STUDIES ON POWDERY MILDEW DISEASE ON DIFFERENT ACCESSIONS OF OKRA (*Abelmoschus esculentus* L. Moench) INDUCED BY *Erysiphe cinchorocearum* DC IN YOLA NORTH AND GUYUK LOCAL GOVERNMENT AREAS OF ADAMAWA STATE, NIGERIA

BY

LINUS, Yakubu Nimrod
(M.TECH/PLS/15/O458)

JULY, 2017

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A THESIS PRESENTED TO THE DEPARTMENT OF PLANT SCIENCE, SCHOOL OF LIFE SCIENCES, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY YOLA, ADAMAWA STATE, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF TECHNOLOGY M.TECH DEGREE IN PLANT PATHOLOGY

JULY, 2017

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.

……………………………………… ……………………

LINUS, Yakubu Nimrod Date

M.Tech/PLS/15/0458

DEDICATION

This work is dedicated to God Almighty for guiding me throughout my studies

APPROVAL PAGE

This thesis entitled "Studies on Powdery Mildew Disease on different Accessions of Okra (*Abelmoschus esculentus* L.Moench) induced by *Erysiphe cinchorocearum* DC. in Yola North and Guyuk Local Government Areas of Adamawa State, Nigeria˒˒ meets the regulation governing the award of Master of Technology (M.Tech.) Degree in Plant Pathology, Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation

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ABSTRACT

Okra (*Abelmoschus esculentus* L.Moench) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. It originated in Ethiopia. Powdery mildew affects all growth stages and responsible for yield losses of 17 to 86.6%. Resistant varieties are the only practically feasible solution of management of powdery mildew disease. Study of powdery mildew disease on different accessions of okra induced by (*Erysiphe cinchoracearum* DC.) was conducted in Yola North and in Guyuk Local Government Areas of Adamawa state Nigeria.To determine the incidence and the severity of the disease in the study areas, to evaluate the reaction of the different accessions to powdery mildew pathogen and to evaluate and compare the performance of the accessions under diseased condition in the study area. Field experiment was a randomized completely block design (RCBD) involving ten (10) okra accessions replicated three times. Results on number of fruit per plant revealed that accession 6 recorded the highest number of 23 and 21 fruit per plant in Guyuk and Yola. Accession 7 recorded minimum number of 6 and 3 fruit per plant in Guyuk and Yola. Results on fruit yield showed that accession 5 recorded the highest fruit yield of 1700 $kgha^{-1}$in Guyuk and 2130 $kgha^{-1}$in Yola. In Guyuk, Yola local recorded the lowest yield of 534 $kgha^{-1}$while accession 7 recorded the lowest yield of 168 $kgha^{-1}$ in Yola. Result on disease severity revealed that Clemson spineless recorded the highest severity value of 84.7% in Guyuk at 9WAS while accession 6 recorded the least value of 30.4% at 9WAS.In Yola, the highest severity value recorded is 86.6% in Yola local while Accession 7 and 15 both recorded the lowest value of 45.8% for disease severity at 9WAS.In both locations, accession 3,4,6,7 and 15 are classified as moderately resistant,Yola local as highly susceptible and accession 1,2,5 and Clemson spineless as susceptible. Based on the findings of this study, it was recommended, accession 1, accession 2, accession 5, and Clemson spineless should be further tested to ascertain their level of tolerance to the disease in the study area.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
FAO	Food and Agricultural Organization of the United Nations
Ha	Hectare
HS	Highly susceptible
MR	Moderately resistant
MS	Moderately susceptible
NACGREB	National Center for Genetic Resources and Biotechnology
NIHORT	National Horticultural Research Institute
R	Resistant
RCBD	Randomized Completely Block Design
S	Susceptible
SPSS	Statistical package for service solution
WAS	Weeks after Sowing

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Okra (*Abelmoschus esculentus* L.Moench) is one of the most widely known and utilized species of the family Malvaceae (Naveed *et al.,* 2009). It is an economically important vegetable crop grown in tropical and sub-tropical parts of the world (Oyelade *et al*., 2003; Andras *et al*., 2005; Saifullah and Rabbani, 2009). Okra plant was previously included in the genus Hibiscus. Later, it was designated to Abelmoschus, which is distinguished from the genus Hibiscus (Aladele *et al.* 2008). Okra originated in Ethiopia (Simmone *et al*., 2004; Sathish and Eswar, 2013) and was then propagated in North Africa, in the Mediterranean, in Arabia and India by the 12th century BC (Nzikou *et al.*, 2006). Okra plant grows to a height of 3-6 feet or more with some local varieties reaching 12 feet with a stem base of up to 4 inches in diameter.

Propagation is through seeds and seeds can be soaked overnight in warm water before sowing to improve germination. Seed quality has been reported to affect yield in various okra varieties (Thapa *et al*., 2012). The soil for growing okra should be fertile, well drained and high in organic matter with a pH ranging from 6.0 to 6.5. The fruits are green to dark green sometimes yellow to red (Tripathi *et al.*, 2011) and contain moderate levels of vitamins A and C. (Kumar *et al.,* 2010). The fruits are long (10-30 cm), beaked, ridged, more or less oblong hairy capsules that dehisce longitudinally.

Okra is an important vegetable crop grown mainly in the tropical and sub-tropical region during summer and rainy seasons. Hence it is classified as a warm season crop (Natural Research Council, 2006). The major okra producing countries in the world include India (6.34 million tons), Nigeria (2.04 million tons), Sudan (0.28 million tons) and Cote d'ivore (0.14 million tons) (FAOSTAT, 2014). In Africa Nigeria is the largest producer followed by Sudan, Cote d’ivore, and others (FAOSTAT, 2014). In Nigeria, there are two distinct seasons for okra production, the summer and the rainy seasons. During the summer season okra fruit are produced in low quantities, scarce and expensive to get (Bamire and Oke, 2003). Okra production constitutes about 4.6% of the total staple food production in Nigeria in the year 1970-2003(CBN, 2004). It is documented that okra ranks first before other vegetable crops and is consumed throughout Nigeria (Babatunde *et al*., 2007). Okra is a crop grown throughout northern Nigeria, but commercial production is concentrated in the Northeastern region where it can be grown all year round under irrigation and rain fed (CAB, 2000). In Adamawa State, Fufore local government is the major producer of okra. Guyuk, Shelleng, Hong and Yola are places where okra is produced in subsistence scale (Adebayo, 1999). Okra crop is susceptible to number of biotic and abiotic factors, including insect pests and diseases. The major insects include cotton jassids, spotted bollworm, *Earias insulana* (Fabr.), pink bollworm, cotton whitefly, *Bemicia tabaci* (Genn.) (Anitha, 2007). There are some major diseases which are affecting the production of okra i.e. okra mosaic virus, cercospora leaf spot, fusarium wilt, powdery mildew and verticillium wilt. Among biotic factors powdery mildew disease is the principal one, which cause 20-40% yield losses (Agrios, 2005).

1.2 Statement of Problem

The infection of okra by various fungi not only results in reduction in crop yield and quality with significant economic losses but also contamination of fruits with poisonous fungal secondary metabolites called mycotoxins (Ismail *et al*., 2011). The ingestion of such mycotoxins contaminated fruits by animals and human's beings has enormous public health significance, because these toxins are capable of causing diseases in man and animals (Moss, 2002). Okra has huge potential for enhancing livelihoods in urban and rural areas and to several stakeholders because it offers a possible route to prosperity for small scale and large – scale producers alike and all those involved in the okra value chain, including women, producers and traders (NAP, 2006). If disease of okra is not properly managed, it could have an economic impact on the level of production by reducing crop yield, quality and subsequently low return (Usman, 2004).

1.3 Justification of the Study

Management of powdery mildew disease is being achieved through the use of chemical spray control and cultural control but cases of the resistance to some of these chemicals have been reported in most production areas (Mathur and Sharma 2006). However, this method has various limitations including environmental pollution, development of resistance in the pathogen and residual toxicity. Resistant varieties were the only possible and feasible solution of management of powdery mildew disease (Malhotra and Singh 2000). Hence the current approach is mainly to see which accession is more tolerant, resistant or susceptible. It is for this reason therefore that this research was conducted for source of resistance against powdery mildew because whole crop can be saved from disease if plants are genetically resistant

1.4 Significance of the Study

The scope or concern of this study is to form an appropriate and adequate knowledge that would prevent losses by providing an adequate information on the accessions that are susceptible, moderately susceptible and resistant to powdery mildew disease in the study areas. These studies will be highly significant for reference purpose and for future studies.

1.5 Objective of the Study

The objectives of the study are:

i. to determine the incidence and severity of powdery mildew in the study areas
ii. to isolate and identify the fungus associated with the disease
iii. to evaluate the reaction of the different accession to powdery mildew pathogen
iv. to evaluate and compare the performance of the accessions under diseased condition in the study area

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic Importance of okra

Young fruit harvested before differentiation of fibers and full seed development, are consumed either alone or in salad after cooking in salty water, are added to stews and in the preparation of certain African sauces. In Nigeria, okra is usually boiled in water resulting in slimy soups and sauces, which are replenished. The fruits also serve as soup thickeners (Scippers, 2000). The leaves buds and flowers are also edible. Okra seed could be dried. The dried seed is a nutritious that can be used to prepare vegetable curds, or roasted and ground to be used as coffee additive or substitute. K, Na, Mg and Ca are the principal elements in pods, which contain about 17% seeds. Presence of Fe, Zn, Mn and Ni also has been reported (Moyin-Jesu, 2007). Fresh pods are low in calories (20 per 100 g), practically no fat, high in fiber, and have several valuable nutrients, including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20% of folate (46 to 88 mg) and about 5% of vitamin A (14 to 20 RAE) (NAP, 2006). Both pod skin (mesocarp) and seeds are excellent source of zinc (80 mg/g) (Glew, 1997; Cook *et al.*, 2000). Okra seed is mainly composed of oligomericcatechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds), while the mesocarp is mainly composed of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins). Pods and seeds are rich in phenolic compounds with important biological properties like quartering derivatives, catechin oligomers and hydroxycinnamic derivatives (Arapitsas, 2008). These properties, along with the high content of carbohydrates, proteins, glycol-protein, and other dietary elements enhance the importance of this foodstuff in the human diet (Manach *et al.*, 2005; Arapitsas, 2008). Dried okra sauce (pods mixed with other ingredients and regularly consumed in West Africa) does not provide any beta carotene (vitamin A) or retinol (Avallone *et al.*, 2008). However, fresh okra pods are the most important vegetable source of viscous fiber, an important dietary component to lower cholesterol (Kendall and Jenkins, 2004). Seven-days-old fresh okra pods have the highest concentration of nutrients (Agbo *et al.*, 2008).

Okra provides an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diet of developing countries (Gopalan *et al.*, 2007). Okra mucilage is suitable for medicinal and industrial application. Medically it is used to prevents constipation, colon cancer, skin pigmentation, controls asthma, obesity and in plasma replacement or blood volume expander. For a year-round of consumption of okra, the fruits are sliced and sun dried or frozen (Alimi, 2004). The occurrence of hard seediness and the low percentage of seed germination are major challenges when growing okra (Passo, 2010). Okra seed hardness result in slow and non-uniform germination. Seed quality and seed germination have adverse effects on the yield of crops. Most times seed quality deteriorates during post-harvest storage as a result of pathogen infestation and poor storage condition (Odofin, 2010). The height of the okra plant can potentially affect yield as those that are taller are usually more prone to windstorms in the event of heavy seasonal or monsoonal rains. Plant height and fruiting are of particular interest for breeding programs. Because the presence of plants with tall and thin stems will increase the rate of lodging near harvesting and this could lead to loss of dry matter and subsequent decrease in fruit yield (Katung, 2007). According to Akenyele and Osekita (2006), days to flowering and plant height at maturity, among other morphological traits, are some of the most variable traits of okra that are necessary for selection programs aimed at improving desirable traits. Okra cultivars and genotypes came to flowering at different days depending on the genotypic characteristics of the genotype (Hossain and Ashratul, 2006).

