OCCURRENCE, DISTRIBUTION AND EVALUATION OF SOME COWPEA (*VIGNA UNGUICULATA* (L.) WALP) VARIETIES FOR THEIR REACTIONS TO STEM ROT IN NORTH - WEST NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA,IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN CROP PROTECTION.DEPARTMENT OF CROP PROTECTION,FACULTY OF AGRICULTURE,AHMADU BELLO UNIVERSITY, ZARIANIGERIA.

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DECLARATION

I hereby declare that the work in this dissertation titled ‘‘Occurrence, Distribution and Evaluation of Some Cowpea (*Vigna unguiculata* (L.) Walp) Varieties for their Reactions to Stem Rot in North West - Nigeria’’ has been performed by me in the Department of Crop Protection under the supervision of Prof. A. B. Zarafi, Dr. S. E. L. Alao and Prof. O. Alabi. The information derived from literature had been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

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CERTIFICATION

This dissertation entitled OCCURRENCE, DISTRIBUTION AND EVALUATION OF SOME COWPEA (*VIGNA UNGUICULATA* (L.) WALP) VARIETIES FOR THEIR REACTIONS TO STEM ROT IN NORTH - WEST NIGERIA by Ismaila YAKUBU meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my parents, Mal. Yakubu Shuaibu and Juwairiyya Abdulkarim.

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ABSTRACT

Report of damage due to stem roton cowpea in some parts of Kaduna and Katsina States calls for urgent attention in finding possible ways of managing the disease.Knowing the status of the disease will help in employing necessary management strategy as it is a prerequisite to any pest management decision. This research was therefore conducted to determine the incidence, severity and causal organism(s) of cowpea stem rot in North - West Nigeria and evaluate some cowpea varieties for their reactions to the causal organism(s).

The incidence and severity of cowpea stem rot in farmers' fields were assessed in three Local Government Areas each in four cowpea producing states of North - West Nigeria, Kano, Kaduna, Katsina and Zamfara during 2013 and 2014 rainy seasons. The results showed that cowpea fields in Kaduna State had significantly higher incidence (29.09 %) and severity (21.14 %) than those in Kano, Katsina and Zamfara States for the two seasons. Katsina State had the lowest incidence (9.24 %) and severity (7.31 %) of the disease. The fungi isolated from diseased cowpea stem were identifiedas *Rhizoctonia solani,Macrophomina phaseolina*, *Sclerotium* sp., *Colletotrichum capsici, Fusarium solani* and *Curvularialunata*. Pathogenicity of the isolated fungi on susceptible cowpea variety SAMPEA 10 was conducted and only *Rhizoctonia solani* reproduced the typical stem rot symptoms observed on farmers' fields.

Four inoculation methods: soil drench, injury pinprick, spray and millet grain soil inoculations were used to test the progress of the disease with *Rhizoctonia solani*. Symptoms which were reddish brown lesions on stem which later girdle the stem at base were observed when inoculum was introduced through pinprick, soil drench and millet grain but no symptoms were observed on cowpea sprayed with the inoculum.

Six improved cowpea varieties (SAMPEA 7, SAMPEA 8, SAMPEA 9, SAMPEA 10, SAMPEA 11 and SAMPEA 12) two accessions (IAR–00–1074 and IAR–07–1050) and four local varieties (Biu local, Maifarin hanci, Kanannado and Dansokoto) were evaluated in the glasshouse and on the field for their reactions to *R. solani* infection. The *R. solani* induced symptoms of varying incidence and severity on all the 12 cowpea varieties with SAMPEA 10, IAR-07-1050 and Biu local recording the highest incidence and severity while Dansokoto recorded the least incidence and severity in both glasshouse and field. Correlation analysis showed that stem rot incidence and severity significantly lead to reduced number of pods and grain yield.

It is thus concluded that *R. solani* induced stem rot is wide spread in North - West Nigeria with varying incidence and severity influenced by agro ecological location. The use of cowpea varieties:Dansokoto, Kanannado and SAMPEA 12 should be encouraged by farmers in areas where the disease cause economic yield loss.

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CHAPTER ONE

1.0 INTRODUCTION

Cowpea {*Vigna unguiculata* (L.) Walp} is an annual, herbaceous and leguminous plant, with centre of origin and domestication reported to be in Africa (Carlos, 2004). Nigeria is the world largest producer and consumer of cowpea, producing 2.95 million metric tonnes in 2013 (FAOSTAT, 2013). The highest production of cowpea comes from the northern part of Nigeria with most of the production coming from North - East (896.1 metric tonnes) and North - West (577.94 metric tonnes) geopolitical zones (NAERLS and PRSD, 2012). The annual production is high, but the average grain yield per hectare in Nigeria is only 776.31 Kg/ha which though above the average yield worldwide of 521.91 Kg/ha in 2013, but is far lower than yield of 5333.33 Kg/ha and 5132.35 Kg/ha obtained in USA and Occupied Palestinian Territory respectively (FOASTAT, 2013). Singh *et al*. (1997) reported diseases, insect pests and parasitic weeds as the most important factors responsible for low cowpea yield in Nigeria. How to reduce the wide gap between actual and potential yields is the issue that needs to be addressed by both researchers and development workers. Reduction of the gap through research and development efforts can also lead to improvements in household nutritional levels, incomes and protection of the environment through reduced pressure on land.

Stem rot constitute a constraint to cowpea production in Nigeria (Suleiman, 2010). The disease was reported in Sri-lanka (Fernando and Linderman, 1994), Tanzania, Benin, South Africa(Adandonon *et al*., 2003)and Nigeria (Onuorah, 1973; Suleiman, 2010) to be caused by a complex of fungi including species of *Pythium*, *Phytophthora*, *Sclerotium*, *Rhizoctonia*, *Macrophomina* and *Fusarium*. Onuorah (1973) reported yield loss of 11 – 40 % caused by stem rot induced by *Pythium aphanidermatum,* S*clerotium rolfsii* and *Fusarium solani* at Moore plantation, Ibadan.

Stem rot is characterised by reddish brown lesions on the stem at soil level which may extend upward to about the fifth node but rarely to the growing tip. The lesions may girdle the stem at the first node or a little below it. The leaf petioles at the nodes and the basal portion of some side shoots are also invaded by the fungus (Onuorah, 1973).

1.1 Justification of the Study

Cowpea is susceptible to a wide range of insect pests and pathogens, which cause damage to the crop at all stages of growth. Soil and seed - borne fungi are among the pathogens that infect cowpea causing stem and root rot, seedling decay and damping - off complex which result in low yield. Stem rot of cowpea in Nigeria was reported by Onuorah (1973) and Suleiman (2010). Report of incidence of cowpea stem rot by farmers in Sabuwa Local Government Area of Katsina State Nigeria in the 2011 cropping season was made. This was followed by observation of the disease symptoms on research fields of IAR, Samaru (IAR Unpublished report). These reports are indications that the disease is becoming important in North - West Nigeria. However, little or no information is hitherto available on the occurrence and distribution of the disease.

According to Isubikalu *et al*. (2000), most farmers have some knowledge on methods of controlling insect pests but have little knowledge of controlling cowpea diseases. The most frequently used control measure against pests and diseases is by synthetic pesticides usage whose intensive and indiscriminate use in agriculture has caused many problems to the environment. Such problems include water, soil, animals and food contamination; poisoning of farmers; elimination of non-target organisms; and selection of pest and weed tolerance to certain pesticides (Nidhi and Trivedi, 2002). Alternative control measures of plant diseases include cultural control, biological control, regulatory

control and the use of crops resistant to certain pests and diseases. The use of resistant crop varieties is the most economical, easiest, safest and one of the most effective means of managing plant diseases in crops (Agrios, 2005). It is therefore important to give appropriate research attention to finding cowpea varieties resistant to stem rot so as to minimize losses caused by the disease in a manner that will not pose threat to the environment, human and beneficial animals.

