEA-7, SAMPEA-8, SAMPEA-9, SAMPEA-10, SAMPEA-11 and SAMPEA-12. At 4 weeks after sowing, spore suspension was sprayed directly onto the upper and lower surfaces of older seedling leaves at the rate of 5×10^6 conidia ml^{-1}. The plants were then covered with polythene bags to raise the relative humidity to 100% for 72 hours. The plants were then observed for the circular or irregular cherry red to reddish brown symptom of the disease on both surfaces of the leaves (as observed on the field) at 14 days after spraying (Charles, 2005).

(a)

(b)

Plate 2: *Cercospora canescens* symptom manifestation on the field

(a)

(b)

Plate 3: *Cercospora canescens* symptom manifestation in the screen house

Plate 4: The 12 cowpea varieties planted in plastic pots in the screen house for pathogenesity test

Plate 5: Cowpea seedling covered with polythene bag to build up relative humidity during pathogenecity test.

3.8 Data Collection

The following data were collected in the experiment: percentage establishment count, number of primary vines per plant, vine length, days to 50% flowering, number pods per plant, number of seeds per pod, 100 seed weight (g), disease incidence (%), disease severity and yield (kg ha^{-1}).

3.8.1 Percentage (%) Establishment

This was carried out at 2 weeks after sowing by counting the number of established plants and expressed in percentage of the total number of expected plants per plot.

3.8.2 Vine Length (cm)

Five (5) plants were randomly sampled from each treatment at 8 WAS and the vine length measured using a thread, which was placed on a ruler and the length recorded.

3.8.3 Number of Primary Vines per Plant

The number of primary vines on each of the five sampled plants in each treatment was counted at 8 WAS and the average recorded accordingly.

3.8.4 Days to 50% Flowering

Days to 50% flowering was calculated by observing individual plots from the first appearance of flower until 50% of the plants have flowered, and the number of days taken (from the date of planting) and recorded appropriately.

3.8.5 Disease Assessment

3.8.5.1 Disease Incidence

Disease incidence was calculated by counting the number of diseased plants and expressing them as percentage of the total number of plants sampled in each plot. This was carried out starting from the first appearance of the visible disease symptom (6 WAS) to when the sampled plants expressed 100% symptom. The formula is given as:

$$\text{Disease Incidence} = \frac{\text{Number of Diseased Plants}}{\text{Total Number of Plants Assessed}} \text{ x } 100$$

3.8.5.2 Disease Severity

The severity of the disease was recorded using an arbitrary scale of 1 – 6 in terms of leaf coverage by the Cercospora leaf spot at 12 WAS (Park, 1987) as shown in Table 2, and the level of resistance were interpreted using the disease severity scores as shown in Table 3. The disease severity was calculated using the formula:

$$\text{Disease severity} = \frac{\text{Sum of individual ratings}}{\text{No. of plants assessed x 6}} \text{ x } 100$$

Where;

No. = Number

6 = Highest rating in the scale

Table 2: Disease Scoring for *Cercospora* leaf spot disease of Cowpea

Scale	*Cercospora* leaf spot characteristics
1	No visible symptom.
2	1 – 10% of the of the leaf lamina covered by spots
3	11 – 20% of the of the leaf lamina covered by spots
4	21 – 40% of the of the leaf lamina covered by spots
5	41 – 80% of the of the leaf lamina covered by spots
6	More than 80% of the of the leaf lamina covered by spots

Modified scale of Park, 1987.

Table 3: Rating Scale used for assessment of disease resistance based on means of disease severity at 12 WAS

Rating	Mean Disease Severity
Highly resistant	0%
Resistant	1 – 10%
Slightly resistant	11 – 20%
Moderately resistant	21 – 40%
Susceptible	41 – 65%
Highly susceptible	More than 65%

Modified scale of Awurum and Emechebe, 2001

3.8.6 Number of Pods per Plant

At pod maturity, the number of pods on each of the five (5) sampled plants was counted, and the average number of pods of the five (5) plants taken as the number of pods per plant.

3.8.7 Number of Seeds per Pod

Five (5) pods were randomly sampled from each of the treatments, and the number of seeds per pod counted. The average number of seeds of the five pods was recorded as the number of seeds per pod for each treatment.

3.8.8 100 Seed Weight (g)

From the threshed seeds, 100 seeds were counted from each of the treatments and the weights taken using an electric weighing scale and recorded appropriately.

3.8.9 Yield per Hectare ($kgha^{-1}$)

The grain yield per plot was calculated and expressed in kilograms per plot for each of the varieties and the result was used to calculate the yield per hectare ($kgha^{-1}$).

3.10 Data Analysis

The data obtained were analyzed using the Generalized Linear Model (GLM) procedure of SAS (Statistical Analysis System, 1996), appropriate for Randomized Complete Block Design. The means that were statistically different were compared using Student-Newman-Kuels Test.

CHAPTER FOUR

RESULTS

4.1 Percentage Establishment, Number of Primary Vines per Plant at 8 WAS, Vine Length at 8 WAS and Days to 50% Flowering of 12 Cowpea Varieties at Yola and Mubi in 2011

The means of treatments for percentage establishment, number of primary vines per plant and vine length (cm) of the 12 cowpea varieties at Yola and Mubi are presented in Table 4. Results in Yola revealed no significant differences ($P \geq 0.05$) were observed in respect of percentage establishment, number of primary vines per plant at 8 WAS and vine length at 8 WAS. However, highly significant differences ($P \leq 0.01$) were observed in number of days to 50% flowering, where results revealed that SAMPEA-8 and SAMPEA-10 came to flowering much earlier at 41 DAS than SAMPEA-5 and SAMPEA-11 which came to flowering at 67 DAS (Figure 2).

The results from Mubi indicated highly significant difference ($P \leq 0.01$) among the cowpea varieties with respect to number of primary vines at 8 WAS (Table 4). SAMPEA-1, SAMPEA-5, IFE-BROWN, SAMPEA-9 and SAMPEA-10 had the highest number of primary vines of 5, while the least number of primary vines was recorded on SAMPEA-2 with an average of 3 primary vines. Results further revealed highly significant difference ($P \leq 0.01$) at 8 WAS with SAMPEA-8 having the highest vine length of 188.60 cm, followed by SAMPEA-10 with 174.70 cm. The shortest vine length was observed on SAMPEA-12 (80.63 cm). Highly significant differences ($P \leq 0.01$) were also observed for number of days to 50% flowering of the twelve cowpea varieties. SAMPEA-8 variety came to flowering much earlier at 45 DAS than SAMPEA-6 which came to flowering at 59 DAS (Figure 2).

Table 4: Means of treatments for Establishment Count, Number of Primary Vines per plant at 8 WAS and Vine Length (cm) at 8 WAS of 12 Cowpea Varieties at Yola in 2011

	Yola			Mubi		
Varieties	Establishment count (%)	Number of primary vines at 8 WAS	Vine length at 8 WAS	Establishment Count (%)	Number of primary vines at 8 WAS	Vine length 8 WAS
SAMPEA-1	100.00[a]	3.00[a]	130.50[a]	90.47[a]	5.00[a]	119.33[abc]
SAMPEA-2	95.20[a]	3.00[a]	97.13[a]	95.20[a]	3.00[b]	104.50[bc]
SAMPEA-4	100.00[a]	4.00[a]	174.87[a]	95.20[a]	4.00[ab]	127.50[abc]
SAMPEA-5	95.23[a]	4.00[a]	144.27[a]	97.60[a]	5.00[a]	121.03[abc]
SAMPEA-6	100.00[a]	4.00[a]	126.87[a]	95.20[a]	4.00[ab]	119.93[abc]
SAMPEA-7	100.00[a]	4.00[a]	121.60[a]	100.00[a]	4.00[ab]	107.53[bc]
IFE-BROWN	97.60[a]	3.00[a]	99.23[a]	100.00[a]	5.00[a]	86.77[c]
SAMPEA-8	100.00[a]	4.00[a]	158.93[a]	92.83[a]	4.00[ab]	188.60[a]
SAMPEA-9	100.00[a]	4.00[a]	145.67[a]	97.60[a]	5.00[a]	144.00[abc]
SAMPEA-10	95.23[a]	3.00[a]	155.27[a]	97.60[a]	5.00[a]	174.70[ab]
SAMPEA-11	95.20[a]	4.00[a]	121.10[a]	92.83[a]	4.00[ab]	129.27[abc]
SAMPEA-12	95.23[a]	4.00[a]	89.99[a]	100.00[a]	4.00[ab]	80.63[c]
Mean	97.81	4.00	130.44	96.21	4.00	125.33
S.E	3.87	0.55	32.57	4.74	0.61	26.51