The number of branches of Okra Accessions also have significant effect on the yield of okra. With increase in the number of branches per plant, there is also an increase in the number of pods per plant which can also leads to a decrease in pod weight, pod width and number of seeds per pod (Nihort, 1980). Manyong, (2002) observed that poor planting genotypes are among the production and yield challenges confronting okra production in Nigeria. Variations in the number of leaves was observed in okra Accessions. Since leaves serves as the sites for photosynthesis activities in any plant. An increase or decrease in the number of leaves may have very serious implication for production of assimilates in the crop (Saifullah and Rabbani 2009). Fruit length together with pod number and pod weight are the most important determinant of production or yield. Ashraful and Hossain (2006) observed that yield of green pod had highly significant positive association with weight of green pod per plant and weight of individual green pod. Weight of individual green pod was directly contributed towards the yield of green pod.

Fungi are the most important and prevalent pathogens, infecting a wide range of host plants and causing destructive and economically important losses of most vegetables in the field and after harvest (Hausbeck and Lamour, 2004). Crop losses due to the soilborne fungus like *Oomycete phytophthora capsici* have been well documented. *Phytophthora capsici* affects a wide range of Solanaceae and Curcubit host worldwide (Erwin and Ribeiro, 2006).

Post-harvest diseases destroy 10-30% of the total yield of crops and in some perishable crops especially in developing countries, they destroy more than 30% of the crop yield (Agrios, 2005). Fruits and vegetables are highly perishable products, the quality is affected by post-harvest handling, transportation, storage and marketing. The improper handling may result in decay and production of micro-organism, which become activated because of the changing physiological state of the fruits and vegetables (Kadar, 2002). Okra fruits due to their low pH, higher moisture content and nutrient composition are very susceptible to attack by pathogenic fungi, which in addition to causing rot may also make them unfit for consumption by producing mycotoxins (Moss, 2002)

Babadoost (2000), reported that the incidence of damping off, foliar blight and fruit rot on okra, melon, peppers, pumpkins and water melon caused by *Phytophthora capsici*, has dramatically increased in Illinois, USA. Early infection caused foliar blight, stem lesion, vine rot, fruit rot, root and crown rot. Okra fruit rot can occur from the time of fruit set until harvest. The rotten tissue become soft with browning and decay (Lee *et al*.,2001; Islam and Babadoost,2002). Few pathogens have been reported as causal agents of diseases in okra fruit in Nigeria such as *Fusarium solani*, *Phytophthora palmivora* and *Rhizoctonia solani* (Benchasri, 2012).

2.2 Common Diseases of Okra

2.2.1 Damping off (Pythium spp. *Rhizoctonia* spp.)

Damping off incited by *Pythium aphanidermatum* cause more than 60% losses in seedlings both in nursery and main field (Manorangitham *et al.,* 2000). Pre- and post-emergence damping off disease caused by Pythiuim species in vegetable crop is economically very important worldwide (Ramamoorthy *et al.,*2002) Cool, cloudy weather, high humidity, wet soils, compacted soil, and overcrowding especially favor development of damping-off. Damping-off kills seedlings before or soon after they emerge. Infection before seedling emergence results in poor germination. If the decay is after seedlings emergence, they fall over or die which is referred to as "damp-off." The destructiveness of the disease depends on the amount of pathogen in the soil and on environmental conditions. Seedlings that emerge develop a lesion near where the tender stem contacts the soil surface. The tissues beneath the lesion become soft due to which the seedlings collapse (Kucherak, 2004).

2.2.2 Okra yellow vein mosaic disease

The Yellow Vein Mosaic Virus is transmitted by white fly *(Bemisia tabaci* Gen) through persistent manner. The characteristic symptoms of the disease are a homogenous interwoven network of yellow veins enclosing islands of green tissues. Initially infected leaves exhibit only yellow coloured veins but in the later stages, the entire leaf turns completely yellow. In extreme cases, the infected leaf become totally light yellow or cream coloured and there is no trace of green colour. At times, enations (raised structures) are observed on the under surface of infected leaf. Plants infected in the early stages remain stunted. It is causing great loss by affecting quality and yield of okra fruit, as high as 93.8% depending on age of plant at the time of infection (Bhagat *et al.*, 2001)

The fruits of the infected plants exhibit pale yellow colour, deformed, small and tough in texture (Fajinmi and Fajinmi 2006).

2.2.3 Leaf spot

This disease is caused by the Curvularia species. Light brown spot appeared on the leaves as initial symptoms, then turned to concentric dark brown spots varying in size (Atia and Tohanny 2004). Crous and Braun, 2003 also reported that the species belonging to genus cercospora sp.Fresen are distributed worldwide and cause cercospora disease on most of the major plant families.The symptoms of the disease are seen initialy on lower and more matured leaves as small spots. Often the centers may turn white and dry up. As disease progress these spots joined together and formed patches. Later, the leaves are dry and remained intact with stem of plant (Ziedan and Farrang, 2011). Leaf spot cause by *Alternaria alternata* starts as light brown spot, then turn to concentric dark brown spots, varying in size, become necrotic. These spots spread to cover large areas of infected leaves. In case of severe infection, infected leaves become brown and die (Antonijevic *et al*.,2007). Alternaria leaf spot in some cases, has led to total loss of yield (Rizzoli and Acler, 2006)

2.2.4 Southern blight (*Sclerotium rolfsii*)

Southern blight occurs during warm and humid weather and has the potential to explode in the field centers, often as is this is the least-scouted area. The plants exhibit a progressive wilt as the fungus infects the roots and lower stem. A coarse white fungal mat can often be observed at the soil, but the fungi produces sclerotia which may resist degradation for many years in the field. Some growers rotate with grass crops such as sorghum or sudan grass, which are not fungal hosts, to alleviate the pressure from this fungus as well as deep plow the resting structures (Palmatear, 2000).

2.2.5 White mold (Sclerotinia sclerotiorum)

The presence of small, black resting structures (sclerotia) and a cottony, white mass (mycelium) are characteristic of the pathogen. Sclerotia, which are able to survive between crop cycles, are the source of inoculum infesting individual fields from year to year (Kucherak, 2004). White mold is easily identified by the characteristics white cottony mycelium of the pathogen that grows on the surfaces of aerial tissues. The hyphae produce enzymes and oxalic acid,creating water soaked lesions, frequently with a distinct margin. Secondary symptoms such as wilting, bleaching and shredding also can be observed on above-ground tissues including stems, leaves, petiole and reproductive organ (Heffer and Johnson 2007).

2.2.6 Blossom blight/wet rot (*Choanephora cucurbitarum*)

Infection began in senescent flower petals and resulted in blighted blossoms and soft rots of pods. Initial symptoms consisted of water-soaked, brown to black lesions, resulting in rapid rotting of the infected tissues. Numerous monosporous sporangia were produced on the lesion surfaces. Severe infections caused early falling of blossoms and fruit drop and reduced plant vigour in the summer season (Park *et al*., 2013). Both young and old blossoms, young fruit, and wounded leaf tissues may become infected and appear water soaked. Newly opened blooms will split and collapse. Fruit may become infected and covered with a dense white mycelium that is whisker-like. Affected parts will often soften and fall to the ground Sathish *et al*., **(**2013).

2.2.7 *Stem rot* (*sclerotium roifsil*)

Early symptoms often include an obvious discoloration of leaves on a few branches. During wet periods, a white fungus growth can be seen on the lower stem near the soil surface and on organic debris on the soil (Tom, 2000). *Macrophomina phaseolina* is considered as one of the most destructive soil borne pathogen of Okra. *Macrophomina phaseolina* is most often seen during summer weather, the fungus can also cause hollow stem, root rot, pre-emergence and post emergence damping off (Gulya *et al*., 2002). *Macrophomina phaseolina* does not survive more than seven days in its mycelial form but it sclerotia can survive over ten months in soil. It usually develops when soil temperature is 80-95^0 F (27^{0}C-35^0 C) for 2 to 3 weeks (Yang and Navi, 2003)**.** Sikora and Fernandez (2005) reported severe attack of root rot diseased caused by Meloidogyne Species on okra and yield losses up to 27%.

2.2.8 *Fusarium wilt*

Caused by the fungus *Fusarium oxysporum* and is characterized by symptoms such as wilting of cotyledons and seedling leaves. Cotyledons become chlorotic at the edges and then necrotic, older plants exhibit symptoms of wilting and leaf chlorosis (Silva *et al*. 2007). Vascular system of infected plants becomes discolored and can be seen by cutting the stem. The disease is also caused by fungi, which persist in the soil for a very long time. Initially the plants show temporary wilting symptoms, which become permanent and progressive, affecting more vines. The leaves of the affected plants show yellowing, loose turgidity and show drooping symptoms. Eventually, the plant dies. In older plants, leaves wilt suddenly and vascular bundles in the collar region become yellow or brown. The fungus invades the root system and colonizes the vascular system. In doing so, water movement is blocked and toxins from the fungus alter normal cell function. Yield losses of 10-45% were observed in the crop sown under field conditions (Mithal, 2006).

The management of fusarium wilt in malvaceae host is difficult, and the main control strategy has been preventing the introduction of the pathogen in new planting areas (Davis et al.2006). Other disease management methods are crop rotation and seed treatment with fungicides.

2.2.9 Powdery mildew (*Erysiphe cinchoracearum* DC.)

Powdery mildew is obligate, biotropic fungi, meaning they can survive on cells in specific living hosts despite their restrictive host specificity (Jules, 2008). Parasitic powdery mildew fungi have to overcome basic resistance and manipulate host cell to establish a haustorium as a factual feeding organ in a host epidermal cells (Rula and Ralph 2007). The parasite powdery mildew fungus develops on the leaf surface (Kaye *et al.,* 2006). The disease is known to attack the plant on the lower most leaves near the soil (Ben *et al.,* 2005).The disease infect almost all ornamental plants (Stephen, 2005). Powdery mildew is commonly seen only on those plants more naturally susceptible to the disease (Stephen and Chatfield 2005). When the cooler part of the okra season is also dry (except for dew), the fungus coats the upper and lower leaf surfaces with a white coating of mycelium. Severe infection will cause the leaves to roll upward and scorch. The disease initiates as white minute patches, first on the upper surface of lower leave or older leaves and then spread to younger once while grayish powdery coast is visible on severe affected leaves. Leaves finally show necrosis resulting in withering, drying and defoliation. The powdery mildew affects all growth stages and responsible for yield losses to the tune of 17 to 86.6 percent Cohen *et al.,* (2009). Powdery mildew can decrease plant canopy. The reduced canopy may result in Sunscald of the remaining fruit, making them unmarketable (Donald, 2008). Powdery mildew can decreased fruit size and number of fruit per plant, and reduce fruit quality, flavor and storage life (Kelnath and Dubose, 2004).

Singh (2001) reported that the fungus that causes powdery mildew diseases can sporolate and cause infection in a very dry as well as wet atmosphere but infection increases with increase in atmospheric humidity. In Nigeria, Anjorin *et al.,* (2013) reported that the incidence and severity of powdery mildew cause by *Erisiphe cinchoracearum* was correlated with maximum and minimum temperature. The cool night and dry weather situation are more favorable for powdery mildew to become severe. The variation of diseases incidence in various localities is mainly attributed to the climatic factors like temperature, relative humidity and distribution and amount of rainfall followed by cultural practices like sanitation and other suitable management practices (Anitha, 2007). Neeraja *et al., (*2004) stated that powdery mildew (*Erysiphe cinchoracearum* DC.) is a serious disease of okra in India, and there is no source of resistance as reveals by some literatures.

Powdery mildew is a serious disease of okra, beans, southern peas, squash, cucumbers, muskmelons, and pumpkins in almost all the areas of the country. Powdery mildew disease seldom (rarely or hardly kill their host). But utilize their nutrient, reduce photosynthesis, increase respiration and transpiration, impair growth and reduce yields, sometimes by as much as 20 to 40% (Agrios,1997). The disease is caused by the fungus *Erysiphe cichoracearum.* Other species of *Erysiphe* like *Erysiphe Polygoni* causes powdery mildew in beans, southern peas, and English peas and *Sphaerotheca macularis* affects strawberries. Okra or Bhindi or Lady's finger (*Abelmoschus esculentus* L.Moench) is an important vegetable crop. Most of the okra cultivars are susceptible to powdery mildew disease, and depending upon the age of the plant at the time of infection, yield losses range between 17 and 86.6% (Sridhar and Poonam 1990). Malhotra and Singh (2000) evaluated okra germplasm against powdery mildew disease and found that resistant varieties were the only possible and practically feasible solution for management of disease. Hussan *et al* (2002) reported that resistance against powdery mildew disease of okra cultivar is due to 2 gene pairs – a recessive gene and an incompletely dominant gene, with the genotype design as aaBB. Similarly, Bhattacharya *et al* (2000) stated that more concentration of phenolase and catalase in cultivars is the reason for resistance to powdery mildew disease of okra.