1.2 Objectives of the Study

The objectives of this research are to:

i determine the incidence and severity of cowpea stem rot in North - West Nigeria,

ii determine the pathogenicity of fungus associated with the disease and

iii evaluate some cowpea varieties for their reactions to the causal organism.

CHAPTER TWO

2. 0 LITERATURE REVIEW

2. 1 Botanical Description of Cowpea

Cowpea (*Vigna unguiculata* (L.) Walp) is a dicotyledonous annual herb belonging to the family fabaceae,with a strong principal root and many spreading lateral roots in surface soil (Adegbite and Amusa, 2008). Thegrowth forms vary and may be erect, trailing, climbing or bushy, usually indeterminate under favourable conditions. Leaves are alternate and trifoliate usually dark green and first pair of them is simple and opposite. Stems are striate, smooth or slightly hairy, sometimes tinged with purple (Aveling, 1999). Flowers are self-pollinating and may be white, dirty yellow, pink, pale blue or purple in colour. They are arranged in raceme or intermediate inflorescences in alternate pairs. Flowers open in the early day and close at approximately midday, after blooming they wilt and collapse (McGregor, 1976). Fruits are pods that vary in size, shape, colour and texture whichmay be erect, crescent-shaped or coiled, usually yellow when ripe, but may also be brown, black or purple in colour. There are usually 8 - 20 seeds per podand seeds vary considerably in size, shape and colour. The seeds are relatively large, 2-12 mm long and weigh 5 - 30 g/100 seeds as seed shape could be reniform or globular. The testa (the coat covering the grain) may be smooth or wrinkled; white, green, red, brown, black, speckled, blotched, or mottled in colour (Aveling, 1999).

2. 2 Origin and Distribution of Cowpea

Cowpea certainly evolved in Africa, as wild types only exist in Africa and Madagascar (Steele, 1976). Interestingly, while West Africa appears to be the major centre of diversity of cultivated forms of cowpea (Ng and Padulosi, 1988) and was probably domesticated by farmers in this region (Ba *et al*., 2004), the centre of diversity of wild

Vigna species is south-eastern Africa (Padulosi and Ng, 1997). Some evidence that domestication occurred in north eastern Africa, based on studies of amplified fragment length polymorphism (AFLP) analysis, has also been presented (Coulibaly *et al*., 2009). The wild cowpea is the likely progenitor of cultivated cowpea (Pasquet, 1999). The crop was first introduced to India during the Neolithic period, and therefore India is the secondary centre of genetic diversity (Pant *et al*., 1982). "Yardlong beans," a unique cultivar of cowpea that produces very long pods widely consumed in Asia as a fresh green or "snap" bean, evolved in Asia and is rare in the African landrace germplasm. Cowpea has been cultivated in southern Europe at least since the 8th century BC and since prehistoric times (Tosti and Negri, 2002). Cowpea was introduced to the West Indies in the 16th century by the Spanish and was taken to the USA about 1700, presumably it was introduced into South America at about the same time (Purseglove, 1977).

2. 3 Importance and Uses of Cowpea

Cowpea is the most economically important indigenous African legume crop that is of vital importance to the livelihood of people in West and Central Africa. Rural families that make up the larger part of the population of these regions derive from its production, food, animal feed, alongside cash income. Cowpea is a valuable source of protein for human and animal nutrition. It is mainly grown to produce dry grains, but about 25 % is consumed as fodder or marketed as green pods. The grain and fresh peas have high protein content (about 25 % on a dry weight basis) and an amino acid profile that complements the proteins present in rice, millet, maize or wheat. Thus, a combination of 75 % cereal and 25 % cowpea diet, on a dry weight basis, provides sufficient proteins for adults (Cisse and Hall, 2002). Besides, cowpea hay has a higher protein content than

grass hay and thus constitutes a valuable feed for livestock (Tarawali *et al*., 1997). There is a big market for the sale of cowpea grain and fodder in West Africa. In Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season have been found to increase their annual income by 25 % (Dugje *et al*., 2009). Cowpea does not require a high rate of Nitrogen fertilization; its roots have nodules in which a soil bacteria, *Rhizobia* help to fix Nitrogen from the air (Dugjie *et al*., 2009). The crop can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60 - 70 kg ha^{-1} nitrogen for succeeding crop in rotation (Aikins and Afuakwa, 2008). Traditionally in West and Central Africa, cowpea is grown on small farms, often intercropped with cereals such as millet and sorghum. The cereal is planted first, followed by the cowpea. The fast growth and spreading habit of traditional cowpea varieties suppress weeds, and soil Nitrogen is increased which improves cereal growth. The two crops are harvested at different times, distributing available labour force (Carlos, 2004).

Cowpea can be used at all stages of growth as vegetable crop, and the leaves contain significant nutritional value (Ahenkora *et al*., 1998) The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature green pods are used in the same way as snap beans, often being mixed with cooked dry cowpeas or with other foods. Nearly mature "fresh-shelled" cowpea grains are boiled as a fresh vegetable or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning (Tarawali *et al*., 2002). In Nigeria, cowpea is consumed in the form of bean pudding, bean cake, baked beans, fried beans, bean soup amongst others. The industrial uses of cowpea is facing some major constraints: primary processors do not exist; the quality of the grain available in open market is poor, with high percentage of physical defects and risk of pesticide residue contamination; strong price fluctuations

along the years are forcing procurement during a short period; the protein content of available cowpea is low compared to that of soybean (Nyankori, 2002).

2. 4 Nutritional Value of Cowpea

The nutritional profile of cowpea grain is similar to that of other pulses, with a relatively low fat content and a total protein content that is two to four times greater than cereal and tuber crops. In a study of 100 cowpea breeding lines in the IITA collection, seed protein content ranged from 23 to 32 % of seed weight (Nielson *et al*., 1993). Similarly, protein content of 12 West African and United States cultivars ranged from 22 to 29 %, with most accessions having protein content values between 22 and 24 % (Hall *et al*., 2003). It contains about 62 % soluble carbohydrates, and small amounts of other nutrients. Thus, most of its nutritional value is provided by proteins and carbohydrates (Nielson *et al*., 1993). According to Purseglove (1977), dry cowpea seed contains 56.8 % carbohydrate, 23.4 % protein, 11.0 % water, 39.9 % fibre, 3.6 % ash and 1.3 % fat. Cowpea is especially rich in lysine, but it is deficient in sulphurous amino acids. Compared to other legumes, methionine and tryptophan levels are high. Except for total sulphurous amino acids, and to a lesser extent isoleucine, levels of essential amino acids are at least as high as those in soybean (Singh *et al*., 1997). The high protein content represents a major advantage in the use of cowpea in nutritional products, for infant and children's food, and to compensate for the large proportion of carbohydrates often ingested in African diets.

2. 5 World Cowpea Production Trend

Cowpea is grown in 45 countries across the world. An estimated 14.5 million hectares of land is planted to cowpea each year worldwide (CGIAR, 2011). Nigeria is the world largest producer and consumer of cowpea, producing 2.95 million metric tons of dried

grain in 2013. Niger is the second largest producer (1,300000 t) followed by Burkina Faso (580,000 t) Myanmar (177,000 t), Mali (168,274 t), Cameroon (165,350 t), Kenya (122,682 t), Uganda (94,200 t), Mozambique (800,000 t) and Democratic Republic of Congo (80,000 t) The average yield worldwide is estimated at 521.91 kilograms per hectare, the lowest of the major tropical grain legumes (FOASTAT, 2013).

The largest cowpea producing State in Nigeria is Borno which produced 445,770 metric tonne (MT) in 2012. The production estimate for the top 15 cowpea producing States in Nigeria is as shown in Table 1.