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

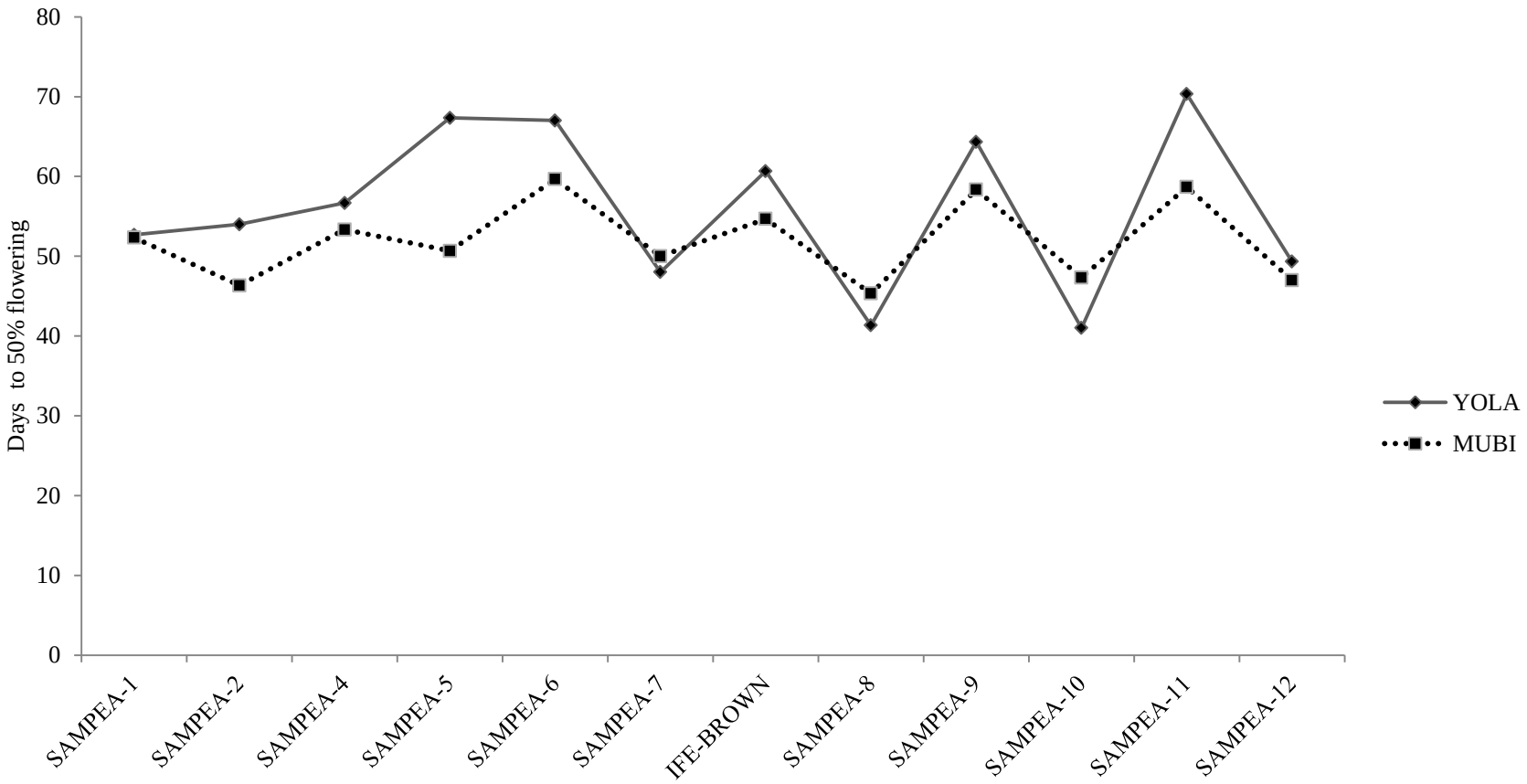

Figure 2 :Means of treatments for Days to 50% flowering of the 12 cowpea varieties at Yola and Mubi

4.2 Means of Treatments for Cercospora Leaf Spot Incidence (%) on 12 Cowpea Varieties at 6 – 9 WAS at Yola and Mubi in 2011

The means of treatments for cercospora leaf spot incidence on the 12 cowpea varieties in Yola and Mubi locations are presented in Figures 3 and 4 respectively. The results revealed highly significant difference ($P \leq 0.01$) among the treatments for disease incidence at 6 WAS at Yola, but no significant difference ($P \geq 0.05$) was observed for disease incidence at 7, 8 and 9 WAS. At 6 WAS in Yola, SAMPEA-4 and SAMPEA-9 recorded the highest disease incidence of 46.67% each, while SAMPEA-12 had no visible symptom of the disease (Figure 3).

At Mubi however, no visible disease incidence was observed at 6 WAS, but at 7, 8 and 9 WAS, significant differences ($P \leq 0.05$) were observed among the 12 varieties. At 8 WAS, the highest disease incidence of 80% was recorded from SAMPEA 12 while SAMPEA-1 had the lowest incidence of 26.67%. At 9 WAS, SAMPEA-10 and SAMPEA-12 had the highest disease incidence of 100.00% each while the lowest incidence was observed on SAMPEA-1 which had 66.67% (Figure 4).

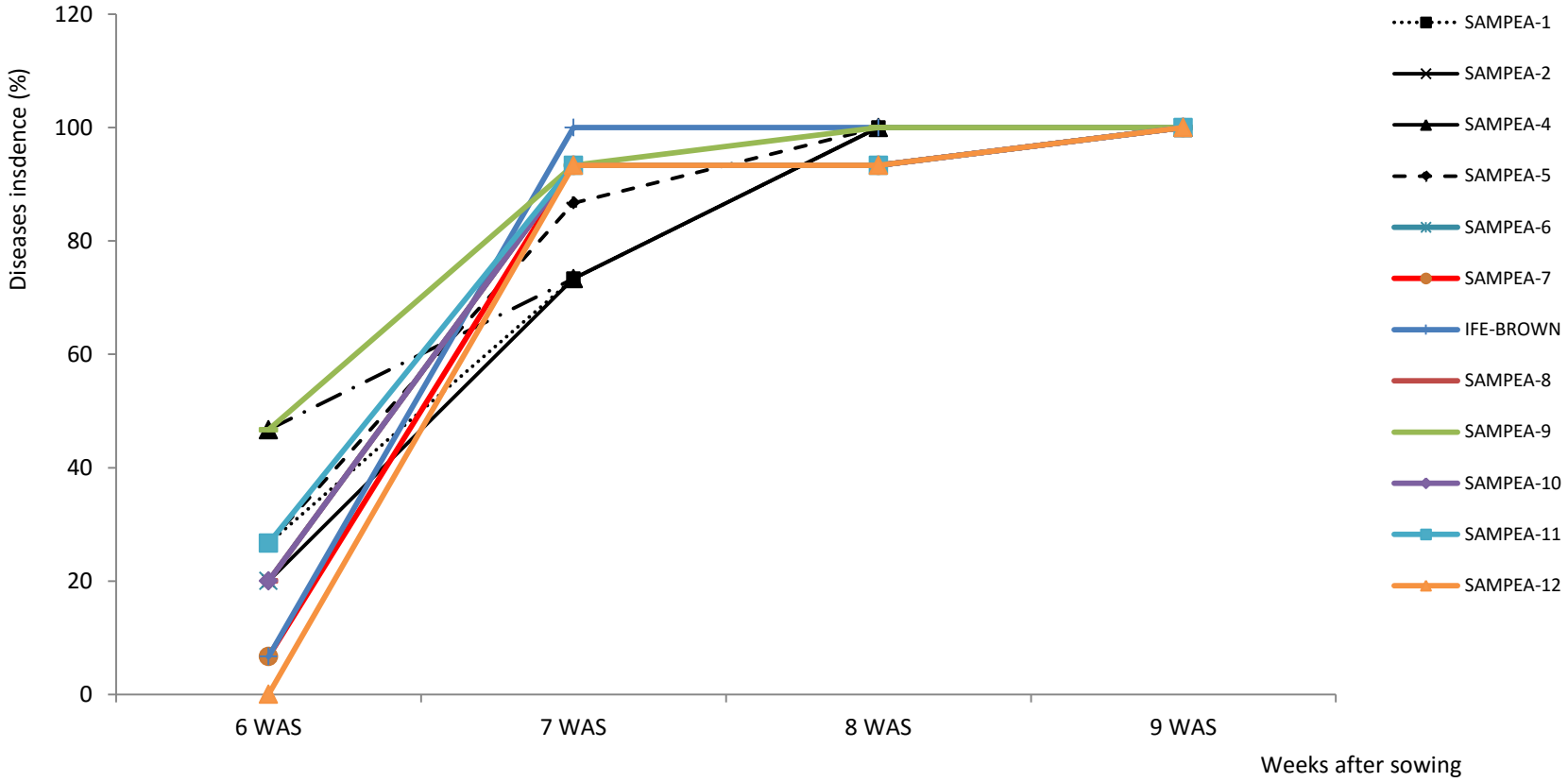

Figure 3: Means of treatments for incidence (%) of Cercospora leaf spot of cowpea in Yola location