2.3 Epidemiology of Powdery Mildew

Relative humidity above 75% is considered necessary for stimulation of sporangia production (leaf infection) and a saturated atmosphere with film of water on the leaf is considered best for disease development (Mehrothra and Agarwal 2007). Powdery mildew disease is favored by low temperature (11-28°C) and dry weather conditions and early infection has more effect on the plant growth and yield than late infection. The most favorable condition for powdery mildew are nighttime temperature of 60^0F and relative humidity of 90 to 99% with 80^0F temperature and 40 to 79% relative humidity during the days. Conditions common in late spring and early fall (Yanar and Gebologlu, 2013). As temperature fall at night, relative humidity increase. High relative humidity stimulates conidia to germinate and also encourages production of chains of conidia in existing infections. The time from when conidia land to the production of new conidia can be as short as 72 hours but is more common 5-7 days (Douglas,2011). Mondal *et al.* (2003) observed powdery mildew incidence in the first and second fortnight of July and the disease was favored by dry mean relative humidity of

14.5 and 30 percent for day and night respectively and cool weather (mean temperature of 25^0C and 15^0C for day and night respectively).

2.4 Dissemination of Powdery Mildew

Pandey *et al*., (2005) reported that Powdery mildew fungi have fairly simple life cycle on most plants. Spores (conidia) are produced in chains on stalks (conidiospores). Conidia are "powdery" and are readily disseminated by wind send food-absorbing protections (haustoria) into the epidermal cells. Threat-like strand of the fungus (hyphae) then grow over the surface of the infected plant part and eventually produce more conidiospores and conidia. The time from when conidia land to the production of new conidia can be as short as 72 hours, but it is comelier 5 – 7 days.

2.5 Management of Powdery Mildew Disease

2.5.1 Chemical management of powdery mildew

Effective control of the disease is possible with fungicidal applications and the recommended fungicides are benomyl (0.1%), wettable sulfur (0.2, 0.3 and 0.5%). Applications of potassium silicate K_2SiO_3 (200 mg/L) and the alternation of systemic fungicide Bayleton WP 5 [Triadimenol (25 mg/L)] and Thiovit 80% WP (sulfur (2.4g/L)) with 12day interval were also highly protective against powdery mildew (Gogoi *et al.*,2013). Among these fungicides, elemental sulphur (S°) is universally known as the most effective one for managing powdery mildews and this fungicide has been used as foliar spray at 2-4 g per liters (2000-3000 ppm). However, the extensive and prolonged use of synthetic fungicides has resulted in the development of resistance in the fungus (Pasche *et al*., 2004).

2.5.2 Cultural management of powdery mildew disease

Plants in summary are as much as possible, provide good air circulation and avoid applying excess fertilizer. A good alternative is to use a slow release fertilizer. Overhead sprinkling may help reduce powdery mildew become spores are washed off the plant. However, overhead sprinklers are not usually recommended as a control method in vegetables because there use may contribute to other pest problems (McCain, 1994). During the growing season, symptomatic leaves should be removed as soon as they are detected and immediately placed in a plastic bag to avoid spread of the powdery spores to other plant (Douglas, 2012).

2.5.3 Biological control of powdery mildew

The Powdery Mildew pathogens (Erysiphales) are collectively considered one of the most important plant pathogens worldwide since many of their hosts are valued as agricultural and ornamental plants. Conventional management of Powdery Mildew employs regular applications of chemical fungicides. This approach can be costly and sometimes ineffective due to the development of resistance in the fungi (Heaney *et al.,* 2000; McGrath, 2001). Biological control of Powdery mildew may offer solutions to this resistance phenomenon and other fungicide-related issues such as residues in food crops, effects on non-target organisms, impacts on farm worker health and safety, etc. Control of Powdery Mildew using commercially-available microbial controls, equivalent to that obtained through chemical fungicide applications, has been found with the spore-forming bacterium Bacillus subtilis (Ehrenberg) Cohn (Bacillales: Bacillaceae) and the pycnidial fungal hyperparasite Ampelomyces quisqualis Cesati (not currently assigned to order or family) (Chase, 2004). Interest in the development of Pseudozyma flocculosa (Traquair, Shaw and Jarvis) Boekhout and Traquair (Ustilaginales: Ustilaginaceae) as a biofungicide has been prompted by results against the Powdery Mildew Sphaerotheca fuliginea (Schlechtendal) Pollacci (Paulitz and Belanger, 2001).

2.5.4 Use of resistant variety

Different methods were adopted to protect the crop from powdery mildew disease of Okra but the genetic resistance against pathogen is the best management strategy because it is ideal, economical and environmentally safe (Mishra *et al.,* 2005). However, variation in pathogens threatens the Okra crop. So, it is very important to continue breeding program for source of resistance against powdery mildew because whole crop can be saved from disease, if plants are genetically resistant. When disease develops in epidemic form then resistant plants mostly escape the disease due to natural selection and create equilibrium between host and pathogen in natural communities. Disease developed through interaction of pathogen and host under favorable environmental conditions can easily be managed through chemicals but this is not environment friendly method (Mishra *et al.,* 2005)

CHAPTER THREE
MATERIALS AND METHODS

3.1 The Study Area

The Study on incidence of Powdery Mildew disease of okra was conducted in two Local Government Areas of Adamawa State namely: Yola North and Guyuk during the 2016 farming season under rain fed condition. Yola North lies between Latitude 7^0 and 11^0 North of the Equator and between Longitude 11^0 and 14^0E of the GMT (Adebayo, 1999). The wet season commences in April and ends in late October, while the dry season starts in November and ends in April. The mean annual rainfall of the area is about 1000 mm. Guyuk Local Government area is located between latitude 9^o 30' and 10^o 00' East and longitude 11^o 30' and 12^o 00' North and has othic luvisols soil. It has an average temperature of 26.1^o C in December to January and 33^oC in April to May (Adebayo, 1999). The area also has an average rainfall of 700 – 800 mm per annum (Adebayo and Tukur, 1999).

3.2 Experimental Design

Field experiment was conducted in Guyuk Local Government and at the Experimental Farm of the School of Agriculture, Modibbo Adama University of Technology Yola. Ten (10) Accessions of Okra constituted the treatments in a randomized complete block design (RCBD) replicated three times giving a total of 30 plots. The plot size for each treatment was 3x2 m, giving a plot size of $6m^2$ with 0.5 m pathways between the plots and 1 m between blocks. The seeds were sown on raised beds in parallel lines. Two seeds per hole were planted at about 3 cm depth at the planting spacing of 60 cm between row and 30 cm within row and later thinned after full emergence to one plant per hole.

3.3 Incidence of Powdery Mildew

The incidence of powdery mildew disease on the ten (10) Accessions of okra was carried out in the study area and the disease incidence was calculated using the formula of Berger, 1980:

$$\text{Disease Incidence} = \frac{\text{Number of diseased leaves}}{\text{Total number of leaves evaluated}} \times 100$$

3.4 Powdery mildew rating

The percentage of each foliar disease severity was recorded by employing disease severity scale from 1 to 5 using modified method of Cohen *et al*. (2009) whereas 1=No leaf lesions (Immune) 2= 25% or less (Highly resistant); 3=26-50% (Moderately resistant) 4=51-75% (Moderately Susceptible) and 5=76-100% (Highly susceptible) infected Area of plant leaf. Severity of disease was monitored at weekly intervals beginning from 5 weeks after sowing until 9 weeks after sowing. Severity of disease was estimated by assessing diseases leaves from the three (3) randomly tagged plants per plot from the middle rows. The extent of damage on the leaves was determined based on visual observation while scoring the disease.

$$\text{Disease Severity} = \frac{\text{Sum of individual ratings}}{\text{Total number of leaves assessed x maximum score in the scale (5)}} \times 100$$

3.5 Sample Collection and Media Preparation

The diseased samples of okra leaves were collected from within the study area and taken to the Plant Science Laboratory for isolation and identification of disease causing agent. Potato Dextrose Agar (PDA) was used for the experiment. The quantity of 39 g of PDA was dissolved in one (1) liter of distilled water. The PDA was poured into conical flask, then covered with cotton and wrapped with aluminum foil before autoclaving at 121^0 C for 15 minutes at 10 lbs. pressure. 20 mls of the media was poured into 9 cm diameter Petri dishes and 6 ml (0.1%) of streptomycin was added to the sterilized media, just before pouring into Petri- dishes to prevent bacterial growth and allowed to cool and solidify under ultraviolet light according to the method of Suleiman and Michael (2013).

3.6 Sterilization of Materials

Petri dishes, bottles, beakers and prepared media were sterilized using autoclave at 121^oC at 15 psi for fifteen (15) minutes. The bench top was sterilized using 70% ethanol. Inoculation needles, wire loop, cork borer and the dissecting knife were sterilized by flaming.

3.7 Isolation from Infected Leaves

Samples of four (4) leaves suspected to be infected with the fungus were collected from the two locations in the study areas. These were washed under running tap water for five minutes to remove mud and completely dry. The leaves were cut into 0.2-0.5 cm pieces, surface disinfected in 0.01% $HgCl_2$ for one minute and washed thrice in sterilize distilled water and again dried completely between sterile filter paper to avoid surface contamination and remove chemical traces. After that, 5 pieces were transfer on PDA medium in Petri plates. The dishes were incubated at 30 ± 1^0 for colonization of powdery mildew causing fungi. The pure culture was obtained through sub-culture technique.

3.8 Multiplication of Pure Culture

Mycelia growth of fungus was cut from the margin of actively growing culture of the fungus with sterilized cork borer and then placed in the center of each Petri dish. The plates were, incubated for 6-7 days at 30^0C temperature.

3.9 Identification of Fungus

The fungus was identified by its colony characteristics and taxonomical keys as describe by Logrieco *et al*. (1990). With the aid of a sterile needle, little circular portion (2mm) of the pure cultured organism was taken to a sterilized slide; this was stained with lacto-phenol cotton blue and were examined under X1 magnifications of the microscope (Fawole and Oso 1995). The morphological and cultural characteristics observed were compared with structures in organisms' identification guide of Hunter and Barnet (1998).

3.10 Pathogenicity Test

Pathogenicity test was carried out on okra plants for confirmation of disease causing fungus by making a suspension of a fungus from one petri dish of a well develop pure culture. Seedlings were raised by sowing the seeds in pots (30 cm in diameter) and watering was done twice a week. Thirty-five days old plants were pin pricked and sprayed with the suspension containing conidia prepared in sterilized distilled water. For inoculation, the upper surfaces of all the leaves were sprayed with a conidial suspension delivered by hand sprayer (Reuveni *et al*., 2000). Inoculated plants were covered with polythene bags and kept in the dark for 12 hours and then maintained for 48 hours at 25^oC. At the end of 48 hours, the pots were kept in screen house under natural humidity. Regular observation was made for the appearance and development of symptoms. Control plants were sprayed with distilled water and kept under similar conditions. The fungus was re-isolated from the leaves showing symptoms and the cultures obtained were compared with the original to confirm the identity according to Koch's postulates.

3.11 Sources of Okra Seeds

The 10 okra Accessions used for this study were obtained from NIHORT and NACREB while Yola local were sourced locally from the market. The names of the Accessions are Yola local, Clemson spineless, Accession 1, Accession 2, Accession 3, Accession 4, Accession 5, Accession 6, Accession 7 and Accession 15.