2.6 Cowpea Insect Pests

Insect pests and diseases are major constraints to cowpea production in West Africa. The crop is severely attacked at every stage of its growth by a myriad of insects that make the use of tolerant varieties and insecticide sprays imperative. The level of insect attack increases from the southern Guinea savannah towards the Sahel savannah zone. Damage by insect pests on cowpea can be as high as 80–100 % if not effectively controlled (Dugjie *et al*., 2009). Cowpea harbours many pests; the major ones in Nigeria include whiteflies (*Bemisia tabaci* Genn.), maruca (*Maruca vitrata* Geyer), leaf eating beetle (*Ootheca mutabilis* Sahl.), variegated grasshopper (*Zonocerus variegatus* L.), legume bud thrips (*Megalurothrips sjostedti*), spiny brown bugs (*Clavigralla tomentosicolis* Stal.) and aphids (*Aphis craccivora* Koch) (Valenzuela and Smith, 2002). Minor insect pests include leafhopper (*Empoasca dolichi* Paoli.), beanfly (*Ophiomyia phaseoli* Coq.), cotton leaf worm (*Spodoptera littoralis* Boisd.), and blister beetle (*Mylabris* spp.).

Table 1: Estimates of Cowpea Production inNigeria between 2010 - 2012

State	Production Estimates ('1000 MT)		
	2010	2011	2012
Borno	449.92	445.73	445.77
Bauchi	319.36	245.22	244.48
Sokoto	105.70	94.82	95.08
Zamfara	102.99	158.61	160.08
Gombe	84.95	83.53	84.76
Kano	75.77	98.53	98.90
Yobe	73.29	56.30	56.51
Katsina	63.41	68.25	69.03
Kebbi	53.33	55.76	54.70
Kogi	51.58	53.72	55.93
Jigawa	48.74	56.70	56.92
Niger	41.75	49.60	51.6
Kaduna	36.94	42.62	43.23
Taraba	34.95	26.48	29.58
Nasarawa	32.75	46.48	50.84

Sources: NAERLS and NPAFS (2010) and NAERLS and PRSD (2012)

Insect pests are the most constraint in cowpea storage. *Callosobruchus maculatus* Fab. and *Bruchidius atrolineatus* Pic. are the major insect pests of stored cowpea in the tropics causing variety of losses which include decrease in germinability, discoloration and change in taste (Bawa *et al*., 2012).

2.7 Cowpea Parasitic Flowering Plants

Among crop plants, cowpea is perhaps unique in being severely attacked by two species in two genera of parasitic angiosperms, namely *Striga gesnerioides* (Willd.) Vatke and *Alectra vogelii* (L.) Benth. Although both parasites constitute severe constraints to cowpea production in most of the growing regions in sub - Saharan Africa, *S. gesnerioides* is considered the more important of the two. The cowpea strain of *S. gesnerioides* attacks only cowpea but there are wild strains that attack leguminous shrubs while two other strains attack tobacco and sweet potato in certain parts of Africa (Emechebe *et al*., 1991).

2. 8 Cowpea Diseases

Cowpea diseases induced by species of pathogens belonging to various pathogenic groups (fungi, bacteria, viruses and nematodes) constitute one of the most important constraints to profitable cowpea production in all agro ecological zones where the crop is cultivated. The most significant and wide spread cowpea diseases are anthracnose (*Colletotrichum destructivum* O'Gara), scab (*Sphaceloma* sp**.)**, Septoria leafspot (*Septoria vignae* and *S. vignicola*), rust {*Uromyces appendiculatus* (Pers.) Unger}, Brown blotch (*Colletotrichum capsici* H. sydow), Fusarium wilt (*Fusarium oxysporum* f.sp. *tracheiphilum* (E.F.Sm.) Snyder and H.N. Hansen), ashy stem blight (*Macrophomina phaseolina* (Tassi) Goid), powdery mildew (*Erysiphe polygoni*), bacterial blight (*Xanthomonas campestris* pv *vignicola*), bacterial pustule (*Xanthomonas*

spp.), yellow mosaic virus, green mottle and tobacco mosaic virus (Singh *et al*., 1997). About nine species of parasitic nematodes were reported on cowpea, the most important of these is *Meloidogyne incognita* (Adegbite *et al*., 2005). Different fungal diseases affect different parts of the crop at different stages of growth as discussed below.

2. 8. 1 Seedlings diseases

The disease of germinating seeds and seedlings, collectively known as damping off is associated with several causal organisms and symptom complexes. In cowpea, organisms associated with damping off include *Pythium aphanidermatum*, *Rhizoctonia solani*, *Colletotrichum capsici*, and *Macrophomina phaseolina*. The symptoms include seed decay, death of seedlings before they emerge (pre emergence damping off). Infected seedlings that emerge express symptoms ranging from stunting, chlorosis, necrosis of lower leaves, lesions along the roots, basal soft rot and eventual death of seedlings (post emergence damping off). Crop loss of 50 – 75 % were observed as a result of damping off (Singh and Rachie, 1985). Use of fungicides proved to be the most effective means of controlling damping off. Other control measures include biological control and good seedbed management. Host plant resistance has proved ineffective as the pathogens are nonspecific in their host requirement (Marley, 2013).

2. 8. 2 Stem and root diseases

The major diseases under this category comprise anthracnose, Pythium root and stem rots, ashy stem blight, Sclerotium stem rot and Rhizoctonia root and stem rots. In each of these diseases there is a progressive rotting of the root system which often involves the basal portion of the stem. This leads to stunted growth, yellowing and dropping of leaves and the plant eventually collapse and dies (Dorrance *et al*., 2003). Yield loss ranges from 11 – 50 % (Singh and Rachie, 1985).

Cowpea anthracnose caused by *Colletotrichum lindemuthianum* is present in almost all areas where cowpea is grown. It is chiefly a stem disease even though it affects all above ground parts. Lesions are lenticular, sunken and tan to brown that coalesce to girdle the stem causing wilting and death of the plant (Singh and Allen, 1979).

Pythium stem rot is characterized by a grey-green water soaked girdle of the stem extending from soil level up to and sometimes including the lower portions of the lower branches. During periods of high humidity copious growth of white, cottony Mycelia occurs at the stem base. Infected plants wilt and die (Singh and Rachie, 1985).

Ashy stem blight is caused by *Macrophomina phaseolina.* The organisminfects roots which show necrotic lesions. It alsocauses lesions on stems which are greyish-black sunken lesions on the lower stem and roots associated with accumulation of black sclerotia (Adam, 1990).

Sclerotium rolfsii infects the bases of stems producing a fan of silky white mycelium and large round sclerotia which are initially white and gradually darken. Infected plants wilt and die (Adegbite and Amusa, 2008).

Rhizoctonia solani causes stem rot with reddish-brown lesions, which appear on the stem at soil level and girdle the stem when conditions are favourable. The stem may sometimes be water soaked and soft, causing the plant to collapse (Olsen and Young, 1998).

Control of stem rot is achieved by fungicides application, such as chloroneb and captafol. Biological control using *Trichoderma harzianum,Trichodermaviride,Burkholderia* spp., *Pseudomonas* spp., *Bacillus* spp., and *Somyctreptes* spp. provides reduction of the disease (Krause *et al.,* 2001). Use of resistant varieties where available is also effective, for example, in Australia a new cowpea variety “Black Stallion” is tolerant to stem rot (Marley, 2013).

2. 8. 3 Foliar diseases

The major foliar fungal diseases of cowpea include brown rust, Cercospora leafspot, web blight and Septoria leafspot. Crop loss of 18 – 50 % was reported as a result of foliar diseases of cowpea (Marley, 2013).

Brown rust is induced by *Uromyces appendiculatus*. On affected leaf, pustules develop on both leaf surfaces, releasing powdery, reddish-brown uredospores. The pustules may be surrounded by yellow haloes, then by rings of secondary pustules. The colour of the pustules becomes black as the pigmented teliospores are produced and the leaf gradually dies (Singh and Allen, 1979).

Cercospora leaf spot induced by *Cercospora canescens* Ellis and Martin, is characterized mostly by circular to irregular cherry red to reddish-brown lesions on both leaf surfaces. The pathogen survives the no-crop period on infected crop residue and in infected seed (Aveling, 2009).