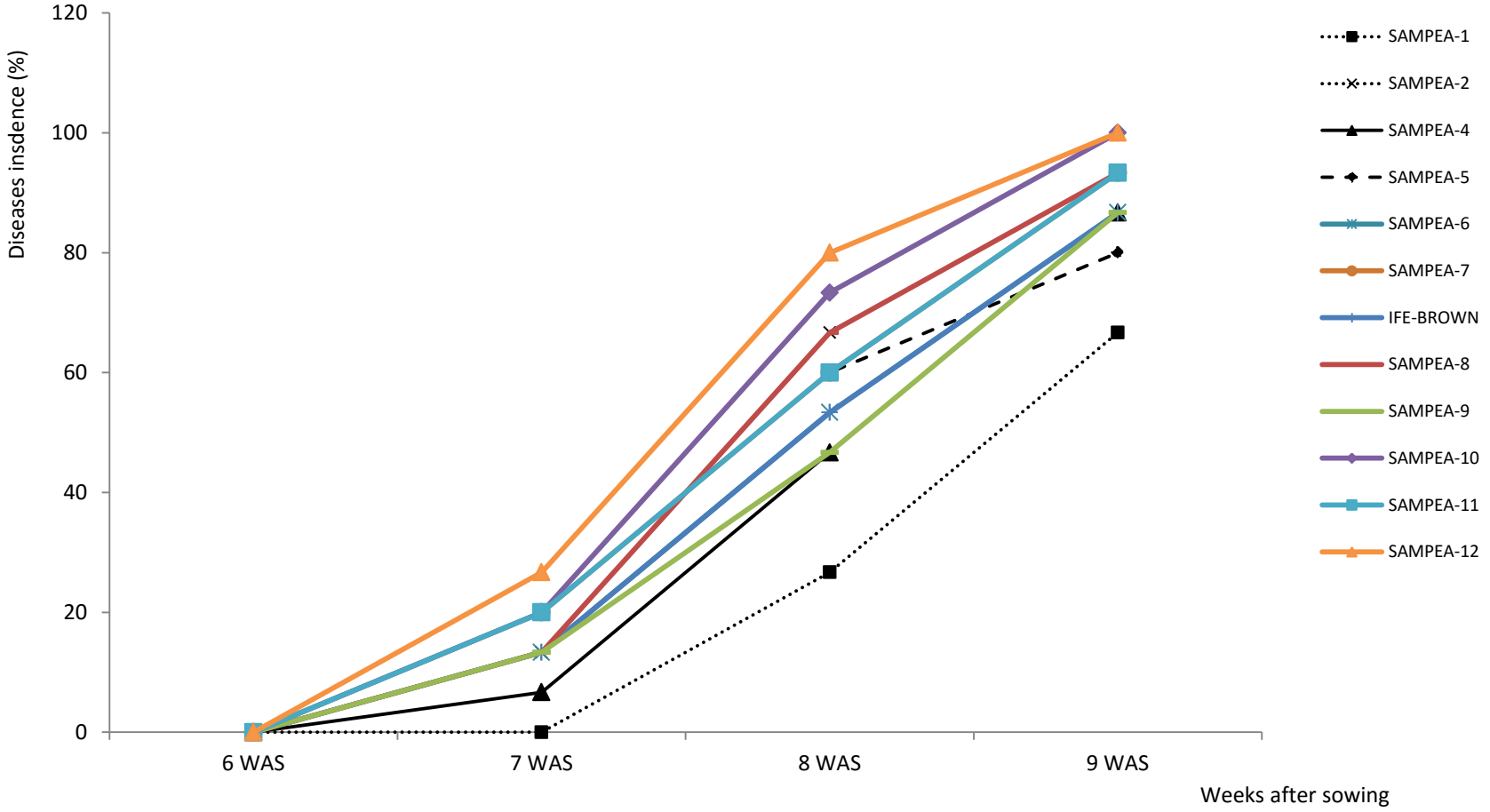

Figure 4: Means of treatments for incidence (%) of Cercospora leaf spot of cowpea in Mubi location

4.3 Combined Means of Treatments for Cercospora Leaf Spot Incidence (%) on 12 Cowpea Varieties at 6 to 9 WAS for Yola and Mubi in 2011

The combined means of treatments for cercospora leaf spot incidence (%) at 7 and 8 WAS is presented in Table 5. Since there was no visible symptom of cercospora leaf spot at Mubi location at 6 WAS, the combined result was not computed. However, the results raveled a highly significant difference ($P \leq 0.01$) on the disease incidence (%) at 7 WAS, where IFE-BROWN recorded the least incidence of 10%, while the highest was recorded on SAMPEA-9 (30%). Although there were variations among the varieties at 8 and 9 WAS, results did not reveal any significant difference ($P \geq 0.05$) in this regard.

4.4 Combined Means of Location for Cercospora Leaf Spot Incidence (%) on 12 Cowpea Varieties at Yola and Mubi in 2011

The combined means of location for cercospora leaf spot incidence (%) on the 12 cowpea varieties is presented in Table 6. The result revealed that there was a difference ($P = 0.05$) between the two locations with respect to disease incidence at 7, 8 and 9 WAS. Location I (Yola) had the highest incidence for both weeks (22.22%, 73.89% and 96.67% respectively) while location II (Mubi) had the least disease incidence for the both weeks as well (15%, 57.78% and 88.89% respectively).

Table 5: Combined means of treatments for Cercospora leaf spot incidence (%) on 12 cowpea varieties at 7 and 8 WAS at Yola and Mubi in 2011

Treatments	6 WAS*	7 WAS	8 WAS	9 WAS
SAMPEA-1	-	13.33^{bc}	50.00^{a}	83.33^{a}
SAMPEA-2	-	16.67^{abc}	70.00^{a}	96.67^{a}
SAMPEA-4	-	26.67^{ab}	60.00^{a}	93.33^{a}
SAMPEA-5	-	23.33^{abc}	73.33^{a}	90.00^{a}
SAMPEA-6	-	16.67^{abc}	66.67^{a}	90.00^{a}
SAMPEA-7	-	13.33^{bc}	63.33^{a}	93.33^{a}
IFE-BROWN		10.00^{c}	60.00^{a}	93.33^{a}
SAMPEA-8	-	16.67^{abc}	73.33^{a}	93.33^{a}
SAMPEA-9	-	30.00^{a}	70.00^{a}	93.33^{a}
SAMPEA-10	-	20.00^{abc}	70.00^{a}	96.67^{a}
SAMPEA-11	-	23.33^{abc}	70.00$_{a}$	93.33^{a}
SAMPEA-12	-	13.33^{bc}	63.33^{a}	96.67^{a}
Mean	-	18.61	65.83	92.78
SE	-	8.10	19.73	10.76

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

* = There was no visible symptom of the disease in Mubi at 6 WAS for combined analysis

Table 6: Combined means of location for Cercospora leaf spot incidence (%) on 12 cowpea varieties in Yola and Mubi in 2011

Source of Variation	6 WAS*	7 WAS	8 WAS	9 WAS
Location I (Yola)	-	22.22[a]	73.89[a]	96.67[a]
Location II (Mubi)	-	15.00[b]	57.78[b]	88.89[b]
Mean	-	18.61	65.83	92.78
Error	-	8.10	19.73	10.76

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

* = There was no visible symptom of the disease in Mubi at 6 WAS for combined analysis

4.5 Means of Treatments for Cercospora Leaf Spot Severity (%) on 12 Cowpea Varieties at 6 to 12 WAS at Yola and Mubi in 2011

The means of treatments for disease severity recorded from 6 to 12 WAS at Yola is presented in Table 7. Throughout the period of observation, highly significant differences ($P \leq 0.01$) were observed among the treatments i.e. from 6 to 12 WAS. At 6 WAS, the highest disease severity was recorded from SAMPEA-4 (33.30%) and SAMPEA-9 (33.30%). The least severity was recorded from SAMPEA 12 (0.00%) which had no visible incidence of the disease. At 7, 8, 9 and 10 WAS, SAMPEA-9 recorded the highest disease severity of 40.00%, 42.23%, 46.70% and 53.37% respectively. SAMPEA-12 still recorded the least severity at 7, 8, 9 and 10 WAS with 23.30%, 24.43%, 31.10% and 38.87%, respectively. At 11 and 12 WAS, SAMPEA-2 had the highest disease severity of 82.23% and 83.37% respectively, while SAMPEA-7 recorded the least disease severity of 46.63% and 48.90% respectively.

The means of treatments for disease severity recorded from 6 to 12 WAS at Mubi presented in Table 8 revealed that no disease severity was recorded at 6 WAS since no incidence was observed that week. However, at 9 WAS a highly significant difference ($P \leq 0.001$) was observed among the treatments, while at 11 WAS, a significant difference ($P \leq 0.05$) was observed. At 12 WAS, a highly significant difference ($P \leq 0.01$) was observed on the disease severity of the 12 cowpea varieties.

The highest disease severity of 44.47 % was recorded from SAMPEA-7 and IFE-BROWN each at 9 WAS, while the least was recorded from SAMPEA-1 which recorded a severity of 25.57%. At 11 and 12 WAS, IFE-BROWN recorded the highest disease severity of 55.57 % and 76.67 % respectively. The least disease severity at 11 WAS were recorded from SAMPEA-1, SAMPEA-4 and SAMPEA-6 which all had a mean severity score of 44.43 % each, but at 12 WAS, SAMPEA-7 had the least disease severity (48.90).