Table 1: Characteristics of accession used for the experiment

S/N	Accessions	Sources	Description
1	Accession 1	NIHORT	Produce 15-18 fruit per plant, 28-32 days to maturity, plant height at maturity (tall) 1.0-1.2 m, fruit length of 21-26.5 cm, fruit are light green in color
2	Accession 2	NIHORT	Produce 17-19 per plant, matured at 40-46 days, can grow up to 38-45 cm at flowering, fruits are dark green in color
3	Accession 3	NIHORT	Produce 12-14 fruit per plant, 38-43 days to flower, height (tall) 1.0-1.1 m, fruits are dark green in color
4	Accession 4	NIHORT	Fruits are dark green in color, produce 15-18 fruit per plant, 28-32 days to maturity, plant height at maturity (tall) 1.0-1.2 m, fruit length of 21-26.5 cm
5	Accession 5	NIHORT	Produce 15-18 fruit per plant, 28-32 days to maturity, plant height at maturity (tall) 1.0-1.2 m, fruit length of 21-26.5 cm
6	Accession 6	NACGRAB	Late maturing, 88-95 days to flowering, produce 25-28 fruit per plant, 2-3 branches per plant, height (short) 42-46 cm, fruits are yellowish green in color
7	Accession 7	NACGRAB	Late maturing, 90-98 days to flowering, produce 8-10 fruit per plant,2-3 branches per plant, height (short) 40-44 cm
8	Accession 15	NIHORT	Flower at 53-60 days, produce 14-16 fruits per plant, height moderately short 50.2 cm-55 cm
9	Clemson spineless	NIHORT	Early maturing, 25.60 days to flowering, produce 5-7 fruits per plant, height (short) 36-39 cm, fruits are yellowish green in color
10	Yola local	Yola Market	Matures in 30-36 days, produce 12-16 fruit per plant, and grows to a height of 30-34 cm at maturity.

Source: NIHORT, National Horticultural Research Institute Ibadan.
NACGRAB, National Centre for Genetic Resources and Biotechnology.

Plate Ia: Fruits of Accession 1

Plate Ib: Fruits of Accession 2

Plate Ic: Fruits of Accession 3

Plate Id: Fruits of Accession 4

Plate Ie: Fruits of Accession 5

Plate If: Fruits of Accession 6

Plate Ig: Fruits of Accession 7

Plate Ih: Fruits of Accession 15

Plate Ii: Fruits of Yola local

Plate Ij: Fruits of Clemson Spineless

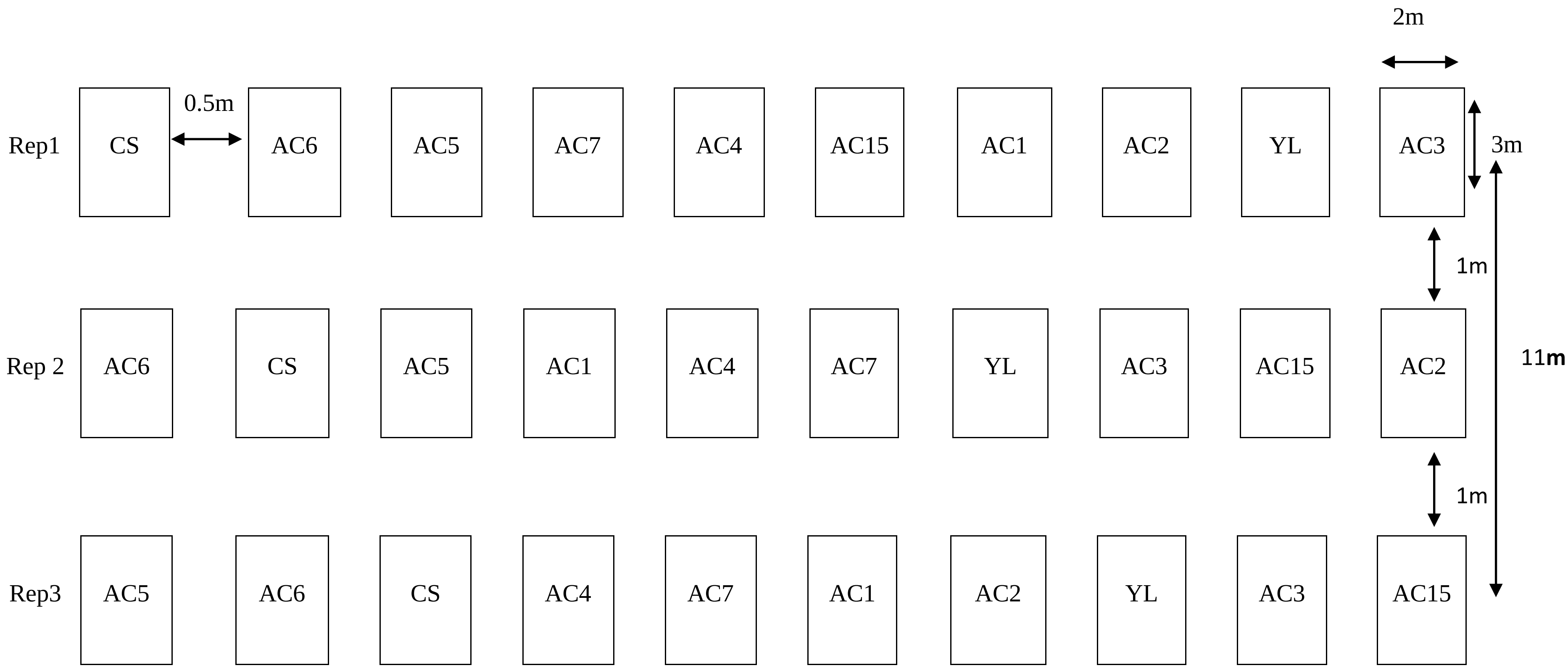

Fig. 1: Experimental Layout and Randomization of Treatments

KEY:

AC1: Accession 1
AC 2: Accession 2
AC3: Accession 3
AC4: Accession 4
AC5: Accession 5
AC6: Accession 6
AC7: Accession 7
AC15: Accession 15
CS: Clemson Spireless
YL: Yola Local

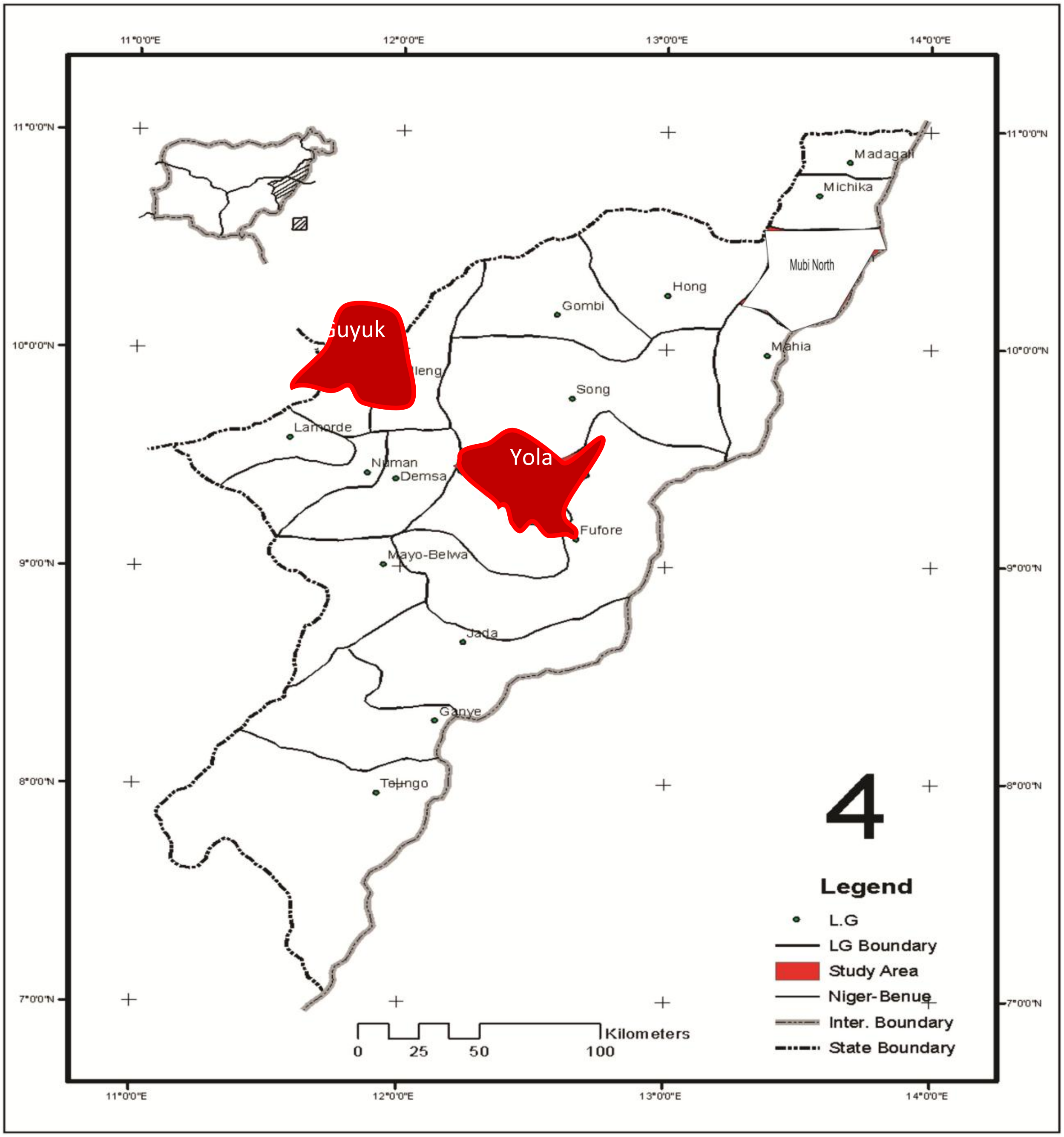

Figure 2. Map of Adamawa State Showing the study areas

3.12 Cultural Practice

The land for the trial was harrowed and leveled to get a fine tilth before sowing okra seeds. Okra seeds were treated with Apron plus-DS at the rate of 3kg of seed per sachet before sowing in order to protect the seeds against soil borne disease. Seeds were sown on a flat land at the rate of 2 to 3 seeds per hole and later thinned to one plant per stand. Two weeks after sowing, the crop was sprayed with Optimal-SP at the rate of 2.5 liters per hectare beginning from three weeks to protect the crop from insect attack. Regular weeding was done when the need arose using hoe in both locations. Mixed fertilizer NPK (15:15:15) was applied at the rate of 100 $kgNha^{-1}$ 100 $kgPha^{-1}$ 100 $kgKha^{-1}$ two times in both location, at 3 weeks after sowing and 6 weeks after sowing (Anon,2004). Fertilizers were applied 5 cm away from the plants and covered with soil immediately. Harvesting of okra was carried out by hand picking when it is fresh and tender. This was done from the month of early August up to the month of early October.

3.13 Data Collection

Data on the plant growth (height), phenology and yield parameter were collected from each plot in all the locations. Data collection was done from the middle rows of each plot starting from three weeks after sowing (3WAS). The following data were collected

Plant establishment

This was done by counting the number of emerged plant stand in the net area of each plot at 3WAS after emergence. This was later expressed as a percentage of the total emerged plants stands.

***Plant height* (cm):** Measured from the soil surface to the tip of the innermost leaf at 4, 6 and 10 weeks after sowing (WAS). Three (3) randomly selected plants in a plot were selected and tagged, Measurement was done using a meter rule. The average of the three plant was calculated and recorded as plant height.

***Number of leaves per plant*:** Three plants were randomly selected per plot and the numbers of fully expanded green leaves were counted at 4, 6 and 10 weeks after sowing (WAS). The mean of each of the three plants was recorded as number of leaves per plant.

Days to 50% flowering: Collected by observing physically when half of the population of plants in each plot bloomed.

***Number of fruits per* plant:** The number of fruit per plant was counted at every harvesting day from three randomly selected and tagged plants in each plot. The total number of pods obtained from the selected plants was divided to get the average number of fruits per plants.

***Fruit weight* (g):** The total weight of fresh fruits from three randomly selected plants per plot was measured by using a digital weighing balance and their average was recorded.

***Fruit length* (cm):** Measurement was taken from the base of the fruit to the tip of marketable fruit collected from sample plants from each plot using a graduated centimeter rule and the means were recorded.

***Total fruit yield* (kgha^{-1}):** Yield obtained at each harvest from the net plot area was sum up as marketable and unmarketable yield and expressed as kgha^{-1}.

***Number of seeds in a pod*:** This was obtained by counting the number of seeds on three matured dry fruit an means were recorded

100 seed weight (g): This was obtained from the threshed seed per plot by randomly counting 100 seeds and the weight recorded when the fruits were fully matured and dried.

***Number of branches per plant*:** Physical counting of the number of branches from three randomly sampled plants was done at 10 weeks after sowing (WAS) and the means were recorded.