Web blight pathogens (*Rhizoctonia solani*) infect leaves and many other young stem tissues. Initial symptoms are small circular brown spots which enlarge and often show concentric banding and become surrounded with irregular shaped water soaked areas. Under humid conditions the lesions develop rapidly and coalesce leading to extensive blighting and defoliation (Adegbite and Amusa, 2008).

Septoria leafspot is caused by *Septoria vignae* and *Septoria vignicola*, but *S. vignicola* is less widely spread and less important. Lesions caused by *S. vignae* are dark red, circular to irregular, appearing similar on both leaf surfaces. Spots are often concentric ringed, and sometimes raised, giving the leaf a freckled appearance. Black fruiting bodies (pycnidia) on the lesions contain threadlike conidia (Singh and Allen, 1979).

The economically viable option for the control of cowpea foliar diseases is the growing of resistant varieties. Cultural practices such as removal or burning of crop residue,

frequent weeding to cut down alternate host and adjusting sowing dates so as to minimize exposure to temperatures and dew periods that favour infection at critical stages of crop development are important in reducing the spread of inoculum. Chemical control using fungicides such as Mancozeb, Maneb, Chlorothalonil and Benomyl are effective in the control of cowpea foliar diseases. The use of biological control agents such as *Bacillus subtilis* and *Verticillium lecanii* are effective in controlling brown rust (Marley, 2013).

2. 8. 4 Pod diseases

Sphacelomascab and brown blotch are the important pod diseases of cowpea. A crop loss of 75 % and complete crop failure has been reportedly caused by brown blotch and Sphaceloma scab respectively (Singh and Rachie, 1985).

Scab induced by *Sphaceloma* spp.is one of the destructive diseases of cowpea in Northern Guinea Savannah zone of West and Central Africa. Typical scab lesions on petiole, stem, peduncle and pod are white turning dark brown when chlamydospores are formed. The most destructive phase is scab of the flowering axis which causes flower or pod abortion or completely prevents flower formation (Adegbite and Amusa, 2008).

Brown blotch is caused by *Colletotrichum truncatum* and is one of the most destructive disease of cowpea in the humid forest of south western Nigeria. The symptoms of the disease are purplish brown discoloration of petioles, leaf veins, stems, peduncles and, especially pods. Discoloration may be accompanied by cracking of stems. Pod infection leads to distortion and mal-development of pods which bear black fruiting bodies. The disease has been found to be seed borne (Emechebe, 1981).

Cowpea Scab and brown blotch can be managed through the use of resistant varieties, practice of good field sanitation, foliar application of benomyl and mancozeb and seed

treatment with appropriate fungicide. Also, the use of botanicals such as garlic extract and Jatropha leaf extract was found to be effective in managing the diseases (Marley, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3. 1 Incidence and Severity of Cowpea Stem Rot in the Surveyed Locations

Survey was conducted in four States of North - West Nigeria (Kaduna, Kano, Katsina and Zamfara) between September - October of 2013 and 2014 at flowering stage of cowpea plant. Three Local Government Areas (LGAs) were surveyed per State (Figure 1) based on advice by Agricultural Development Project (ADP) considering production and/or report of cowpea diseases in the areas. In each LGA, three farm communities were selected. Two cowpea fieldswere chosen at random at each farm community and surveyed for the occurrence of stem rot of cowpea. In each field approximately 0.1 ha, a 2×2 m^2 quadrant was placed at four corners of the field and at the centre. In fields approximately larger than 0.1 ha, a 2×2 m^2 quadrant was placed in three places at each side of the field and at the centre. Total number of cowpea stands as well as number of infected stands in each quadrant were counted and recorded. All the cowpea stands were assessed for disease incidence and severity. Cropping pattern for each location was recorded. Diseased plants were collected, placed in labelled paper bags and brought to the Pathology Laboratory at the Department of Crop Protection, Ahmadu Bello University, Zaria, Nigeria where isolation and identification of fungi were done.

Disease incidence (DI) was calculated using the following formula:

$$\text{DI} = \frac{\text{Number of infected plants}}{\text{Total number of plants assessed}} \times 100$$

Disease severity was obtained by scoring individual plants based on a modified scale of 0 - 6 by Fernando and Linderman, (1994), where

0 = No visible symptoms.

1 = Lesions at base of stem (≤ 15 % stem length); leaves pale green

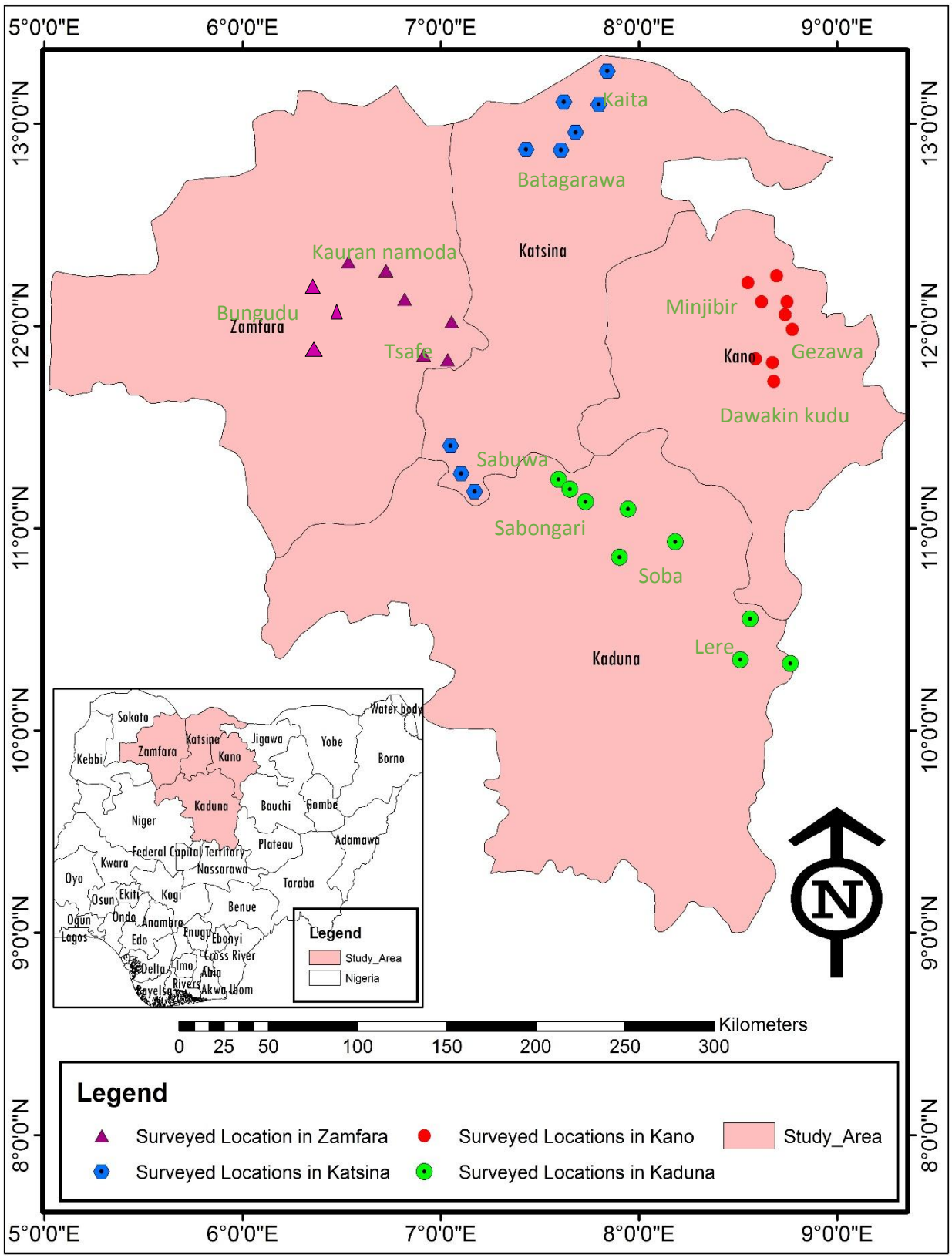


Figure 1: Surveyed locations in four states of North-West Nigeria

Source: Modified from www.nationsonline.org

2 = Lesions advanced upward (16 - 30 % stem length); leaves wilting

3 = Lesions advanced upward (31 - 45 % stem length); leaves wilted

4 = Lesions advanced upward (46 - 60 % stem length); stem rotting at base

5 = Lesions advanced upward (> 60 % stem length); stem rotten at base

6 = Plant rotten, wilted and death

Disease severity percentage was determined using the following formula:

$$\text{Disease severity (\%)} = \frac{\text{Sum of disease rating}}{\text{Highest rating } \times \text{total number of plants rated}} \times 100$$