Table 7: Means of treatments for cercospora leaf spot severity (%) on 12 cowpea varieties at 6 to 12 WAS at Yola in 2011

	Disease severity (%) at the following WAS						
Varieties	6	7	8	9	10	11	12
SAMPEA-1	24.43^{a}	33.30^{ab}	37.77^{ab}	41.10^{ab}	44.43^{bc}	57.80^{bcde}	60.00^{bc}
SAMPEA-2	26.67^{a}	33.33^{ab}	36.63^{ab}	44.43^{ab}	45.57^{bc}	82.23^{a}	83.37^{a}
SAMPEA-4	33.30^{a}	35.53^{ab}	40.00^{ab}	42.20^{ab}	45.57^{bc}	50.00^{de}	51.13^{c}
SAMPEA-5	25.53^{a}	31.10^{ab}	33.30^{abc}	38.87^{b}	42.23^{c}	57.80^{bcde}	57.80^{bc}
SAMPEA-6	23.33^{a}	34.43^{ab}	37.77^{ab}	41.10^{ab}	45.57^{bc}	62.20^{bcd}	63.30^{b}
SAMPEA-7	6.67^{b}	29.97^{ab}	33.30^{abc}	37.80^{b}	43.30^{bc}	46.63^{e}	48.90^{c}
IFE-BROWN	6.67^{b}	24.43^{ab}	31.10^{bc}	37.80^{b}	41.10^{c}	58.90^{bcde}	60.00^{bc}
SAMPEA-8	22.20^{a}	37.77^{ab}	38.37^{ab}	41.13^{ab}	44.43^{bc}	49.97^{de}	51.10^{c}
SAMPEA-9	33.30^{a}	40.00^{a}	42.23^{a}	46.70^{a}	53.37^{a}	65.53^{bc}	77.80^{a}
SAMPEA-10	21.10^{a}	27.77^{ab}	33.30^{abc}	41.10^{ab}	43.33^{bc}	63.30^{bcd}	64.43^{b}
SAMPEA-11	27.77^{a}	37.77^{ab}	38.87^{ab}	43.33^{ab}	50.03^{ab}	68.90^{b}	76.70^{a}
SAMPEA-12	0.00^{b}	23.30^{b}	24.43^{c}	31.10^{c}	38.87^{c}	53.33^{cde}	55.53^{bc}
Mean	20.91	32.39	35.63	40.56	44.82	59.72	62.51
SE	6.14	5.43	3.67	2.57	2.78	5.29	4.26

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

Table 8: Means of treatments for cercospora leaf spot severity (%) on 12 cowpea varieties at 6-12 WAS at Mubi in 2011

	Disease severity (%) at the following WAS						
Varieties	6*	7	8	9	10	11	12
SAMPEA-1	-	0.00[a]	22.20[a]	25.57[c]	38.87[a]	44.43[b]	64.43[ab]
SAMPEA-2	-	15.53[a]	23.30[a]	28.90[bc]	39.97[a]	45.57[b]	62.20[ab]
SAMPEA-4	-	7.77[a]	31.10[a]	34.43[abc]	41.10[a]	44.43[b]	62.23[ab]
SAMPEA-5	-	30.00[a]	33.30[a]	38.90[abc]	44.43[a]	45.57[b]	65.53[ab]
SAMPEA-6	-	22.23[a]	34.43[a]	40.00[abc]	43.33[a]	44.43[b]	67.77[ab]
SAMPEA-7	-	23.30[a]	30.03[a]	44.47[a]	45.57[a]	46.70[b]	48.90[b]
IFE-BROWN	-	17.77[a]	27.77[a]	44.47[a]	47.77[a]	55.57[a]	76.67[a]
SAMPEA-8	-	17.77[a]	29.97[a]	34.43[abc]	47.80[a]	45.57[b]	55.57[b]
SAMPEA-9	-	22.23[a]	33.30[a]	37.00[abc]	41.13[a]	48.90[b]	53.33[b]
SAMPEA-10	-	26.67[a]	29.97[a]	39.20[abc]	48.90[a]	51.10[ab]	54.43[b]
SAMPEA-11	-	25.53[a]	31.10[a]	41.10[ab]	45.57[a]	47.77[b]	63.33[ab]
SAMPEA-12	-	24.43[a]	28.90[a]	36.63[abc]	42.20[a]	45.57[b]	66.67[ab]
Mean	-	19.44	29.62	37.09	43.89	47.13	61.76
SE	-	10.50	5.12	5.29	4.27	3.47	7.49

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.
* = No visible symptom was observed

4.6 Combined means of treatments for Cercospora Leaf Spot Severity (%) on 12 Cowpea Varieties at 7-12 WAS at Yola and Mubi in 2011

Table 9 shows the combined means of treatments for disease severity (%) at 7 to 12 WAS for the two locations. From the results, no significant difference ($P \geq 0.05$) was observed for disease severity at 7 WAS, except at 10 WAS in which significant difference ($P \leq 0.05$) was observed while highly significant differences ($P \leq 0.01$) were recorded at 8, 9, 11 and 12 WAS.

At 8 WAS, SAMPEA-9 had the highest disease severity of 37.77%, while SAMPEA-12 recorded the least disease severity of 26.67%. At 9 and 10 WAS, SAMPEA-11 recorded the highest severity of 42.22% and 47.80%, while SAMPEA-1 had the lowest disease severity of 33.33% and 41.65% respectively. The highest disease severity was recorded on SAMPEA-2 at 11 and 12 WAS with mean score of 63.90% and 72.78%, while SAMPEA-7 had the lowest disease severity of 46.67% and 48.90% respectively.

4.7 Combined Means of Location for Cercospora Leaf Spot Severity (%) on 12 Cowpea Varieties at Yola and Mubi in 2011

The combined means of location for disease severity (%) on the 12 treatments presented in Table 10 revealed that there were significant differences ($P \leq 0.05$) between the locations on disease severity (%) at 7, 8, 9, and 11 WAS.

In all the observations at 7, 8, 9 and 11 WAS, Yola location recorded the highest disease severity with 23.37%, 35.63%, 40.56% and 59.72% respectively, while Mubi location had the lowest disease severity of 19.44%, 29.61%, 37.09% and 47.13% respectively.

Table 9: Combined means of treatments for cercospora leaf spot severity (%) on 12 cowpea varieties at 7-12 WAS at Yola and Mubi in 2011

	Disease severity (%) at the following WAS					
Varieties	7	8	9	10	11	12
SAMPEA-1	16.65[a]	29.98[ab]	33.33[c]	41.65[bc]	44.43[b]	64.43[ab]
SAMPEA-2	24.43[a]	29.97[ab]	37.[63abc]	42.77[abc]	45.57[b]	62.20[ab]
SAMPEA-4	21.65[a]	35.55[a]	38.32[abc]	43.33[abc]	44.43[b]	62.23[ab]
SAMPEA-5	30.55[a]	33.30[ab]	38.88[abc]	43.33[abc]	45.57[b]	65.53[ab]
SAMPEA-6	28.33[a]	36.10[a]	40.55[abc]	44.45[abc]	44.43[b]	67.77[ab]
SAMPEA-7	26.63[a]	31.67[ab]	41.13[abc]	43.33[abc]	46.70[b]	48.90[b]
IFE-BROWN	21.10[a]	29.43[ab]	41.13[abc]	44.43[abc]	55.57[a]	76.67[a]
SAMPEA-8	27.77[a]	34.43[ab]	37.78[abc]	46.12[ab]	45.57[b]	55.57[b]
SAMPEA-9	31.12[a]	37.77[a]	41.85[ab]	47.25[ab]	48.90[b]	53.33[b]
SAMPEA-10	27.22[a]	31.63[ab]	40.15[abc]	46.12[ab]	51.10[ab]	54.43[b]
SAMPEA-11	31.65[a]	34.98[a]	42.22[a]	47.80[a]	47.77[b]	63.33[ab]
SAMPEA-12	23.87[a]	26.67[b]	33.87[bc]	40.53[c]	45.57[b]	66.67[ab]
Mean	25.91	32.62	38.82	44.35	47.13	61.76
SE	8.79	4.17	4.17	4.17	3.47	7.49

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

Table 10: Combined means of location for cercospora leaf spot severity (%) on 12 cowpea varieties at 7-12 WAS at Yola and Mubi in 2011

Source of Variation	7 WAS	8 WAS	9 WAS	10 WAS	11 WAS	12 WAS
Location I (Yola)	32.39[a]	35.63[a]	40.56[a]	44.82[a]	59.72[a]	62.51[a]
Location II (Mubi)	19.44[b]	29.61[b]	37.09[b]	43.87[a]	47.13[b]	61.76[a]
Mean	25.91	32.62	38.82	44.35	53.43	62.13
Error	8.79	4.17	4.17	4.17	4.38	5.99

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

4.8 Means of treatments for Number of Pods per Plant, Number of Seeds per Pod, 100 Seed Weight (g) and Yield (kgha^{-1}) of the 12 Cowpea Varieties in Yola and Mubi in 2011

The means of treatments for number of pods per plant, number of seeds per pod, 100 seed weight (g) and yield (kgha^{-1}) of twelve cowpea varieties in Yola and Mubi are shown in Table 11. There were no significant difference ($p \geq 0.05$) observed in number of pods per plant and number of seeds per pod and yield per hectare (kgha^{-1}), but highly significant differences ($P \leq 0.01$) was observed on 100 seed weight of the varieties. The highest 100 seed weight was recorded on SAMPEA-6 which had 16.89g followed by SAMPEA-12 and SAMPEA-11 with 16.70g and 16.33g respectively. The least weight was recorded from IFE-BROWN variety.