3.14 Data Analysis

The data collected were analyze using Statistical package for service solution (SPSS) appropriate for Randomized Completely Block Design (RCBD) and means separation was carried out using Duncan Multiple Range Test(DMRT) Gomez and Gomez (1984).

CHAPTER FOUR

RESULTS

4.1 Results on Days to 50% Flowering and Number of Branches of 10 Okra Accessions in Yola and Guyuk during 2016 rainy seasons.

The result revealed a highly significant ($p \leq 0.01$) difference with respect to days to 50% flowering and number of branches per plant in both location. Result on days to flowering revealed that Accession 1 and Accession 2 came to flowering earlier than all other Accessions at 43.00 and 43.33 days in Yola while Accession 7 and Accession 6 reached days to 50% flowering much later than the remaining Accessions at 103.67 days and 100.00 days. In Guyuk, Accession 1 and Clemson spineless flower earlier than other Accession at 36.33 and 39.67 days while Accession 7 and Accession 6 came to flowering later at 100.00 and 92.33 days in Guyuk (Table 2).

Result for number of branches per plant showed highly significant differences ($p\leq0.01$) among the Accessions in both locations. In Guyuk, Accession 6 recorded numerous numbers of branches per plant followed by Accession 15 with 10 and 7.00 number of branches per plant while Accession 5 and Accession 3 recorded minimum number of branches per plant having 4 and 2 respectively. In Yola, Accession 6 recorded the highest number of branches per plant (8.00) follow by Accession 15 with (7.00). The minimum number of branches per plant was observed in Yola local with 4 number of branches per plant and Clemson spineless with 2.0 number of branches per plant (Table 2).

4.2 Effect of Powdery Mildew on Plant Height and Number of Leaves of Okra Accessions in Yola and Guyuk

Record on plant height showed significant difference ($p=0.05$) between the average plant height of the different okra Accessions in Yola. At 6 WAS it was observed that Accession 5 had the highest mean plant height of 23.03 cm followed by Accession 3 with 19.70 cm and Clemson spineless with 19.30 cm. The shortest cultivar was Accession 7 (8.53 cm) and Accession 6 (8.96 cm) (Table 3). At 10 WAS there was a highly significant difference ($p=0.01$) between the Accessions. The maximum mean height was observed in Accession 5 (98.1 cm) followed by accession 1 while the minimum mean height was observe in Yola local (35.4 cm) and Accession 15 (35.1 cm). Results on plant height of okra varieties in Guyuk showed highly significant difference ($p=0.01$) .

Table 2: Effect of powdery mildew on days to 50% flowering and number of branches of Okra Accessions during 2016 rainy season in Yola and Guyuk

	LOCATIONS			
	Guyuk		Yola	
Accessions	Days to 50% flowering	No. of Branches	Days to 50% flowering	No. of branches
Accession 1	36.33^{cd}	5.00^{b}	43.33^{b}	4.67^{ab}
Accession 2	50.67^{bc}	5.0^{b}	43.00^{b}	6.67^{b}
Accession 3	47.33^{bc}	2.0^{ab}	56.33^{bc}	4.00^{ab}
Accession 4	41.33^{d}	4.0^{b}	46.00^{bc}	6.00^{b}
Accession 5	62.00^{c}	3.0^{b}	65.00^{b}	6.00^{b}
Accession 6	92.33^{b}	10.0^{a}	100.00^{a}	8.00^{a}
Accession 7	100.00^{a}	2.0^{bc}	103.67^{a}	5.00^{b}
Accession 15	68.33^{ab}	7.0^{b}	74.33^{ab}	7.00^{a}
Yola Local	39.67^{cd}	4.0^{b}	48.67^{bc}	3.67^{bc}
Clemson spineless	40.67^{d}	4.0^{b}	49.67^{bc}	2.33^{bc}
P < F	<.001	0.004	0.001	0.019
S.E	2.725	1.662	3.537	1.942

Key: Means with the same letter(s) in the same column are not significantly different at $p = \leq 0.01$ or $p < = 0.05$ using DMRT.

Accession 1 and Accession 3 recorded the highest mean height of (97.9 cm) and (91.3 cm) respectively while the shortest mean height was observed in Clemson spineless (22.3 cm) and Accession 7 (31.5 cm) at 6 WAS. At 10 WAS Accession 1 showed the highest mean height value of (104.0 cm) while Clemson spineless showed the shortest mean height value of (26.1 cm) followed by Accession 15 (29.1 cm). Result on the number of leaves in okra varieties in Yola showed highly significant difference ($p=0.01$) at both 6 WAS and 10 WAS. At 6 WAS in Yola, Accession 5 gave the highest number of leaves of 22.13 while the lowest leave number was recorded in Accession 7 and Accession 15. At 10 WAS Accession 6 had the highest leave number of 55.80 followed by Accession 5 with 31.7 leaves. The lowest number of leaves was recorded in Clemson spineless (16.83) and Accession 1 with 17.17 leaves at 10 WAS. Result in Guyuk, showed that there is a significant difference ($p<0.05$) in number of leaves at 6 WAS. At 6 WAS Accession 15 recorded the highest number of leaves (21.73) follow by Accession 6 with (21.63) leaves .The lowest number of leaves was recorded in Accession 2 (12.33) and Accession 3 (13.07) respectively. At 10 WAS there is highly significant difference ($p<0.01$) in the number of leaves between the Accessions. Accession 6 recorded the highest number of leaves of 42.67 while the lowest number of leaves was recorded in Accession 1.

4.3 Effect of Powdery Mildew Disease on the Number of Fruit per plant, Fruit Length and Yield of Okra

Significant difference were observe among Okra Accessions for number of pods per plant in both locations ($p\leq0.05$). In Guyuk, the highest number of pods per plant was noted in Accession 6 with 23.33 number of fruit per plant followed by Accession 2 with 15.30 number of pod per plant while Clemson spineless and Accession 7 recorded the minimum number of 3.97 and 3.77 pods per plant (Table 5).

Result in Yola, revealed that Accession 6 and Accession 5 recorded the highest number of 21.00 and 13.40 fruits per plant while Accession 3 and Accession 7 recorded the least number of 6.30 and 2.65 number of pods per plant (Table 5). Result on fruit length showed significant differences among the Accessions under studies. Statistically maximum pod length of 19.73 cm and 16.7 cm was found in Accession 1 and Clemson spineless in Guyuk while the minimum pod length of 6.50 cm and 6.30 cm was recorded in Yola local and Accession 7.

Table 3: Effect of powdery mildew on height of Okra Accessions during 2016 rainy season in Yola and Guyuk

	Height (cm) at WAS					
	Guyuk		Locations		Yola	
Accessions	4WAS	6WAS	10WAS	4WAS	6WAS	10WAS
Accession 1	7.90^{a}	97.9^{a}	104.0^{a}	7.83^{a}	14.57^{b}	89.0^{a}
Accession 2	2.50^{ab}	33.6^{bc}	33.2^{bc}	7.74^{a}	16.33^{a}	40.0^{b}
Accession 3	4.53^{bc}	91.3^{a}	93.5^{a}	7.05^{b}	19.70^{a}	83.1^{a}
Accession 4	5.27^{bc}	42.3^{ab}	38.6^{ab}	4.93^{ab}	11.83^{b}	39.0^{b}
Accession 5	5.37^{bc}	75.9^{b}	72.4^{b}	10.00^{a}	23.03^{a}	98.1^{a}
Accession 6	4.23^{bc}	34.7^{bc}	37.1^{bc}	4.37^{ab}	8.96^{b}	72.5^{ab}
Accession 7	3.97^{ab}	31.5^{bc}	31.2^{bc}	3.40^{ab}	8.53^{b}	46.3^{b}
Accession 15	4.87^{bc}	49.4^{ab}	48.8^{ab}	7.03^{bc}	14.63^{b}	35.1^{bc}
Yola Local	5.53^{bc}	22.3^{d}	26.1^{bc}	10.53^{a}	19.30^{a}	38.9^{b}
Clemson spineless	7.03^{a}	38.9^{ab}	29.1^{bc}	4.93^{ab}	13.27^{b}	35.4^{bc}
P<F	<.001	<.001	<0.001	0.007	0.044	0.008
S.E	0.521	6.84	7.21	1.709	4.17	18.28

Key: Means with the same letter(s) in the same column are not significantly different at p = ≤ 0.01 or p < = 0.05 using DMRT.

Table 4: Effect of powdery mildew on number of leaves of Okra Accessions during 2016 rainy season in Yola and Guyuk

	Number of leaves at WAS					
	Locations					
	Guyuk			Yola		
Accessions	4WAS	6WAS	10WAS	4WAS	6WAS	10WAS
Accession 1	5.87[b]	15.67[a]	16.50[bc]	4.73[ab]	12.17[bc]	17.17[bc]
Accession 2	5.13[b]	12.33[b]	23.33[ab]	5.73[a]	15.47[a]	24.17[b]
Accession 3	5.33[b]	13.07[b]	33.00[b]	6.07[a]	17.40[a]	28.67[b]
Accession 4	5.80[b]	20.87[a]	26.50[ab]	4.63[ab]	13.20[bc]	22.17[bc]
Accession 5	4.93[b]	16.00[a]	19.83[bc]	5.67[a]	22.13[a]	31.17[b]
Accession 6	4.00[bc]	21.63[a]	42.67[a]	3.63[bc]	9.36[b]	55.80[a]
Accession 7	4.20[b]	15.77[a]	23.33[ab]	3.73[bc]	8.27[b]	28.17[b]
Accession 15	24.50[a]	6.00[bc]	21.73[ab]	6.60[a]	14.63[ab]	25.50[b]
Yola Local	5.60[b]	15.30[a]	18.00[bc]	6.33[a]	18.47[a]	16.83[bc]
Clemson spineless	5.13[b]	14.33[a]	23.33[ab]	5.63[a]	12.77[bc]	22.50[bc]
P<F	0.026	0.204	<.001	0.604	0.146	0.001
S.E	0.564	3.957	2.847	0.716	4.469	4.194

Key: Means with the same letter(s) in the same column are not significantly different at p = $\leq$ 0.01 or p < = 0.05 using DMRT.

In Yola, Accession 1 recorded the highest fruit length of 16.60 cm followed by Clemson spineless with 16.27 cm while the minimum fruit length of 7.27 cm and 6.30 cm was recorded on Accession 15 and Accession 6 (Table 5).

The result on yield of Okra indicated a highly significant ($p \leq 0.01$) differences in both locations between Accessions. In Yola, It was observed that Accession 5 had the highest mean value of 2130.00 $kgha^{-1}$, followed by Accession 2 with 2012.00 $kgha^{-1}$. The lowest yield value of 168.00 $kgha^{-1}$ was observed on Accession 7 (Table 5).

In Guyuk, Accession 5 recorded the highest yield of 1700. Kgha-1 followed by Accession 1 with 1322 $kgha^{-1}$. The minimum mean value of 534 $kgha^{-1}$ was recorded in Clemson Spineless.

4.4 Effect of Powdery Mildew Disease on the Fruit Weight of Okra, 100 Seed Weight and Number of Seeds in a Pod

Result showed highly significant difference ($p \leq 0.01$) in both locations. In Guyuk, the heaviest green pod was recorded in Accession 5 with 22.99 g followed by Accession 1 with 21.99 g. While the minimum pod weight of 8.31 g and 7.18 g was observed in Accession 6 and Accession 7 (Table 6).

Result in Yola showed that maximum pod weight of 26.88 g was observed in Accession number 5 followed by Clemson spineless with 16.71 g while Accession 4 and Accession 7 recorded the minimum pod weight of 6.50 g and 4.48 g respectively (Table 6).

Accession 15 and Accession 4 recorded the highest seed weight of 5.6 g and 5.6 g in Guyuk while minimum seed weight of 4.2 g and 3.9 g was observed in Clemson spineless and Accession 5. In Yola, the maximum seed weight of 5.6 g was recorded in Accession 15 while the minimum seed weight of 4.7 g was observed in Accession 5 followed by 4.0 g in Accession 6

In Guyuk the Accession that gives the highest number of seed in a pod is Accession 4 followed by Accession 3 with an average of 138.3 and 111.0 seeds per pod. The minimum number of seeds per pod was observed in Accession 1 followed by Yola local with an average of 66.2 and 59.8 seeds per pod. In Yola, Accession 5 recorded the maximum number of seed in a pod with the mean value of 123.3 seeds per pod.