3. 2 Isolation and Identification of the Organisms

Infected cowpea stem 5 cm long was cut from uprooted diseased plants collected during field survey, and adhering soil washed off using tap water. Causal organisms were isolated following the standard procedure of fungal isolation. The stem tissue was cut into pieces of about 2 - 3 mm long, surface sterilized by immersion in 0.1 % Sodium Hypochlorite (NaOCl) for three minutes, rinsed in three changes of sterile distilled water (SDW) and blotted dry with a sterile filter paper. The disinfected stem tissue was plated onto freshly prepared Potato Dextrose Agar amended with 0.6 µg/ L streptomycin (PDAs), incubated at room temperature (27 ± 2^0 C) and observed daily for fungal growth. Fungal growth were sub-cultured into freshly prepared PDAs to obtain pure cultures. Pure cultures were stained with cotton blue lactophenol, examined and photographed using camera mounted microscope (Olympus) at ×100 magnifications. Fungi were identified using cultural and microscopic characteristics based on the manual by Watanabe (2002). Identities of the isolates were confirmed by the Centre for Biosciences and Agriculture International (CABI), Egham, United Kingdom. Pure cultures of isolated fungi were sub cultured on the PDAs slants in McCartney bottles and preserved until needed for further studies. The number of fungi isolated from each State were recorded

and frequency of isolation for each fungus was obtained by expressing it as percentage of the fungi isolated.

3. 3 Pathogenicity Test

3.3.1 Culturing organisms on millet grains

Inoculum of each fungus was cultured as follows: 3000 g millet grains obtained from Samaru local market were soaked for 24 hours in 8 L distilled water, excess water drained at 24 hours after soaking, 250 g of the grain each weighed into 12 conical flasks (2 L size) and autoclaved at 121°C under 15 psi for 30 min. After cooling, each fungus was transferred into a flask by aseptically placing six, 5 mm discs cut out from a 5 - day old pure culture of each fungus growing on PDAs using sterile cork borer. The grains were incubated for 15 days on a laboratory bench at 27 ± 2 ^{0}C with daily shaking, air-dried and preserved until needed.

3.3.2 Inoculation

To 1000 g of heat sterilized loamy soil contained in 15 cm diameter pot, 50 g of the prepared millet grain inoculum was added two days before cowpea seeds were sown. Control treatment consisted of sterilized soil to which sterilized millet grains were added. Seeds of cowpea variety SAMPEA 10 obtained from the Institute for Agricultural Research (IAR) were surface-sterilized with 1 % NaOCl, rinsed thrice in SDW and sown in pots at three seeds per pot. The plants were watered regularly and observed daily for symptoms. Plants showing stem rot symptoms were recorded. Three weeks old seedlings showing symptoms of stem rot were removed two days after appearance of lesions and plated onto PDAs. The re-isolated fungi were cultured on PDAs, colony and microscopic characteristics were recorded and compared with the inoculated isolate.

3.4 Evaluation of Different Inoculation Methods on the Development of Cowpea Stem Rot in the Glasshouse

Seeds of cowpea variety SAMPEA 10 were sown on heat sterilized loamy soils contained on 15 cm diameter plastic pots at the rate of three seeds per pot. The pots were arranged in completely randomised design with four repetitions. Four inoculation methods: Millet grain soil inoculation, injury pinprick, soil drench and spray were used. The procedure for millet grain soil inoculation has been described above for pathogenicity test. The inoculum suspension for injury pinprick, soil drench and spray was prepared as follows: Three petri dishes each containing 14 - day-old culture of the causal organism grown on PDAs were harvested by scrapping mycelia mat with sterile glass slides into 200 ml SDW, blended at low speed on Warren blender, filtered through a double layer muslin cloth and made up to 200 ml by adding SDW.

For the injury pinprick method, stem base of the cowpea seedling was injured by creating five pricks per stem with sterile needle and dropping 0.1 ml of the spore suspension on the pricks. Soil drenching involved pouring of 5 ml of spore suspension on the soil around the stem base of each plant. For the spray method, spore suspension (5 ml/stem), was sprayed on the stem base of cowpea seedlings using hand held sprayer. Seedlings inoculated with sterile distilled water served as control. In order to maintain high relative humidity around the plants, the seedlings were covered with polyethylene bags 24 hours before and after inoculation. The seedlings were observed daily for disease symptoms. Number of days to symptoms appearance was noted while incidence and severity were recorded at weekly intervals for seven weeks.

3.5 Evaluation of Cowpea Varieties for their Reactions to the Causal Organism

Six improved cowpea varieties (SAMPEA 7, SAMPEA 8, SAMPEA 9, SAMPEA 10, SAMPEA 11 and SAMPEA 12), two accessions (IAR–00–1074 and IAR–07–1050), two

local varieties (Biu local and Maifarin hanci) obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University Zaria and two local varieties (Kanannado and Dansokoto) obtained from Samaru local market were evaluated for their reactions to the causal organism in the glasshouse. Seeds were sterilized in 1 % NaOCl for 2 minutes, rinsed twice in SDW and sown at three seeds per pot. Pots were arranged in Completely Randomised Design with four repetitions. The plants were inoculated using millet grain soil inoculation procedure described above. Plants were foliar sprayed trice at weekly interval with Cypermethrin 10 EC at the rate of 25 ml/250 L of water using a 250 L volume hand held sprayer starting from 4 WAS when aphids infestation was noticed. Disease incidence and severity on the plants were recorded weekly for seven weeks starting from 2WAS. Disease incidence of each repetition was calculated as percentage of diseased plants in each repetition while disease severity was determined by scoring individual plants in each repetition using the severity scale described earlier. Data on number of pods per plant was collected at harvest on all the plants while grain yield per plant was obtained after threshing. Using the severity values, the varieties were grouped into five different classes based on a modified scale of Adejumo *et al*. (2001) where varieties with severities (%) of

0 = Immune

1 - 15 = Highly resistant

16 – 30 = Moderately resistant

31 – 45 = Moderately susceptible

> 45 = Highly susceptible

The 12 cowpea varieties and accessions evaluated in the glasshouse were also evaluated under field conditions in August to November, 2014. The treatments were arranged in a Randomised Complete Block Design RCBD) with three replications. In a replicate, each

variety was sown on 4.5 m^2plot in which three seeds per hole were sown with an intra row spacing of 20 cm and inter row spacing of 75 cm. Plots were separated from each other by one bare, 75 cm weeded ridge while replicates were separated from each other by 1 m wide margin. Two days before sowing, the top soil of each stand was inoculated by placing 50 g of previously prepared millet seed inoculum. Another 4.5 m^2plot of each variety served as control.Disease incidence and severity on the 4.5 m^2 plots were recorded weekly for seven weeks starting from 2 WAS. Cypermethrin 10 EC, 200 ml/200 L of water, was foliar - sprayed using a Knapsack sprayer and was applied thrice at weekly intervals starting from 6 WAS. Cowpea pods were harvested at maturity. Data on pod number per plot was collected at harvest and grain yield per plot was obtained after threshing. Varieties were separated into different resistant groups using the scale described above

3. 6 Statistical Analysis

The data generated from field survey, field evaluation, glasshouse and laboratory experiments were subjected to analysis of variance (ANOVA) procedure of SAS (SAS, 2002) and means were separated using the Duncan Multiple Range Test (DMRT) at 5 % level of significance.