The means of treatment for number of Pods per Plant, Number of Seeds per Pot, 100 Seed Weight (g) and Yield (kgha^{-1}) of the Twelve Cowpea Varieties in Mubi revealed no significant difference ($p \geq 0.05$) on the number of pods per plant and yield per hectare (kgha^{-1}), but highly significant difference ($P \leq 0.01$) were observed in number of seeds per pod and 100 seed weight. The highest number of seeds per pod was recorded from SAMPEA-6 (15) followed by SAMPEA-11 (14), while the least number of seeds per pod was recorded from SAMPEA-2 with an average of 12 seeds. For 100 seed weight, SAMPEA-12 had the highest weight of 17.45 g followed by SAMPEA-11 (16.70 g), while the least weight was recorded from IFE-BROWN (12.68 g).

Table 11: Means of treatments for Number of pods per plant, Number of seeds per pod, 100 seed weight (g) and Yield per hectare ($kgha^{-1}$) of the 12 cowpea varieties at Yola and Mubi in 2011

	Yola				Mubi			
Varieties	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Yield ($kgha^{-1}$)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Yield ($kgha^{-1}$)
SAMPEA-1	30.00^{a}	14.00^{a}	15.99^{a}	2060.60^{a}	48.00^{a}	13.00^{b}	16.17^{abc}	4084.10^{a}
SAMPEA-2	38.00^{a}	13.00^{a}	14.03^{ab}	1556.00^{a}	33.00^{a}	12.00^{b}	13.94^{e}	1694.90^{a}
SAMPEA-4	11.00^{a}	13.00^{a}	16.13^{a}	1305.00^{a}	44.00^{a}	13.00^{b}	15.54^{bcde}	3288.70^{a}
SAMPEA-5	13.00^{a}	13.00^{a}	15.34^{ab}	1055.00^{a}	44.00^{a}	13.00^{b}	15.73^{bcd}	2703.20^{a}
SAMPEA-6	27.00^{a}	14.00^{a}	16.89^{a}	1999.90^{a}	35.00^{a}	15.00^{a}	15.40^{bcde}	1926.90^{a}
SAMPEA-7	14.00^{a}	13.00^{a}	15.26^{ab}	1777.10^{a}	27.00^{a}	13.00^{b}	14.70^{cde}	3194.90^{a}
IFE-BROWN	14.00^{a}	12.00^{a}	13.08^{b}	853.7^{a}	34.00^{a}	13.00^{ab}	12.68^{f}	2192.40^{a}
SAMPEA-8	21.00^{a}	12.00^{a}	15.34^{ab}	1849.1^{a}	47.00^{a}	13.00^{ab}	14.17^{de}	1794.10^{a}
SAMPEA-9	20.00^{a}	13.00^{a}	15.88^{a}	719.60^{a}	40.00^{a}	14.00^{ab}	16.37^{abc}	2895.80^{a}
SAMPEA-10	12.00^{a}	13.00^{a}	14.88^{ab}	1022.90^{a}	41.00^{a}	13.00^{b}	15.46^{bcde}	2608.70^{a}
SAMPEA-11	28.00^{a}	13.00^{a}	16.33^{a}	1336.90^{a}	91.00^{a}	14.0^{ab}	16.70^{ab}	4104.10^{a}
SAMPEA-12	20.00^{a}	13.00^{a}	16.70^{a}	1556.00^{a}	32.00^{a}	13.00^{ab}	17.45^{a}	2280.80^{a}
Mean	21.00	13.00	15.49	1378.03	43.00	13.00	15.35	2730.72
S.E	12.03	1.18	1.01	652.65	25.50	0.85	0.66	1087.52

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

4.9 Combined Means of Treatments for Number of Pods per Plant, Number of Seeds per pod, 100 Seeds Weight and Yield (kgha^{-1}) of the 12 cowpea varieties at Yola and Mubi in 2011

The Combined Means of Treatments for Number of Pods per Plant, Number of Seeds per pod, 100 Seeds Weight (g) and Yield (kgha^{-1}) are presented in Table 12. From the results, it was observed that there was no significant difference ($P \geq 0.05$) among the 12 cowpea varieties on number of pods of per plant and yield per hectare (kgha^{-1}). However, significant difference ($P \leq 0.05$) was observed among the varieties on number of seeds per pod with SAMPEA-6 recording the highest number of seed per pod of 15 seeds, while the least was recorded from SAMPEA-2 with a mean of 12.33 seeds per pod. Highly significant difference ($P \leq 0.01$) was observed among the treatments on 100 seed weight (g). SAMPEA-12 had the highest seed weight of 17.07g followed by SAMPEA-11 (16.51 g). The least weight was recorded from IFE-BROWN which had 100 seed weight of 12.88 g while SAMPEA-2 had 13.98 g.

Table 12: Combined means of treatment for Number of pods per plant, Number of seeds per pod, 100 seed weight and Yield ($kgha^{-1}$) for the 12 cowpea varieties at Yola and Mubi in 2011

Varieties	Number of pods per plant	Number of seeds per pod	100 seeds weight	Yield per hectare ($kgha^{-1}$)
SAMPEA-1	40.00[a]	13.00[ab]	16.08[abc]	3072.40[a]
SAMPEA-2	35.00[a]	12.00[b]	13.98[d]	1348.10[a]
SAMPEA-4	27.00[a]	13.00[b]	15.83[abc]	2296.90[a]
SAMPEA-5	29.00[a]	13.00[ab]	15.54[bc]	1879.10[a]
SAMPEA-6	31.00[a]	15.00[a]	16.15[abc]	1963.00[a]
SAMPEA-7	21.00[a]	13.00[ab]	14.98[bcd]	2486.00[a]
IFE-BROWN	24.00[a]	13.00[ab]	12.88[e]	1523.10[a]
SAMPEA-8	34.00[a]	12.00[b]	14.76[cd]	1821.60[a]
SAMPEA-9	28.00[a]	13.00[ab]	16.13[abc]	1807.70[a]
SAMPEA-10	27.00[a]	13.00[ab]	15.17[bcd]	1815.80[a]
SAMPEA-11	60.00[a]	13.00[ab]	16.51[ab]	2720.50[a]
SAMPEA-12	26.00[a]	13.00[ab]	17.07[a]	1918.40[a]
Mean	32.00	13.00	15.42	2054.38
M.S.E	19.56	1.07	0.84	933.14

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

4.10 Combined means of Locations for Number of Pods per Plant, Number of Seeds per Pod, 100 Seed Weight (g) and Yield ($kgha^{-1}$) of the 12 Cowpea Varieties at Yola and Mubi in 2011

The means of locations for number of pods per plant, number of seeds per pod, 100 seed weight (g) and yield ($kgha^{-1}$) of the 12 cowpea varieties are as presented above in Table 13. Significant differences ($P \leq 0.05$) were observed on number of pods per plant and yield ($kgha^{-1}$) of the varieties. The highest number of pods per plant of 43 was recorded at Mubi location, while the least was recorded at Yola location with 21 pods per plant. The yield obtained from the two locations also showed a difference where Mubi location had the highest average yield of 2,730.70 $kgha^{-1}$, while Yola recorded an average yield of 1,378.00 $kgha^{-1}$.

Table 13: Combined means of locations for Number of pods per plant, Number of seeds per pod, 100 seed weight and Yield ($kgha^{-1}$) of the 12 cowpea varieties at Yola and Mubi in 2011

Locations	Number of pods per plant	Number of seeds per pod	100 seeds weight	Yield per hectare ($kgha^{-1}$)
Location 1 (Yola)	21.00[b]	13.00[a]	15.49[a]	1378.00[b]
Location 2 (Mubi)	43.00[a]	13.00[a]	15.36[a]	2730.70[a]
Mean	32.00	13.00	15.42	2054.38
S.E	19.56	1.07	0.84	933.14

Means with the same letter(s) in the same column are not significantly different at P = 0.05 using SNK Test.

4.11 Disease Assessment of the 12 Cowpea Varieties for Resistance to Cercospora Leaf Spot Disease at Yola and Mubi in 2011

The disease assessment of the 12 cowpea varieties for cercospora leaf spot disease carried out using the data for disease severity at 12 WAS at Yola and Mubi presented in Table 14 revealed that SAMPEA-2, SAMPEA-9 and SAMPEA-11 were highly susceptible to cercospora leaf spot disease in Yola, while the remaining nine (9) were susceptible. At Mubi, four (4) of the varieties (SAMPEA-5, SAMPEA-6, IFE-BROWN and SAMPEA-12) were highly susceptible, while the remaining eight (8) were susceptible. The most susceptible variety in Yola was SAMPEA-2 which had a mean disease severity of 83.37% while the least susceptible was SAMPEA-7 which recorded 48.90%. In Mubi, the most susceptible variety was IFE-BROWN which recorded mean disease severity of 76.67, while the least was SAMPEA-7 with mean severity of 48.90 as in Yola.