Table 5: Effect of powdery mildew on number of fruit/plant and yield of Okra Accessions during 2016 rainy season in Yola and Guyuk

	Locations					
	Guyuk			Yola		
Accessions	No. of fruit/plant	Fruit Length (cm)	Yield (Kg/ha^{-1})	No. of Fruit/Plant	Fruit length (cm)	Yield (Kg/ha^{-1})
Accession 1	13.0^{b}	19.73^{a}	1322^{a}	8.0^{bc}	16.60^{a}	899^{b}
Accession 2	15.0^{b}	7.90^{ab}	792^{ab}	10.0^{bc}	7.40^{ab}	2012^{a}
Accession 3	10.0^{ab}	9.13^{bc}	671^{ab}	6.0^{ab}	9.27^{b}	719^{b}
Accession 4	14.0^{b}	8.27^{bc}	900^{ab}	7.0^{ab}	7.60^{ab}	525^{b}
Accession 5	11.0^{b}	7.47^{ab}	1700^{a}	13.0^{bc}	7.30^{ab}	2130^{a}
Accession 6	23.0^{a}	6.50^{ab}	642^{ab}	21.0^{a}	6.30^{ab}	971^{b}
Accession 7	5.0^{bc}	6.30^{ab}	625^{ab}	2.0^{c}	7.73^{ab}	168^{bc}
Accession 15	12.0^{b}	7.80^{ab}	1167^{b}	8.0^{ab}	7.27^{ab}	763^{b}
Yola Local	13^{b}	7.27^{ab}	1055^{b}	7.0^{ab}	8.47^{b}	991^{b}
Clemson spineless	3^{bc}	12.90^{b}	534^{bc}	8.0^{bc}	16.27^{a}	683^{b}
P<F	0.001	0.001	<.001	0.01	0.001	0.003
S.E	2.437	0.576	2140	2.633	0.558	407.5

Key: Means with the same letter(s) in the same column are not significantly different at $p = \leq 0.01$ or $p < = 0.05$ using DMRT.

Table 6: Effect of Powdery Mildew on Fruit Weight, 100 Seed Weight And Number of Seed in Pod of Okra Accessions Assessed During 2016 Rainy Season in Yola and Guyuk

	Locations					
	Guyuk			Yola		
Accessions	Fruit Weight(g)	100 Seed Weight (g)	No.of Seed/pod	Fruit Weight (g)	100 Seed Weight (g)	No.of Seed/pod
Accession 1	21.99[a]	5.167[a]	75.0[ab]	12.07[ab]	5.5[a]	68.5[bc]
Accession 2	8.38[bc]	5.333[a]	95.0[bc]	16.57[b]	5.4[a]	96.8[b]
Accession 3	18.51[b]	5.53[a]	111.0[bc]	8.39[bc]	5.5[a]	99.3[b]
Accession 4	10.54[bc]	5.633[a]	66.2[c]	6.50[cd]	5.6[a]	63.0[bc]
Accession 5	22.99[a]	3.900[b]	138.3[a]	26.88[a]	4.7[b]	123.3[a]
Accession 6	8.31[bc]	4.30[b]	105.5[b]	12.05[ab]	4.0[c]	97.7[b]
Accession 7	7.18[cd]	4.50[a]	96.7[bc]	4.48[d]	4.8[b]	115.8[ab]
Accession 15	15.61[ab]	5.60[a]	96.5[bc]	8.07[bc]	5.6[a]	100.2[b]
Yola Local	15.41[ab]	5.36[a]	59.8[c]	6.61[cd]	5.5[a]	61.3[bc]
Clemson spineless	9.70[bc]	4.23[b]	92.8[ab]	16.71[b]	5.6[a]	95.7[b]
P<F	0.001	0.001	0.001	0.001	0.001	0.001
S.E	1.259	0.3160	8.38	0.867	0.1534	6.98

Key: Means with the same letter(s) in the same column are not significantly different at p = ≤ 0.01 or p < = 0.05 using DMRT.

123.3 followed by Accession 7 with 115.8 seeds in a pod. While minimum number of seed in a pod was recorded in Accession 4 followed by Yola local with the mean value of 63.0 and 61.3 seeds in a pod (Table 6).

4.5 Incidence of Powdery Mildew Disease of Okra in Yola North and Guyuk during 2016 Rainy Season

The result on the incidence of powdery mildew disease on the performance of okra Accessions in Guyuk shows highly significant difference ($p<0.01$) among the okra Accession. At 5 WAS the highest mean value of disease incidence was recorded in Yola local (14.2 %) followed by Accession 1 (10.2 %) and Clemson spineless with 8.26 (Table 7). The lowest mean value for the incidence was recorded in Accession number 2 (3.73 %) and Accession 7 (3.8 %). At 8 WAS the highest disease incidence was recorded in Yola local (42.6 %) follow by Accession 1 with (33.9 %). Accession 6 recorded the lowest value for disease incidence of (10.2 %) followed by Accession 5 (11.0 %), Accession number 4 (11.5 %) and Accession 7 (11.9 %). At 9 WAS, Yola local recorded the highest disease incidence of 66.5 % followed by 52.4 % in Clemson spineless. The lowest disease incidence value recorded in Guyuk is observed in Accession 6 (19.7 %) and Accession 4 (18.0 %). Accession 7 and Accession 5 also recorded lower disease incidence values of 19.3 % and 19.9 % respectively (Table 7).

The result obtained on the incidence of powdery mildew disease of okra Accessions in Yola are presented in (Table 7). There is a significant difference ($p<0.05$) at 5 WAS to 9 WAS. Clemson spineless recorded the highest value of 15.73 % at 5 WAS follow by Yola local with 13.33 %. At 6 WAS Yola local recorded the highest mean value of 34.7 % followed by Clemson spineless with the mean value of 32.3 % while Accession 4 and Accession 7 had the lowest mean value of 12.0 % and 12.8 % (Table 7). At 8 WAS, Yola local recorded the highest mean value of 70.8 % follow by Clemson spineless with 67.5%.The lowest incidence recorded at 10 weeks after sowing was in Accession 7 (22.7 %) and Accession 4 (23.9 %). Accession 2, Accession 15, Accession 3 and Accession 1 recorded 30.5 %, 32.7 %, 36.4 % and 36.4 % disease incidence percentage. At 9 WAS Yola local and Clemson spineless recorded the highest disease incidence value of 84.3 % and 79.2 %.The lowest value of disease incidence in Yola at 9 weeks after sowing was observed in Accession 7 (32.9 %) followed by Accession 4 (39.2 %) and Accession 2 with (41.1 %).

Table 7: Effect of Powdery Mildew Disease on Incidence of Okra Accessions during 2016 Rainy Season in Yola and Guyuk

	Incidence at WAS									
	Locations									
	Guyuk					Yola				
Accessions	5WAS	6WAS	7WAS	8WAS	9WAS	5WAS	6WAS	7WAS	8WAS	9WAS
Accession 1	10.2^{a}	21.61^{b}	27.0^{b}	33.9^{a}	43.8^{ab}	4.36^{ab}	13.8^{bc}	22.9^{b}	36.4^{b}	54.9^{bc}
Accession 2	3.73^{bc}	8.73^{ab}	13.3^{bc}	14.5^{bc}	25.4^{bc}	8.1b^{c}	17.0^{b}	26.9^{b}	30.5^{b}	41.1^{b}
Accession 3	3.86^{bc}	10.46^{ab}	14.6^{bc}	18.3^{bc}	27.9^{bc}	7.86^{bc}	17.5^{b}	26.8^{b}	34.6^{b}	48.8^{b}
Accession 4	3.9^{bc}	7.06^{ab}	11.7^{ab}	11.5^{bc}	18.0^{bc}	4.5a^{b}	12.0^{bc}	19.5^{b}	23.9^{bc}	39.2^{b}
Accession 5	7.2^{ab}	7.51^{ab}	10.0^{ab}	11.0^{bc}	19.9^{bc}	9.16^{bc}	23.6^{ab}	30.1^{b}	43.0^{b}	53.7^{bc}
Accession 6	6.4^{ab}	5.67^{ab}	5.9^{c}	10.2^{bc}	17.4^{bc}	8.86^{bc}	22.4^{ab}	25.5^{b}	39.4^{b}	43.4^{b}
Accession 7	3.8^{bc}	7.13^{ab}	10.4^{ab}	11.9^{bc}	19.3^{bc}	5.93^{ab}	12.8^{b}	15.0^{ab}	22.7^{bc}	32.9^{b}
Accession 15	4.5^{bc}	9.99^{ab}	14.4^{bc}	18.3^{bc}	32.4^{ab}	8.86^{bc}	19.1^{b}	23.0^{b}	32.7^{b}	47.0^{b}
Yola Local	8.26^{ab}	19.74^{b}	36.7^{a}	33.7^{a}	52.4^{a}	13.33^{b}	34.7^{a}	51.7^{a}	70.8^{a}	84.3^{a}
Clemson spineless	14.2^{a}	29.93^{a}	27.6^{b}	42.6^{a}	66.5^{a}	15.73^{a}	32.3^{a}	54.3^{a}	67.5^{a}	79.2^{a}
P<F	0.051	<.001	0.001	<.001	<.001	0.001	0.008	0.001	0.004	0.008
S.E	2.69	4.26	4.61	5.03	9.14	1.6655	5.70	6.94	11.16	12.29

Key: Means with the same letter(s) in the same column are not significantly different at p = ≤ 0.01 or p < = 0.05 using DMRT.

Table 8: Effect of Powdery Mildew Disease on Severity of Okra Accessions during 2016 Rainy Season in Yola and Guyuk

	Severity at WAS									
	Locations									
	Guyuk					Yola				
Accessions	5WAS	6WAS	7WAS	8WAS	9WAS	5WAS	6WAS	7WAS	8WAS	9WAS
Accession 1	19.42[a]	55.0[a]	61.3[a]	70.7[a]	73.6[a]	13.88[c]	40.0[b]	49.7[b]	68.1[a]	73.6[a]
Accession 2	13.88[b]	20.0[ab]	35.2[b]	41.6[b]	50.0[b]	13.88[c]	26.7[b]	41.2[b]	51.3[b]	62.5[ab]
Accession 3	15.27[b]	26.7[bc]	30.4[b]	36.0[b]	41.3[ab]	12.49[c]	33.3[bc]	48.6[b]	54.1[b]	59.7[bc]
Accession 4	9.72[b]	23.3[bc]	30.7[b]	38.8[b]	43.1[ab]	29.16[a]	28.3[bc]	32.5[bc]	47.2[bc]	56.9[bc]
Accession 5	11.11[b]	25.0[bc]	33.6[b]	45.8[b]	51.4[b]	13.88[c]	30.0[bc]	40.2[b]	52.7[b]	61.1[b]
Accession 6	16.65[b]	18.3[ab]	24.1[bc]	27.7[bc]	30.4[bc]	15.27[c]	34.0[bc]	32.3[bc]	48.6[bc]	52.8[b]
Accession 7	9.71[bc]	23.3[bc]	22.1[bc]	25.0[bc]	37.5[bc]	12.49[c]	26.7[b]	34.7[bc]	38.9[b]	45.8[c]
Accession 15	25.82[a]	35.3[b]	41.4[ab]	47.2[b]	52.8[b]	8.33[ab]	28.3[bc]	36.9[c]	47.2[bc]	45.8[c]
Yola Local	13.88[b]	30.0[b]	68.0[a]	47.2[b]	54.2[b]	33.33[a]	60.0[a]	48.6[b]	76.4[a]	86.6[a]
Clemson spineless	26.88[a]	37.7[b]	56.7[a]	79.8[a]	84.7[a]	20.83[b]	41.7[b]	63.2[a]	76.4[a]	80.6[a]
P<F	0.001	0.002	0.001	<.001	<001	0.001	0.124	0.022	0.035	0.023
S.E	6.92	8.61	8.71	8.83	9.09	5.48	10.63	7.95	11.16	10.21

Key: Means with the same letter(s) in the same column are not significantly different at $p = \leq 0.01$ or $p < = 0.05$ using DMRT.

4.6 Severity of Powdery Mildew Disease of Okra Accessions in Yola North and Guyuk during 2016 Rainy Season

Data on disease severity are presented in (Table 8). Highly significant differences ($p<0.01$) among the Accessions under studies were recorded in both Yola North and Guyuk with the disease severity value ranging from 8.33 % to 86.6 % in Yola North and 9.71% to 84.7 % in Guyuk.