CHAPTER FOUR

4.0 RESULTS

4.1 Incidence and Severity of Cowpea Stem Rot in the Surveyed Locations

In the survey conducted in 2013 and 2014, the symptoms observed were typical of stem rot (Plate 1). The symptoms were reddish brown lesions on the stem at soil levelwhich sometimes girdle the stem and severely infected plants wilt or break at the base and fall over.



Plate I: Cowpea stem rot symptom observed during survey



Plate II: Healthy cowpea plant observed during survey

The survey showed that cowpea stem rot is widely distributed in North - West Nigeria, though the disease is not evenly distributed. The disease incidence and severity for 2013 were generally higher than those of 2014 (Table 2). The disease incidence and severity in the two seasons showed that Kaduna State had the highest disease incidence (29.09 %) and severity (21.14 %) while Katsina State had the lowest incidence (9.24 %) and severity (7.31 %) which was statistically similar to that of Zamfara State (Table 2).

Disease incidence and severity for the different Local Government Areas (LGAs) also significantly varied ($p \leq 0.05$) from each other (Table 3). Lere LGA recorded the highest incidence (38.51 %) and severity (25.36 %) while Kaita LGA recorded the lowest incidence (3.76 %) and severity (2.82 %) which did not statistically differ from that of Batagarawa LGA.In 2013, highest disease incidence (46.09 %) was recorded in Lere LGA followed by Soba LGA, Dawakin kudu LGA which did not statistically differ from that of Gezawa LGA and Sabongari LGA (Figure 2a). Kaita LGA recorded the lowest disease incidence of 6.22 % followed by Batagarawa LGA. When the disease severities were compared, highest severity (29.98 %) was recorded in Lere LGA, followed by Soba which did not statistically differ from that of Sabongari LGA (Figure 2b). The lowest disease severity (4.38 %) was recorded in Kaita LGA followed by Batagarawa LGA, Tsafe LGA and Kauran namoda LGA.In 2014, Lere LGA also recorded the highest disease incidence (30.21 %), followed by Gezawa LGA, which did not statistically differ from that of Sabongari LGA, Dawakin kudu LGA and Soba LGA (Figure 3a). Kaita LGA recorded the lowest disease incidence (1.33 %). Highest disease severity (20.74 %) was also recorded in Lere LGA which did not statistically differ from that of Gezawa LGA (Figure 3b). The lowest disease severity (1.26 %) was also recorded in Kaita LGA.

Table 2: Cowpea stem rot incidence and severity in four surveyed states during 2013 and 2014 rainy seasons

Treatment	Disease incidence (%)	Disease severity (%)
Year		
2013	21.55[a]	15.90[a]
2014	14.49[b]	11.97[b]
SE±	1.82	1.36
State		
Kaduna	29.09[a]	21.14[a]
Kano	20.94[b]	16.32[ab]
Katsina	9.24[c]	7.31[c]
Zamfara	12.81[c]	10.97[bc]
SE±	2.58	1.93
Interaction		
State x Year	NS	NS

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT).

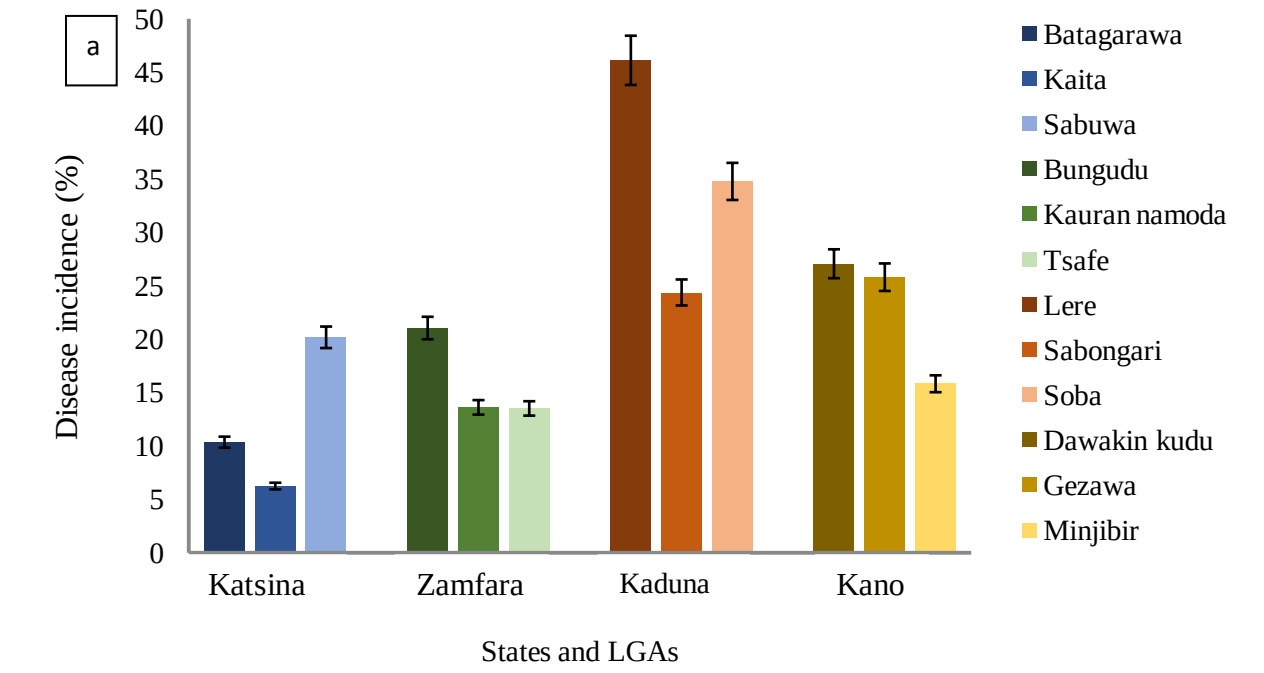
NS = Not significant at 5 %

Table 3: Cowpea stem rot incidence and severity in twelve Local Government Areas surveyed during 2013 and 2014 rainy seasons

	Treatment	Disease incidence (%)	Disease severity (%)
State	Year		
	2013	21.55[a]	15.90[a]
	2014	14.49[b]	11.97[b]
	SE±	0.66	0.49
	Local Government Area		
Kaduna	Lere	38.15[a]	25.36[a]
	Sabongari	21.93[b]	18.51[b]
	Soba	26.73[b]	19.12[b]
Kano	Dawakin kudu	23.69[b]	18.39[b]
	Gezawa	24.67[b]	18.74[b]
	Minjibir	14.46[cde]	11.50[cde]
Katsina	Batagarawa	7.95[fg]	5.76[fg]
	Kaita	3.76[g]	2.82[g]
	Sabuwa	16.00[cd]	13.18[cd]
Zamfara	Bungudu	16.44[c]	14.20[c]
	Kauran namoda	11.30[def]	9.92[de]
	Tsafe	10.71[ef]	8.49[ef]
	SE±	1.61	1.20
	Interaction		
	Year x Local Government Area	*	*

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT).