Table 14: Disease assessment of the 12 cowpea varieties for resistance to cercospora leaf spot disease at Yola and Mubi in 2011

Treatments	YOLA	Rating	MUBI	Rating
SAMPEA-1	60.00	Susceptible	64.43	Susceptible
SAMPEA-2	83.37	Highly Susceptible	62.20	Susceptible
SAMPEA-4	51.13	Susceptible	62.23	Susceptible
SAMPEA-5	57.80	Susceptible	65.53	Highly Susceptible
SAMPEA-6	63.30	Susceptible	67.77	Highly Susceptible
SAMPEA-7	48.90	Susceptible	48.90	Susceptible
IFE-BROWN	60.00	Susceptible	76.67	Highly Susceptible
SAMPEA-8	51.10	Susceptible	55.57	Susceptible
SAMPEA-9	77.80	Highly Susceptible	53.33	Susceptible
SAMPEA-10	64.43	Susceptible	54.43	Susceptible
SAMPEA-11	76.70	Highly Susceptible	63.33	Susceptible
SAMPEA-12	55.53	Susceptible	66.67	Highly Susceptible

CHAPTER FIVE

DISCUSSIONS

5.1 Effects of Cercospora Leaf Spot Disease on Growth Parameters of Twelve Cowpea Varieties in Yola and Mubi in 2011 Cropping Season

Cercospora leaf spot has been reported to cause a considerable yield loss in cowpea through its effect on the leaves, branches and under severe conditions stems and pods. (Plantwise, 2010). In this study, the effect of cercospora pathogen on the establishment of the twelve cowpea varieties was not recorded in both Yola and Mubi locations, where good plant establishment was obtained. This may be attributed to the fact that cercospora leaf spot only manifest on cowpea plants at about 4 WAS, which coincides with the period of flower initiation of the plants as reported by Arunee *et al.* (1999) and Charles, (2005). The effect of the disease was not significant on the number of primary vines and vine length of the cowpea varieties at Yola, however, at Mubi, there was a variation on both the number of primary vines per plant and the vine length which may be due to the favourable condition for the disease development at that location. The mean temperature at Mubi (Appendix 12) at that period (September) coincided with the most favourable temperature for the pathogen sporulation. This agrees with the findings of Singh (1997), who reported that most mycellial growth takes place at 26^{o}C and most conidial germination at 25^{o}C.

In this study, it was observed that the cowpea varieties had varying days to flowering, particularly SAMPEA-8 which came to flowering earlier than the other varieties (at 41 and 45 DAS at Yola and Mubi respectively). This trend was observed for the two locations combined. This may be attributed to the effect of the cercospora leaf spot on the period of time to 50% flowering of the 12 cowpea varieties and the differential behaviour of cowpea genotypes to varying environments. This was previously reported by Thiyagarajan and Kajasekeran (1983) and Ariyo and Okeleye (1998), but contrary to the findings of Akande (2007) who observed that location by genotype interaction was significant for all parameters including incidence of cercospora leaf spot, except number of days to 50% flowering. The early flowering of SAMPEA-8 under the disease condition further confirmed the report by the National Centre for Genetic Resources and Biotechnology (2009) that SAMPEA-8 is an extra-early maturing variety. The early maturity of cowpea verities have been reported by Ofori and Djagbletey

(1995); Ndon and Ndaeyo (2001) to aid yield especially in drier regions, since the plants have an advantage to escape the effect of drought on their yield.

5.2 Effects of Cercospora Leaf Spot Incidence at 6 – 9 WAS on Twelve Cowpea Varieties in Yola and Mubi in 2011 Cropping Season

In this study, it was observed that the twelve cowpea varieties reacted differently and at different levels with respect to the incidence of cercospora leaf spot at the first week of observation (6 WAS) in Yola, though there was no further variation on the percentage incidence of the disease on the varieties in the subsequent weeks. This may be due to the inherent differences in the ability of the varieties to react to the disease at the initial stage, where some of the varieties did not show visible symptom at 6 WAS. However, all the varieties responded to the disease within 3 weeks of inoculation with the pathogen. This agrees with the findings of Arunee *et al.* (1999) that cercospora leaf spot infection occurs rapidly under favourable conditions coupled with sufficient inoculum.

The absence of a visible symptom of the disease in Mubi at 6 WAS indicated that though the disease was present, there was no visible symptom on the leaves; this may be due to the active vegetative growth and vigor of the plants at that period which was reported to affect the appearance of a visible symptom of the disease. This agrees with Charles (2005) who reported that vigorously growing leaves rarely become infected by the pathogen. However, the reaction of the cowpea varieties to the disease varied at 7, 8 and 9 WAS indicating the difference in reaction of the 12 cowpea varieties in Mubi location, which appeared to have favoured plant growth and development, but unfavorable for the disease development. The weather data of Mubi (Appendix 12) at 6-9 WAS revealed that the relative humidity necessary for cercospora pathogen to optimally cause infection was not available. Low temperature and relative humidity was recorded, which might have reduced the effect of the inoculum on some of the varieties. According to Pandey and Pandey (2002), relative humidity of 81-86% is most favourable for growth of cercospora leaf spot pathogen. The high variation in the incidence (%) of cercospora leaf spot at 7 WAS in the combined result on the varieties and also the locations (Yola and Mubi) might also be due to the difference in first symptom appearance in the two locations.

5.3 Effects of Cercospora Leaf Spot Severity (%) on Twelve Cowpea Varieties in Yola and Mubi in 2011 Cropping Season

The level of leaf spot severity caused by *Cercospora canescens* depends on two major factors: first the infectivity of the pathogen to the leaves; and toxic cercosporin produced by the pathogen (Arunee *et al.*, 1999). Since the two factors directly influence disease severity, the variety should be screened to possess gene resistant to infectivity as well as to toxin cercosporin (Srihattagum *et al.*, 1998). A significant effect of location and variety was observed by Akande (2007) on the severity of cercospora leaf spot disease. In this study, the 12 cowpea varieties reacted at varying levels of severity to cercospora leaf spot when considered from 6 to 12 WAS in Yola, which was an indication that the varieties have different levels of resistance to the disease. This may be due to the inherent genetic makeup of the varieties to resist the disease at different levels (Allerd *et al.*, 1992; Allerd, 1999 and Sinsiri *et al.*, 2006).

In Mubi location however, the differences were observed at 9, 11 and 12 WAS and may also be due to the fact that the varieties had different levels of reaction to the disease under changing environmental conditions. This agrees with (Sinsiri *et al.*, 2006) who reported that some varieties have the ability retard cercospora disease severity under certain environmental conditions. The combined results may however reveal the levels of resistance or susceptibility of the varieties, because SAMPEA-7 and SAMPEA-2 recorded the least and highest severity at 11 and 12 WAS respectively in the combined analysis. This may further help in selection of variety for any of the locations since the genotype by environment interaction studies is of paramount importance in the specific environments in which the genotypes are to be grown (Akande, 2007).

The effect of cercospora leaf spot severity on the 12 cowpea varieties observed in the two locations revealed that the severity of cercospora leaf spot was dependent on the locations and that the reaction of the 12 cowpea varieties to the disease in the two locations (Yola and Mubi) are different. This may be as a result of differences in the environments of the two locations with respect to rainfall, temperature and relative humidity, which provided different conditions for the disease development on the different varieties, since both locations were provided with the same inoculum of the disease. This result agrees with the findings by Sinsiri *et al.* (2006) who screened cowpea cultivars for high resistance for *pseudocercospora cruenta*

in Northeast Thailand and reported that the differences in responding to the disease of the cowpea cultivars may be attributable to the differences in environmental conditions where genotype by environment interactions caused differences in response to the disease.

5.4 Effects of Cercospora Leaf Spot on number of pods per plant, Number of seeds per Pod, 100 seed weight and Yield of Twelve Cowpea Varieties in Yola and Mubi in 2011 Cropping Season

Cercospora leaf spot has been observed to have caused considerable yield loss in cowpeas in Nigeria. In this regard considerable efforts are been made to control the disease under natural conditions. Cercospora leaf spot under severe conditions reduced the number of pods per plant, average number of seeds per pod and 100-seed weight of a susceptible cowpea variety (Williams, 1977; Ferry *et al.*, 1977 Sinsiri *et al.*, 2006 and Plantwise, 2010). In this study, the number pods per plant in both Yola and Mubi and number of seeds per pod in Yola did not show variation. This may be due to the fact that the leaves were not yet affected enough by the cercospora leaf spot to prevent utilization of assimilates for photosynthesis as reported by Awurum and Emechebe (2001). However, the number of seeds per pod in Mubi location varied significantly from 12 seeds per pod in SAMPEA-2 to up to 15 seeds per pod in SAMPEA-6. This agrees with Plantwise (2010) report that cercospora leaf spot has an effect on the number of seeds per pod in cowpea. It was also observed that the number of pods per plant was dependent on location, where Yola location had an average of 21 pods per plant and Mubi had up to 43 pods per plant. This may be attributed to the high incidence and severity of the disease in Yola than Mubi. This agrees with the previous findings by Akande (2007) who stated that there is a differential behaviour of cowpea genotypes to cercospora leaf spot in varying environments.