The result on the performance of okra in Guyuk shows that there is a highly significant difference ($p<0.01$) in the increase of powdery mildew disease severity among the Accession of okra from 5 WAS to 9 WAS. Accession 15 recorded the mean value of 45.8% at 5 WAS follow by Yola local which recorded 26.38 %.At 6 WAS the highest severity value of 56.7 % was recorded in Yola local followed by Accession 1 with 55.0 %. Accession 6 recorded the lowest severity value of 18.3 % followed by Accession 2 with the mean value of 20.0 %. At 8 WAS, Yola local recorded the highest severity value of 79.8 % followed by Accession 1 with 70.7 % while Accession 15 and Clemson spineless both recorded severity values of 47.2 %.The lowest value was obtained in Accession number 7 (25.0 %) follow by Accession 6 (27.7 %). At 9 WAS the highest severity value of powdery mildew disease was observed in Yola local (84.7 %) followed by Accession 1 with the mean value of 73.6 % while the lowest severity value of 30.3 % and 37.5 % was observed in Accession 3 and Accession 7.

In Yola, Yola local recorded the highest severity value of 33.33 % follow by Clemson spineless with 20.83 at 5 WAS. At 6 WAS the highest severity value was obtained in Yola local with the value of 60.0 % followed by Clemson spineless with the mean value of 41.7 % and Accession 1 with 40.0 % at (Table 8).The lowest mean value recorded was in Accession 2 and Accession 7 both recording 26.7 % followed by Accession 4 and Accession 15 both recording 28.3 % disease severity percentage. At 8 WAS, Yola local and Clemson spineless recorded the same severity values of 76.4 % followed by Accession 1 (68.1 %).The lowest severity values obtained at 8 WAS are recorded in Accession 7 (38.9 %) followed by Accession 4 and Accession 15 which recorded the same severity values of 47.2 % (Table 8). At 9 WAS, Yola local recorded the highest severity value of 86.6 % followed by Clemson spineless 80.6 % and Accession 1 with 73.6 %. Accession 7 and Accession 6 recorded the lowest severity values of 45.8 % and 52.8 %.

Plate III: Leaves of okra infected by powdery mildew disease

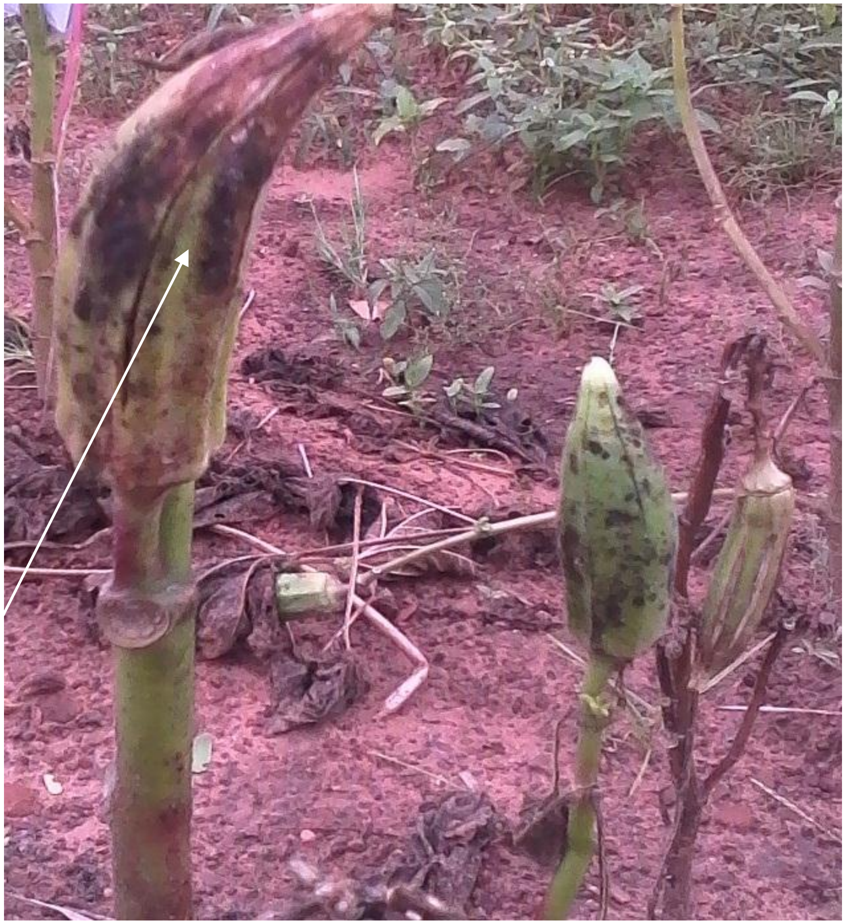

Plate IV: Okra fruits infected by Powdery mildew pathogen

Plate IVa: Accession 1 leaf showing chlorotic symptoms of powdery mildew disease

Plate IVb: Accession 6 showing necrotic symptoms of powdery mildew disease

Plate IVc: Chlorotic leaf covered with mycelium after pathogenicity test.

CHAPTER FIVE

DISCUSSIONS

It has been reported that optimum plant population and seedling establishment is the key element for higher yields of okra in the field (Usman, 2001). Result on days to 50 % flowering showed a variation in the number of days to 50 % flowering among the 10 Accessions. In this study Accession 2 came to flowering earlier in Yola followed by Accession 1. In Guyuk, Accession 1 came to flowering earlier follow by Yola local. A similar behavior among the okra cultivars for days to flowering was also reported by Hossain and Ashratul (2006). The differences on days to 50 % flowering on the other hand may be as a result of premature leaf loss due of powdery mildew disease which affects the formation of flowers in the study area.

The number of branches per plant varied among the Accessions and locations in this study. Most of the Accessions showed branching in both locations, but Accessions in Yola produced more number of branches than in Guyuk. Accession 6 recorded the highest number of branches in Yola and Guyuk. This finding agrees with the report given by NIHORT (1980) that as the number of branches increases the number of fruit per plant also increase which also leads to the reduction in weight of okra. In Yola, the minimum number of branches per plant was observe in Clemson spineless while in Guyuk, the minimum number of branches per plant was observe in Accession 3.

Record of average plant height reveals that there is considerable variation between the height of these varieties at different weeks after sowing in both Yola and Guyuk. The result reveals that Accession 1 and Accession 5 are the tallest in both locations while Accession 2 and Clemson spineless are the shortest. According to Akinyele and Osekita (2006) plant height at maturity, among other morphological traits, is one of the most variable traits of okra that are necessary for selection program aimed at improving desirable traits. Stephen (2005) reported that stunted growth due to shortening of the internodes and leaves forms brown color is as result of powdery mildew disease.

Leaves play a very important role in plant photosynthesis. Heavily infected leaves turn yellow, then become brown and finally dry as a result of powdery mildew disease. Records in both locations revealed that Accession 1 and Yola local had the minimum number leaves per plant in Guyuk and Yola. Results on disease severity indicated that Accession 1 recorded higher severity value of in both locations. Data on yield showed that Accession 1 recorded better yield in both locations despite the disease severity on the Accessions. This might likely be as a result disease recovering resistance shown by the Accessions in both locations. This finding agrees with reports given by Singh (1995) that Yield reduction from defoliation is proportional to the severity and length of time leaves are infected.

Significant variabilities for number of fruit per plant in different Okra Accessions was observed in both locations. Results in both locations shows that Accession 6 recorded the highest number of fruit per plant in both locations respectively followed by Accession 5 in Yola and Accession 2 in Guyuk. This may likely be as result of moderate resistant shown by the Accessions. Accession 7 recorded minimum number of fruit per plant for Yola and Guyuk respectively. This result agrees with findings given by Bello *et al* (2006) who reported that variability for pod per plant in different okra cultivars might be due to the genetic characteristics and adaptability of these cultivars to the environmental conditions of the area. This may likely be the reason for production of reasonable number of fruits per plant by Accession 2 in Yola and Accession 4 in Guyuk, despite showing some level of susceptibility to powdery mildew disease in the study area.

Okra pod is considered as the most economical part of its production and pod length, along with pod number and pod weight are the most important factors determining its production. Result from this study showed significant relationship for fruit length among the genotypes in both locations. Result in both locations shows that Accession 1 and Clemson spineless recorded the highest pod length in both in both locations. This finding agrees with report given by Ashratul and Hossain (2006) that increase in pod length might be due to better interaction of genetic make-up of cultivar to the prevailing environmental conditions. It is evident from this study, that Accession 1 and Clemson spineless recorded the highest fruit length despite the pressure of powdery mildew disease recorded by the Accessions.

Results on the yield of okra in both locations show a significant difference among the Accessions. In Guyuk Accession 5 and Accession 1 recorded the highest yield of while the minimum yield of pod was observed in Clemson spineless and Accession 7. Result in Yola revealed that Accession 5 and Accession 2 recorded the highest yield while the minimum yield was noted in Accession 4 and Accession 7. Ashratul and Hossain,(2006) reported that the number of pods per plant, the weight of pod per plot and due to the genetic makeup and more adoptability of cultivar towards the climatic condition of the areas can affect the yield of okra.

Powdery mildew disease have been reported to be responsible for decrease in plant canopy, thereby reducing yield through decreased in fruit size, fruit quality and flavor (Donald, 2008). Result obtained from this study in both locations revealed that there was a highly significant relationship between number branches per plant, number of leaves per plant, severity of powdery mildew disease on the weight of okra in both locations. In both locations Accession 5 recorded the highest fresh fruit weight of per plant in Yola and Guyuk .The lowest value recorded for fresh fruit weight in both locations was observed in Accession 7 in both locations respectively. Results on severity of powdery mildew in both locations shows that Accession 5 weights much higher than Accession 7 despise showing moderately level of susceptibility to powdery mildew disease. This study confirmed the findings by Katung (2007) who reported that changes in environmental condition influence the growth and performance of okra.

Good seed quality, seed yield and seed germination have adverse effects on the yield of okra (Odofin, 2010). Records on 100 seed weight shows significant relationship between the number of fruit per plant, number of branches per plant, weight of okra and the weight of seeds among the Accessions in both locations. Result in both locations revealed that Accession 6 recorded the highest number of branches in Guyuk and Yola respectively and maximum number of fruits per stand in both locations. Results in Yola shows that Accession 6 recorded the lowest 100 seed weight value while in Guyuk, Clemson spineless and Accession 6 recorded the least 100 seed weight value. This study collaborates with the annual report given by NIHORT (1980) that the number of branches per plant can increase the number of fruit per plant and reduce fruit weight, seed weight and number of seeds in a pod.

The number of seeds in a pod is very important because seeds of okra are rich in phenolic compounds with important biological properties (Arapitsat, 2008).The dried okra seed can be roasted and ground to be used as coffee substitute (Moyin-Jesu, 2007). Result in this study revealed a highly significant difference in the number of seeds in a pod in both locations. In both locations, Accession 5 recorded the highest number of seed in a pod in both locations. The minimum number of seeds in a pod was observed in Yola local in both locations. This might probably be as result of high severity values recorded in the genotype in both locations. Thapa *et al.*, (2012) reported that seed quality can also affect the yield of okra. This may likely be the reason for lower number of seeds in a pod in the genotype Yola local as evident in both locations.

The result on percentage incidence of powdery mildew indicated that there was a lot of variation with respect to the incidence and severity of powdery mildew as observe among the Accessions in both locations. In Yola, Accession 4 and Accession 7 recorded the lowest incidence of disease from 5 WAS-9 WAS with the mean incidence of while the highest incidence was observed in Yola local followed by Clemson spineless

The result observed in Guyuk shows that the lowest incidence of disease from 5 WAS -9 WAS was recorded in Accession 6 and Accession 4. The highest value for disease incidence was recorded in Yola local and Clemson spineless .These result agrees with the findings of Anitha (2007) who reported that the variations of disease incidences in various localities is mainly attributed to the climatic factors like temperature, relative humidity and distribution and amount of rainfall followed by cultural practices like sanitation and other suitable management practices.