* = significant at 5 %



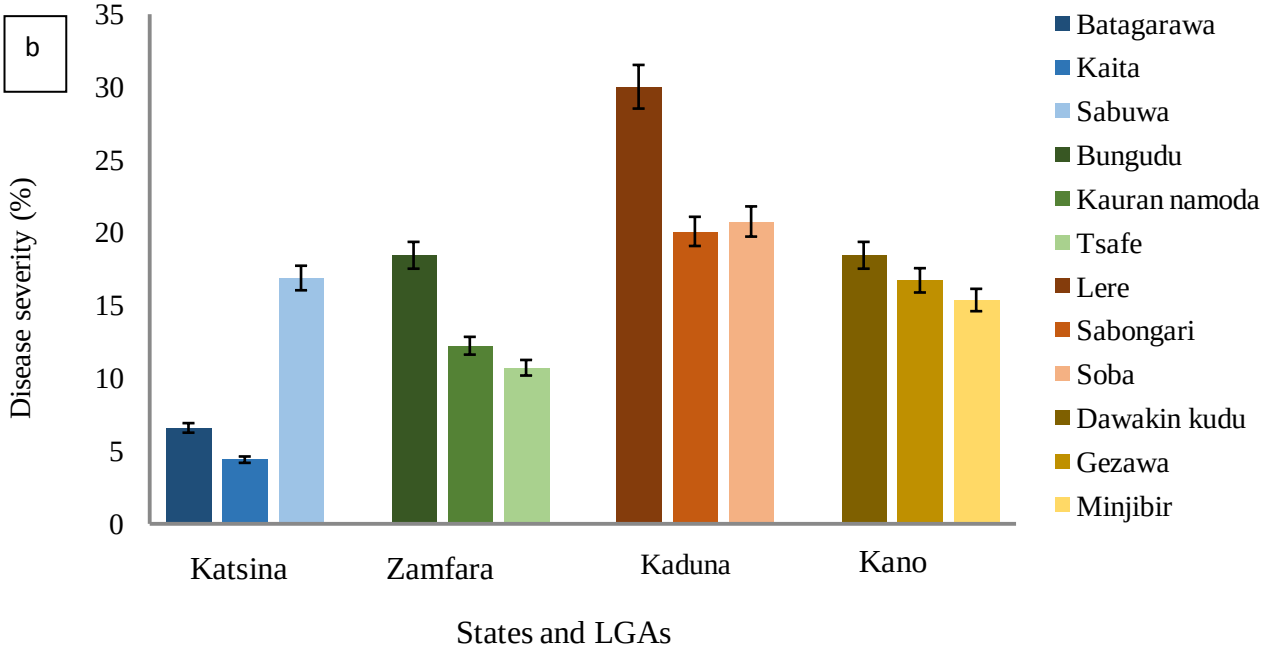


Figure 2: Cowpea stem rot incidence (a) and severity (b) in 12 Local Government Areas of North - West Nigeria 2013

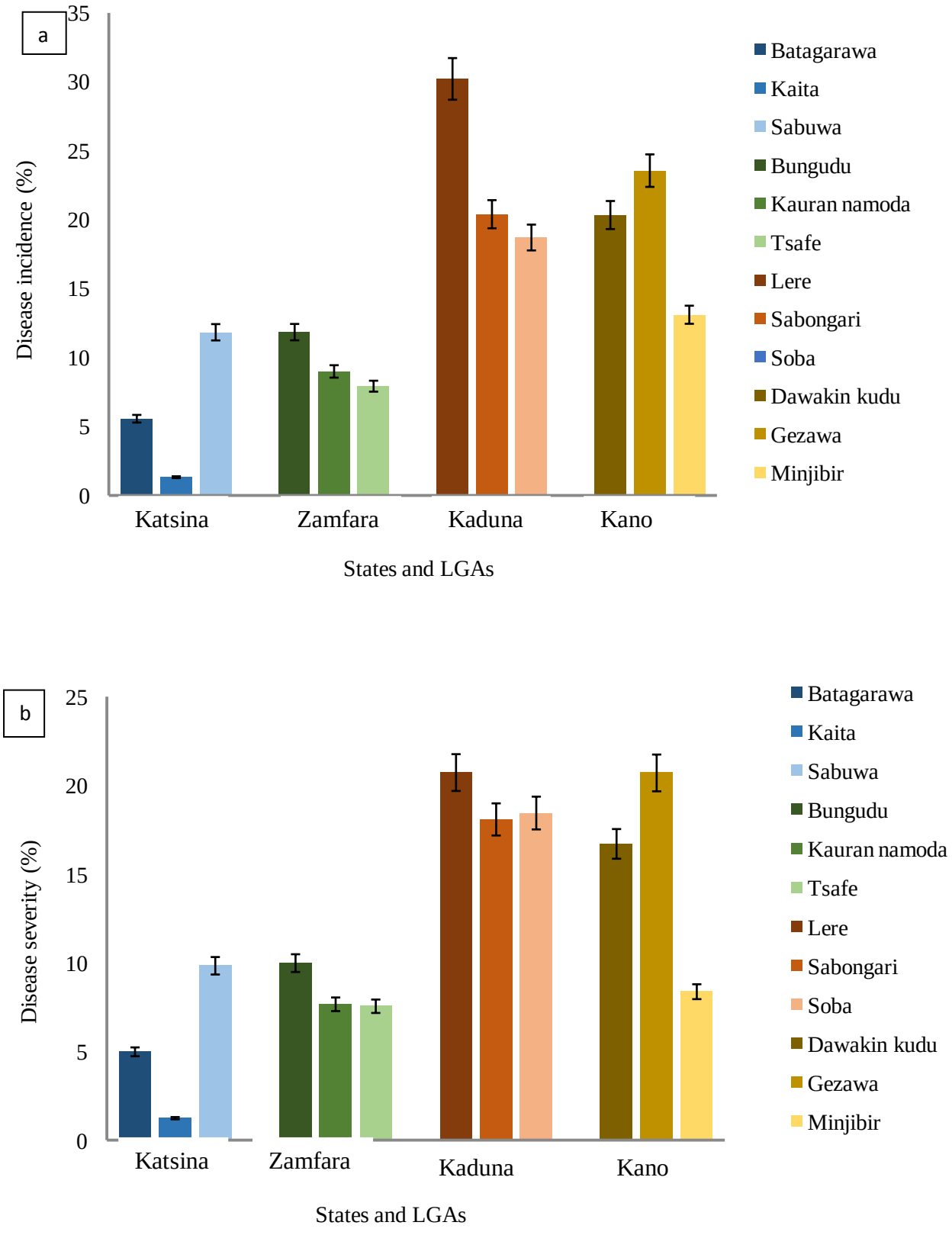


Figure 3: Cowpea stem rot incidence (a) and severity (b) in 12 LGAs of North - West Nigeria 2014

The result of the study indicates that the disease is widely distributed in North - West Nigeria as it was found in each of the LGAs surveyed. In Kaduna State, symptoms of cowpea stem rot were observed in all the fields surveyed (Figure 4). In Kano State though the disease was observed in each of the surveyed LGAs, no disease symptoms were observed in Wase and Geranya of Minjibir LGA (Figure 5). In Katsina State, stem rot symptoms were observed in all the surveyed locations except Tafkin Almu in Batagarawa LGA, Kwanar yandaka and Kaita in Kaita LGA (Figure 6). In Zamfara State, stem rot symptoms were not observed in Gidan Alhaji Isuhu in Bungudu LGA and Kasuwar Daji in Kauran namoda LGA (Figure 7).

The cropping pattern practised in the surveyed locations varied, in Kaduna State it was predominantly cowpea - maize relay and the maize stalk is left on the field after removing the cobs. In Kano and Zamfara, it was predominantly cowpea - sorghum or millet intercrop and where cowpea is intercropped with millet, the millet stalks are buried on the furrows during weeding to decay and enrich the soil for succeeding crop. In Katsina State it was predominantly cowpea-maize relay in Sabuwa LGA and cowpea-sorghum intercrop in Batagarawa and Kaita LGAs.

4.2 Isolation and Identification of Fungi

Fungi isolated from diseased plant stems were identified as *Rhizoctonia solani* Kuhn, *Macrophomina phaseolina* (Tassi) Goidanich, *Sclerotium* sp., *Colletotrichum capsici* (H. Sydow) E. Butler and Bisby, *Fusarium solani* (Mart) Saccand *Curvularialunata* (Wakker) Boedjn. (Appendix 1). The cultural and morphological characteristics of the different isolates were studied on PDAs.