The effect of cercospora leaf spot on 100 seed weight of cowpea as earlier reported was observed in both Yola and Mubi, where the seed weight of the 12 cowpea varieties ranged between 13 to 17 g at both locations and also the two locations combined. This may be as a result of the effect of cercospora leaf spot on the performance of the twelve varieties (Plantwise, 2010) coupled with the ability of the varieties to accumulate assimilates under the disease conditions. The seed yield of the cowpea varieties was observed to be higher at Mubi than Yola location, this may be attributed to the effect of the cercospora leaf on the yield of cowpea as reported by Booker and Pathmanathan (2007), that cercospora leaf spot causes

yield loss of up to 42% in cowpea. Furthermore, Plantwise (2010) also reported that Seed yield loss of cowpea was correlated with Cercospora leaf spot disease severity from artificially simulated, chemically regulated and naturally occurring epidemics at Ibadan, Nigeria.

5.5 Assessment of Twelve Cowpea Varieties for Resistance to Cercospora Leaf Spot Disease in Yola and Mubi in 2011 Cropping Season

The development of disease epiphytotics on cowpea depends on several factors relating to the host, the pathogen, the environment and the complex interaction of these factors (Agrios, 1997). According to Trivoli *et al.* (2006) lesion size and development has been used extensively in pathology studies to assess disease severity and in plant breeding to rank germplasm for resistance to various pathogens. In this study, the assessment of the 12 cowpea varieties for resistance in Yola and Mubi revealed that all the varieties were susceptible to cercospora leaf spot disease, with SAMPEA-2, SAMPEA-9 and SAMPEA-11 varieties recording highly susceptible in Yola and SAMPEA-5, SAMPEA-6, IFE-BROWN and SAMPEA-12 were the highly susceptible varieties in Mubi. This result agrees with the report by Akande (2007) who stated that many of the improved cowpea varieties currently grown in Nigeria are highly susceptible to cercospora leaf spot disease. Ajibade and Amusa (2001) also reported that out of 75 cowpea lines evaluated in 1999 and 2000, about 40% of the germplasm were found to be susceptible. However, some of varieties used in this study though susceptible, recorded an appreciable yield. This indicates that the yield of these varieties was less affected by the disease. This finding corresponds with that of Amadi (1994) who observed that yield of cowpea was appreciable over the growing seasons in spite of the various disease levels of cercospora leaf spot. Akande (2007) in a separate experiment reported that although a cowpea variety IT84S-2246 was found to be susceptible to cercospora leaf spot and brown blotch, it was still highly productive; and concluded that the seed yield potential of this variety reduced the effects of the diseases on the yield.

From the results of this study, SAMPEA-2 variety was found to be the most susceptible to cercospora leaf spot in Yola with severity of (83.37%) followed by SAMPEA-9 (77.80%), while IFE-BROWN was most susceptible in Mubi (76.67%) followed by SAMPEA-12 with 66.67% severity at 12 WAS. The IFE-BROWN variety was severally reported to be susceptible to cercospora leaf spot disease by many researchers. Ajibade and Amusa (2001) reported that IFE-BROWN which is widely adopted and cultivated cowpea

cultivar in the South-Western Nigeria had 80% cercospora incidence on the field. Akande (2007) in his research also reported that IFE-BROWN was one of the most susceptible varieties to cercospora leaf spot disease at Ibadan among the varieties used. The least susceptible variety in both Yola and Mubi was SAMPEA-7 which recorded 48.90% cercospora leaf spot severity at 12 WAS in both locations. It was followed by SAMPEA-8 and SAMPEA-4 at Yola with severity of 51.10% and 51.13% respectively, and SAMPEA-9 and SAMPEA-10 in Mubi with 53.33% and 54.43% cercospora leaf spot severity. This high severity of the disease observed at Yola might have been responsible for the lower yield in that location. This is in line with the findings of Akande (2007) who observed that the negative correlation between cowpea seed yield and incidence and severity of cercospora leaf spot was partly responsible for the low seed of the cowpea varieties in one of the locations.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This experiment was carried out in Yola and Mubi to screen 12 cowpea varieties for cercospora leaf spot disease during the 2011 cropping season with the objectives of identifying the most resistant cowpea variety or varieties to the Cercospora leaf spot disease, to estimate the level of resistance of each of the cowpea varieties, and to estimate the yield of these varieties under the disease condition in the study areas. The 12 cowpea varieties used in the study were SAMPEA-1, SAMPEA-2, SAMPEA-4, SAMPEA-5, SAMPEA-6, IFE-BROWN, SAMPEA-7, SAMPEA-8, SAMPEA-9, SAMPEA-10, SAMPEA-11 and SAMPEA-12. The experiment was carried out in a Randomized Complete Block Design, replicated three times. The data collected in the experiment were analyzed using the Generalized Linear Model (GLM) procedure of SAS (Statistical Analysis System) and the means were separated using Student-Newman-Kuels-Test.

Symptoms of cercospora leaf spot disease were observed on the primary vines which in turn affected the number of primary vines and vine length at Mubi, where SAMPEA-1 had the highest (5) number of vines and the lowest (3) in SAMPEA-2. SAMPEA-8 had the longest vine (188.60cm). SAMPEA-8 was observed to come to flowering much earlier than the other varieties in both locations and also in the combined result. The incidence (%) of cercospora leaf spot was observed in both locations at varying levels with all the varieties (100%) having the incidence at 9 WAS at Yola, while SAMPEA-2, SAMPEA-10 and SAMPEA-12 had the highest incidence at 9 WAS in Mubi and in the two location combined. The least incidence was recorded on SAMPEA-1 (66.67%) at 9 WAS in Mubi. The severity (%) of the disease was also observed to be more severe in Yola than Mubi, where a warm weather coupled with high relative humidity which is favourable for the disease development was recorded. At the peak of the disease severity (12 WAS), SAMPEA-2 had the highest severity at Yola (83.37%), while IFE-BROWN had the highest severity at Mubi, and the least severity (48.90%) was observed on SAMPEA-7 in both locations and in the two locations combined. SAMPEA-6 variety had the highest number of seeds per pod in Mubi, while the 100 seed weight varies between 13 g to 16 g in both Yola and Mubi and in the two locations combined. The yield of the 12 cowpea varieties though not statistically different in both

location and in the two locations combined, varied with location. Mubi location recoded the higher average yield of 2,730 kgha^{-1} than Yola location which had 1,378.00 kgha^{-1}. The highest yield in Yola was recorded from SAMPEA-1 (2,060.60 kgha^{-1}) and SAMPEA-6 (1999.90 kgha^{-1}), while SAMPEA-1 and SAMPEA-11 were the highest in Mubi with 4,104.10 and 4,101.80 kgha^{-1} respectively.

From this study, it was observed that all the 12 varieties were susceptible to cercospora leaf spot disease with SAMPEA-2, SAMPEA-9 and SAMPEA-11 having the highest susceptibility level to the disease in Yola; while SAMPEA-5, SAMPEA-6, IFE-BROWN and SAMPEA-12 were the highly susceptible at Mubi. The least susceptible was SAMPEA-7 which had severity of 48.90% at 12 WAS in both locations, followed by SAMPEA-8 (51.10) and SAMPEA-4 (51-13%) in Yola and; SAMPEA-9 (53.33%) and SAMPEA-10 (54.43%) in Mubi. The yield of some of these varieties however, though susceptible was appreciable in both locations, among which are SAMPEA-1, SAMPEA-4, SAMPEA-7 and SAMPEA-11.

6.2 Conclusion

From the results obtained in this study, it can be concluded that all the varieties were susceptible to cercospora leaf spot disease, with SAMPEA-2, SAMPEA-9 and SAMPEA-11 varieties recorded with high level of susceptibility in Yola, while SAMPEA-5, SAMPEA-6, IFE-BROWN and SAMPEA-12 varieties were the highly susceptible in Mubi. SAMPEA-2 was the most susceptible variety to cercospora leaf spot disease in Yola, while IFE-BROWN was the most susceptible in Mubi. The least susceptible in both Yola and Mubi and even in the two locations combined was found to be SAMPEA-7, and therefore may regarded as tolerant to cercospora leaf spot in the two locations. With respect to yield potential under the disease conditions however, SAMPEA-1 was found to have the highest yield (kgha^{-1}) in both Yola and Mubi, while the least yield was recorded from SAMPEA-9 in Yola due to its high susceptibility to the disease and SAMPEA-2 in Mubi.

It was also observed that all the varieties that showed higher severity level to the disease (except SAMPEA-9 in Yola) had appreciable yield relative to the average obtainable yield per hectare. While varieties such as IFE-BROWN in Yola that seemed to have lesser severity to the disease had lesser yield. In Mubi however, this variety was highly susceptible to the disease, but had an appreciable yield (kg ha^{-1}) that was close to the average obtainable yield per hectare.

6.3 Recommendations

Based on the findings from this study, the following suggestions are made:

- The performance of the cowpea varieties which were found to be high yielding under the disease conditions in this study should be investigated further in many locations with a view to ascertain their level of susceptibility or otherwise to cercospora leaf spot.
- In view of the absence of a resistant variety in this study, it is hereby recommended that more lines should be included and tested in these locations with a view to getting resistant varieties.
- Those varieties that were able to produce appreciable yield under the disease pressure should further be tested in other locations so as to recommend them to farmers.