Result on severity of powdery mildew disease of okra in both locations shows a gradual increase in severity of the disease over time. There is a significant variation in the performance of the 10 okra Accessions from 5 WAS-9 WAS. Accession 3 was observed to have less disease severity values in Guyuk at 9 WAS as compared to other varieties in Guyuk. The study also shows that Accession 7 recorded the less disease severity values in Yola at 9 WAS as compared to other Accessions. This finding agrees with the report given by Hussan *et al* (2000) that resistance against powdery mildew disease of okra cultivar is due to 2 gene pairs- a recessive gene and an incompletely dominant gene with the genotype designed as aaBB. Bhattacharya *et al* (2000) also reported that more concentration of phenolase and catalase in cultivars is the reason for resistance to powdery mildew disease of okra.

Result on the severity of powdery mildew disease shows that Yola local recorded the highest disease severity values in Yola and Guyuk. Singh (2001) reported that the fungus that causes powdery mildew disease can sporulate and cause infection in a very dry as well as wet atmosphere but infection increases with increase in atmospheric humidity. Severity of disease decrease plant canopy, reduce yield and number of fruits per plant, reduce fruit quality, flavor and storage life (Donald, 2008).

The development of powdery mildew disease is directly related to atmospheric temperature, relative humidity and amount of rainfall. In current climatological studies, there is a positive correlation between the powdery mildew disease incidence and severity with maximum temperature, relative humidity and rainfall on the Accessions under studies. It was observed that all the Accessions were significantly correlated with environmental factors and disease severity increase with increased in environmental factors. The incidence of powdery mildew disease in the month of August was not much in both locations when the relative humidity is above 90% in both locations. Data collected shows that at Guyuk, the severity values is much lower compared to Yola in the month of August. This work have agreed with the report given by Singh (2001) that the fungus that causes powdery mildew can sporulate and cause infection in a very dry as well as wet atmosphere but infection increase with increase in atmospheric humidity. Yanar and Gebologlu (2013) also reported that the most favorable condition for powdery mildew is relative humidity of 90-99 %. Data collected in Yola shows that there is an increase in the amount of rainfall. Incidence ranges from 15.0-84.3 % during the month of September when the rainfall is around 67.5mm and relative humidity of 92.3 %. Results in Guyuk shows that as the rainfall decreases, there is also a decrease in relative humidity which also affects the incidence and severity of powdery mildew disease severity as compared to Yola. This also agreed with the report given by Anitha (2007) that variation of disease incidence in various localities is mainly attributed to the climatic factors like temperature, relative humidity and amount of rainfall. This shows that the occurrence and disease severity depend upon the season and sowing period.

CHAPTER SIX

Summary, Conclusion and Recommendations

6.1 Summary

A comparative study on the reaction and performance of some selected okra Accessions to powdery mildew disease under field conditions was under taken during the 2016 rainy season on ten (10) Accessions of okra sourced from National Horticultural Research Institute (NIHORT), National Center for Genetic and Biotechnology (NACGRAB) and one locally sourced from Yola Market. This study was carryout to determine the incidence and severity of the selected Accessions by the disease, to isolate the pathogen that causes the disease, to evaluate the reaction of the different Accessions to powdery mildew pathogen and to evaluate and compare the performance of the Accessions under diseased condition and identify the Accessions that could be resistant or tolerant to powdery mildew disease for possible recommendation to farmer and researchers. Records on days to 50% flowering shows that Accession 1 and Accession 4 came to flowering earlier in both locations followed by Accession 2 in Guyuk and Clemson spineless in Yola. Data on number of branches shows that Accession 6 recorded the highest number of branches in both locations.

Data on plant height and number of leaves showed that Accession 1 and Accession 5 and are the tallest Accessions while Accession 6 and Accession 3 had the highest number of leaves per plant in both locations.

Results on number of fruit per plant reveal that Accession 6, recorded the highest number of fruit per plant in both locations. Followed by Accession 2 and Accession 4 in Guyuk and Accession 5 and Accession 2 in Yola. Data on fruit length showed that Accession 1 recorded the highest fruit length follow by Clemson spineless in both Guyuk and Yola. Result on 100 seed weight showed that Accession 4 and Accession 15 recorded the maximum weight in both locations.

Record on disease severity in both locations, revealed that Accession 7, Accession 6, Accession 3 and Accession 15 had the least percentage severity of powdery mildew disease.

Results on fruit yield showed that Accession 5 recorded the highest fruit yield in both locations. In Guyuk, Accession 1 and Accession 15 also recorded a better yield. While Accession 2 and Accession 6 also recorded higher yield.

This study revealed that okra Accessions, Accession 6, Accession 7, Accession 3 and Accession 15 were found to be tolerant to powdery mildew disease in both Guyuk and Yola.

6.2 Conclusion

Powdery mildew is an important disease of okra. It causes severe losses in yield as evident from the study in both locations. The result on the study revealed that all the Accessions were infected by the powdery mildew disease at various stages of the plant growth with varying degrees of severity. Wide variability in number of fruits per plant, fruits length, days to 50% flowering, plant establishments and yield exist among the Accessions in both locations. Based on the level of disease severity, the Accessions were classified in three groups. In Guyuk, Accession 6 and Accession 7 was classified as moderately resistant (MR), Accession 2, Accession 3, Accession 5, Accession 15 and Clemson spineless, moderately susceptible (MS) while Accession 1, susceptible (S) and Yola local, highly susceptible (HS). In Yola, Accession 3, Accession 4, Accession 6, Accession 7 and Accession 15 was classified as moderately susceptible (MS). Accession 1, Accession 2, Accession 5 and Clemson spineless, susceptible (S) while Yola local was classified as highly susceptible (HS). However, some of the Accessions like Accession 5, Accession 2 and Yola local were able to give better yield despite the disease severity. Accession 7 recorded few numbers of fruit per plant and low yield despite showing moderate resistant and moderate susceptibility to powdery mildew disease in both locations.

6.3 Recommendations

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

1. Accession 1, Accession 2, Accession 5, and Clemson spineless should be further tested to ascertain their level of tolerance to the disease in the study area
2. Accession 7 should be considered for breeding work to improve on its yield because of its moderate resistant to powdery mildew disease.
3. Resistant Accessions should be used directly for conventional breeding to incorporate the desired attributes in the otherwise good genotypes by following good horticultural practices
4. Adjustment of planting dates should be carry out in order to minimize losses due to powdery mildew disease as this will help avoid coincidence with susceptible stage of the crop ,thus resulting to diseases escape.

5. Further screening to powdery mildew disease should be done with more Accessions and other locally grown cultivars in the study area

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APPENDIX 1**: Mean Squares of the Effect of Powdery Mildew on days to 50% Flowering and Number of Branches of Okra Accessions during 2016 Rainy Season**

Location (Guyuk)				Location (Yola)		
Source of variation	Df	Days To 50% Flowering	No of Branches	D.F	Days To 50% Flowering	No of Branches
Rep	2	5.43	10.033	2	24.10	20.433
Accessions	9	1538.90**	17.807**	9	1552.89**	8.889**
Error	18	11.14	41.44	18	18.77	5.565
Total	29			29		

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 2: Mean Squares of the Effect of Powdery Mildew on Height of Okra Accessions during 2016 Rainy Season

Location (Guyuk)					Location (Yola)			
Source of variation	Df	Height at 4 WAS	Height at 6 WAS	Height at 10WAS	D.f	Height at 4 WAS	Height at 6 WAS	Height at 10 WAS
Rep	2	0.7680	38.61	27.52	2	24.299	16.08	974.4
Accessions	9	7.0105*	2143.82*	2409.91*	9	16.897*	66.18*	1879.2*
Error	18	0.4076	70.08	78.06	18	4.482	26.09	501.1
Total	29				29			

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 3: Mean Squares of the Effect of Powdery Mildew on Number of leaves of Okra Accessions at WAS during 2016 Rainy Season

Location (Guyuk)					Location (Yola)			
Source of variation	Df	4 WAS	6 WAS	10 WAS	D.F	4 WAS	6 WAS	10 WAS
Rep	2	0.3720	15.65	67.72	2	2.3803	57.01	13.88
Accessions	9	1.3807	36.43	177.75**	9	3.2571*	52.88*	368.14**
Error	18	0.4772	23.48	12.16	18	0.7700	27.96	26.38
Total	29				29			

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 4: Mean Squares of the Effect of Powdery Mildew on Number of fruit/plant, Fruit Length and Yield of Okra Accessions during 2016 Rainy Season

Location (Guyuk)						Location (Yola)		
Source of variation	Df	No of Fruits/Plant	Fruit Length (cm)	Yield (kg/ha^{-1})	D.F	No of Fruits/Plant	Fruit Length (cm)	Yield (kg/ha^{-1})
Rep	2	25.040	0.1743	206201	2	6.79	0.0490	229308
Accessions	9	84.894**	50.48228**	12403**	9	73.09**	42.8216*	1156976
Error	18	9.321	0.4980	68668	18	10.42	0.4664	249108
Total	29				29			

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 5: Mean Squares of the effect of Powdery Mildew on Fresh Weight, 100 seed Weight and Number of Seed in a Pod of Okra Accession Assessed during 2016 Rainy Season

Location (Guyuk)					Location (Yola)			
Source of variation	Df	Fresh Weight (g)	100 Seed Weight (g)	No of Seed in a Pod	D.F	Fresh Weight (g)	100 Seed Weight (g)	No of Seed in a Pod
Rep	2	4.683	0.1323	100.4	2	0.738	0.07900	215.86
Accessions	9	103.471**	1.278*	1568.2**	9	136.136**	0.85096	1357.54**
Error	18	3.22	113.8	105.4	18	1.133	0.03530	73.12
Total	29				29			

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 6: Mean squares of the effect of Powdery Mildew on incidence of Okra Accessions at WAS during 2016 Rainy Season

Location (Guyuk							Location (Yola)					
Source of variation	Df	5WAS	6WAS	7WAS	8WAS	9WAS	D.f	5 WAS	6 WAS	7WAS	8 WAS	9 WAS
Rep	2	0.361	22.23	171.87	100.81	258.8	2	3.514	79.69	171.87	68.3	103.6
Accessions	9	14.416	198.00**	511.29**	413.07**	840.7**	9	13.869	184.56*	511.29**	819.6*	226.7*
Error	18	8.99	27.17	72.17	57.88	125.3	18	10.76	48.68	186.9	68.3	33.4
Total	29						29					

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 7: Mean Squares of the Effect of Powdery Mildew on Severity of Okra Accession at WAS during 2016 rainy Season

Location (Guyuk)							Location (Yola)					
Source of variation	Df	5 WAS	6 WAS	7WAS	8WAS	9WAS	D.F	5 WAS	6 WAS	7 WAS	8 WAS	9WAS
Rep	2	4.042	790.8	21.96	204.5	101.7	2	85.097	326.8	145.3	229308	97.7
Accessions	9	42.732	568.1	1853.89**	900.4**	807.4**	9	60.763	317.0*	504.9*	1156976	466.2*
Error	18	22.33	111.2	83.81	116.8	123.9	18	36.44	169.6	186.7	249108	156.2
Total	29						29					

*=Significant (p=0.05), **= highly significant (p=0.01) and ns= not significant

APPENDIX 8: Weather Data for Guyuk and their corresponding Rainfall, Temperature and Relative Humidity during 2016 season

Month	WAS	Rainfall(mm)	Temperature(^{O}C)	RH(%)
August	3	10.2	24.4	91.2
	4	6.8	25	91.0
	5	13.42	25.4	90.2
	6	15.6	26	92.4
		Total=45.42	×=25.2	×=91.2
September	7	12.6	26.9	87
	8	8.9	27.4	86
	9	16.6	26.6	85
		Total=38.14	×=26.9	×=86

Source: Agronomy Department, Savannah Sugar Company Limited. Numan, Adamawa State

RH=Relative Humidity

× =Mean

WAS= Weeks after Sowing

%= Percentage

APPENDIX 9: Weather Data for Yola North and their corresponding Rainfall, Temperature and Relative Humidity During 2016 season

Month	WAS	Rainfall(mm)	Temperature(^{0}C)	RH(%)
August	3	13.5	28.3	92
	4	9.3	27.9	91
	5	22.6	25.3	92
	6	4.4	27.7	92
		Total=49.8	×=27.3	×=91.6
September	7	26.4	27.3	92
	8	26.5	29	92
	9	14.6	28	93
		Total=67.5	×=28.1	×=92.33

Source: Geography Department, School of Environmental Sciences, Modibbo Adama University of Technology Yola, Adamawa State.

RH=Relative Humidity

× =Mean

WAS= Weeks after Sowing

%= Percentage