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APPENDICES

Appendix 1: Mean squares from the analysis of variance for Establishment count, Number of primary vines per plant at 4 and 8 WAS, Vine length at 4 and 8 WAS, and Days to 50% flowering for the 12 varieties of cowpea in Yola.

Source of variation	df	Establishment count	Number of primary vines at 8 WAS	Vine length at 8 WAS	Days to 50% flowering
Replication	2	91.20	1.27	162.96	2.90
Treatment	11	17.01^{ns}	0.18^{ns}	2108.13^{ns}	302.78^{**}
Error	22	15.01	0.30	1060.95	0.17
Total	35				

** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 2: Mean squares from the analysis of variance for Number of pods per plant, Number of seeds per pod, 100 seed weight and yield per hectare for the 12 cowpea varieties at Yola.

Source of Variation	df	Number of pods per plant	Number of seeds per pod	100 seeds weight (g)	Yield (Kg ha^{-1})
Replication	2	260.83	2.22	0.43	2387742.42
Treatment	11	211.58^{ns}	1.23^{ns}	3.64^{**}	641537.71^{ns}
Error	22	144.82	1.40	1.01	425951.65
Total	35				

** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 3: Mean squares from the analysis of variance for Establishment count, Number of primary vines per plant at 4 and 8 WAS, Vine length at 4 and 8 WAS, and Days to 50% flowering for the 12 varieties of cowpea in Mubi.

Source of variation	df	Establishment count	Number of primary vines at 8 WAS	Vine length at 8 WAS	Days to 50% flowering
Replication	2	26.90	0.11	0.11	8.11
Treatment	11	29.38^{ns}	1.09^{**}	1.09^{**}	76.76^{**}
Error	22	22.47	0.37	0.37	1.60
Total	35				

** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 4: Mean squares from the analysis of variance for Number of pods per plant, Number of seeds per pod, 100 seed weight and yield per hectare for the 12 cowpea varieties in Mubi.

Source of Variation	Df	Number of pods per plant	Number of seeds per pod	100 seeds weight (g)	Yield (Kg ha^{-1})
Replication	2	172.92	2.06	0.35	815350.21
Treatment	11	833.81^{ns}	2.37^{**}	5.19^{**}	2011645.67^{ns}
Error	22	650.20	0.72	0.44	1182695.03
Total	35				

** = Highly significant difference at 0.01 level of probability

ns = Not significant at 0.05 level of probability

Appendix 5: Combined mean squares from the analysis of variance for Establishment count, Number of primary vines per plant at 4 and 8 WAS, Vine length at 4 and 8 WAS, and Weeks to 50% flowering for the 12 varieties of cowpea.

Source of variation	df	Establishment count	Number of primary vines at 8 WAS	Vine length at 8 WAS	Weeks to 50% flowering
Location	1	45.92^{ns}	13.26^{**}	471.76^{ns}	6.31^{**}
Replication	2	19.26^{ns}	0.86^{ns}	2675.42^{ns}	0.11^{ns}
Treatment	11	17.92^{ns}	0.74^{*}	4534.63^{**}	6.43^{**}
Location x Trt.	11	28.47^{ns}	0.53^{ns}	608.72^{ns}	1.31^{**}
Error	46	22.22	0.34	1054.77	0.11
Total	71				

* = Significant difference at 0.05 level of probability
** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 6: Combined mean squares from the analysis of variance for Number of pods per plant, Number of seeds per pod, 100 seed weight and yield per hectare for the 12 cowpea varieties.

Source of Variation	df	Number of pods per plant	Number of seeds per pod	100 seeds weight (g)	Yield (Kg ha^{-1})
Location	1	8841.18^{**}	2.53^{ns}	0.30^{ns}	32935456.36^{**}
Replication	2	153.98^{ns}	3.65^{*}	0.03^{ns}	221113.12^{ns}
Treatment	11	623.14^{ns}	2.16^{*}	8.07^{**}	1492228.34^{ns}
Location x Trt.	11	422.25^{ns}	1.44^{ns}	0.77^{ns}	1160955.04^{ns}
Error	46	392.17	1.04	0.73	899004.0
Total	71				

** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 7: Mean squares from the analysis of variance for cercospora leaf spot incidence (%) on 12 cowpea varieties at 6 to 9 WAS at Yola and Mubi in 2011

Source of Variation	df	YOLA				MUBI			
		6 WAS	7 WAS	8 WAS	9 WAS	6 WAS	7 WAS	8 WAS	9 WAS
Replication	2	211.11	77.78	0.00	0.00	-	300.00	4011.11	1077.78
Treatment	11	614.14^{**}	423.23^{ns}	36.36^{ns}	0.00	-	148.48^{*}	589.90^{ns}	250.51^{ns}
Error	22	65.67	283.84	72.73	0.00	-	57.58	314.14	120.20
Total	35								

* = Significant difference at 0.05 level of probability
** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 8: Mean squares from the analysis of variance for cercospora leaf spot severity at 6 to 12 WAS on 12 cowpea varieties at Yola in 2011

Source of variation	df	6 WAS	7 WAS	8 WAS	9 WAS	10 WAS	11 WAS	12 WAS
Replication	2	16.04	24.37	0.34	19.58	56.50	19.31	115.02
Treatment	11	346.78^{**}	83.55^{**}	69.81^{**}	46.88^{**}	44.37^{**}	287.34^{**}	382.57^{**}
Error	22	37.65	29.46	13.47	6.59	7.75	27.94	18.13
Total	35							

** = Highly significant difference at 0.01 level of probability

Appendix 9: Mean squares from the analysis of variance for cercospora leaf spot severity (%) at 6 to 12 WAS on 12 cowpea varieties at Mubi in 2011

Source of variation	df	6 WAS	7 WAS	8 WAS	9 WAS	10 WAS	11 WAS	12 WAS
Replication	2	-	461.94	22.71	49.04	136.67	19.34	112.01
Treatment	11	-	215.82^{ns}	42.00^{ns}	96.90^{**}	32.87^{ns}	33.34^{*}	173.20^{**}
Error	22	-	110.18	26.20	28.03	18.23	12.03	56.15
Total	35							

* = Significant difference at 0.05 level of probability
** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 10: Combined mean squares from analysis of variance for cercospora leaf spot incidence (%) at 7 and 8 WAS on 12 cowpea varieties at Yola and Mubi in 2011

Source of Variation	df	7 WAS	8 WAS	9 WAS
Location	1	938.89^{**}	4672.22^{**}	1088.89^{**}
Replication	2	355.55^{**}	1716.67^{**}	538.89^{**}
Treatment	11	223.74^{**}	280.30^{ns}	82.83^{ns}
Location x Trt.	11	538.89^{**}	732.83^{ns}	204.04^{ns}
Error	46	65.70	389.13	115.70
Total	71			

** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 11: Combined mean squares from the analysis of variance for cercospora leaf spot severity (%) on 12 cowpea varieties at 7-12 WAS at Yola and Mubi in 2011

Source of Variation	df	7 WAS	8 WAS	9 WAS	10 WAS	11 WAS	12 WAS
Location	1	3021.24**	651.61**	215.97**	15.59^{ns}	2850.13**	10.13^{ns}
Replication	2	245.11*	8.76^{ns}	49.29^{ns}	167.19**	38.01^{ns}	219.43**
Treatment	11	123.56^{ns}	64.33**	52.79**	28.91*	173.10**	288.11**
Location x Trt.	11	175.81*	47.48**	90.89**	48.32**	147.58**	267.66**
Error	46	77.27	19.59	17.40	13.55	19.15	35.86
Total	71						

* = Significant difference at 0.05 level of probability
** = Highly significant difference at 0.01 level of probability
ns = Not significant at 0.05 level of probability

Appendix 12: Weather Data for Yola and Mubi in 2011

Month	YOLA			MUBI		
	Total Rainfall (mm)	Mean Temperature (^{o}C)	Mean Relative Humidity (%)	Total Rainfall (mm)	Mean Temperature (^{o}C)	Mean Relative Humidity (%)
Jan.	0.0	31.3	12.4	0.0	20.4	20.0
Feb.	0.0	32.0	60.7	0.0	16.3	22.5
March	0.0	33.6	56.3	0.0	19.5	25.7
April	2.8	33.7	54.8	7.9	23.4	28.3
May	62.0	31.2	74.3	61.0	27.8	31.5
June	59.7	28.7	72.6	93.9	30.9	42.4
July	61.5	29.5	78.5	140.0	24.8	45.0
Aug.	142.3	26.2	82.4	195.0	21.4	48.4
Sept.	79.8	29.0	83.0	182.3	25.0	46.0
Oct.	28.7	28.8	81.0	83.7	24.4	44.3
Nov.	0.0	28.8	68.5	0.0	20.6	26.8
Dec.	0.0	27.8	52.0	0.0	17.6	18.6

Source: Department of Meteorological Services, Adamawa State University Mubi and Department of Geography Meteorological Station, Modibbo Adama University of Technology Yola.