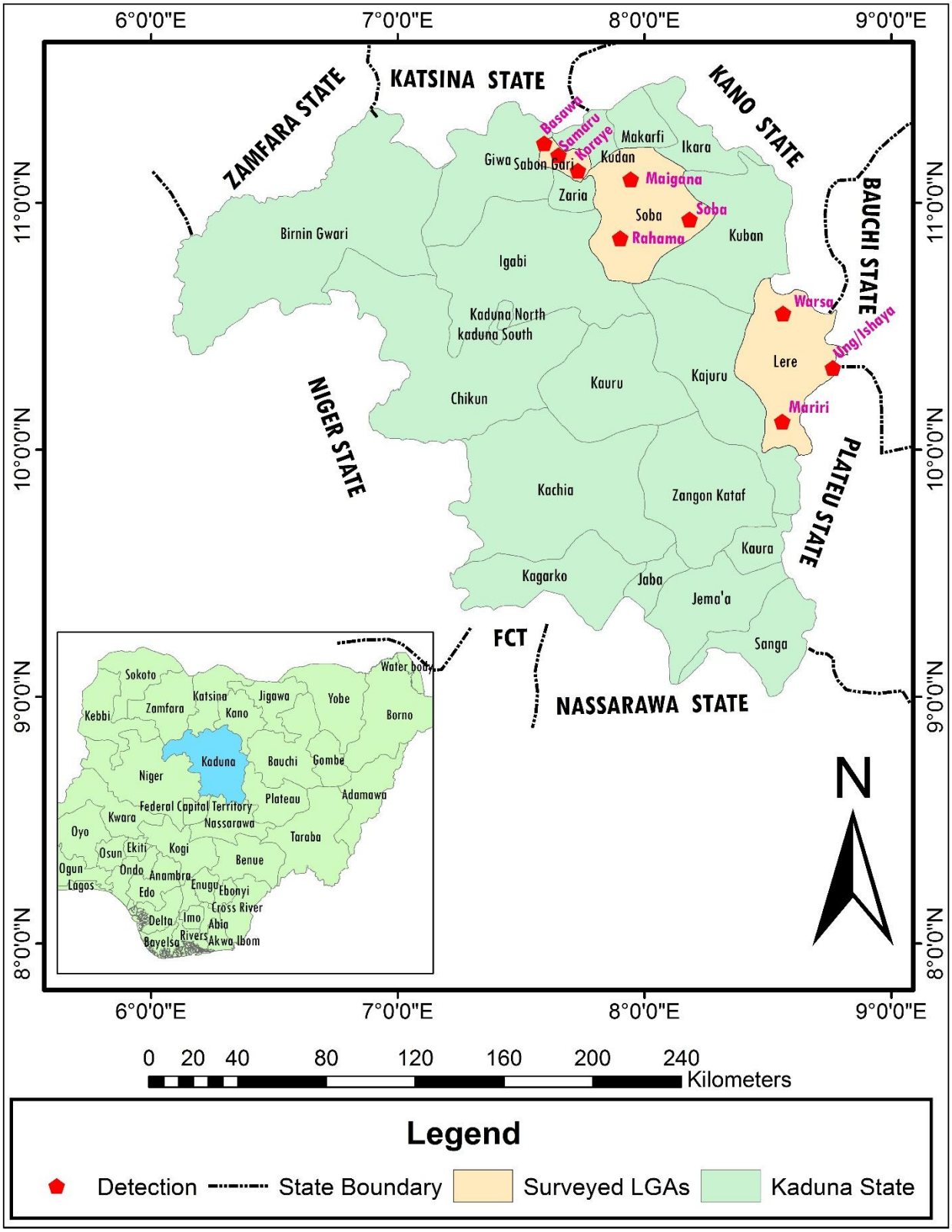


Figure 4: Distribution of cowpea stem rot in the surveyed Local Government Areas of Kaduna State

Source: Modified from www.nationsonline.org

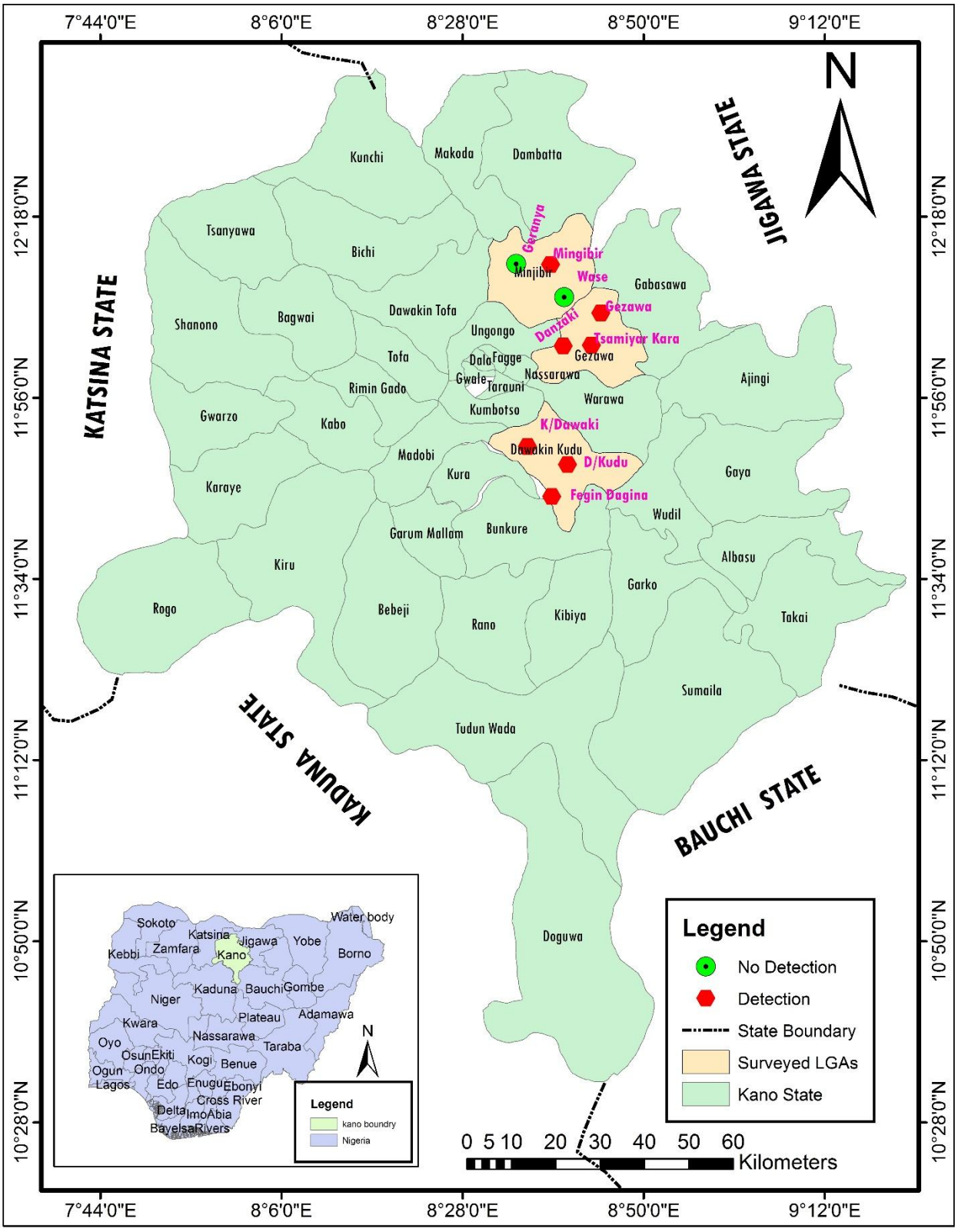


Figure 5: Distribution of cowpea stem rot in the surveyed Local Government Areas of Kano State

Source: Modified from www.nationsonline.org

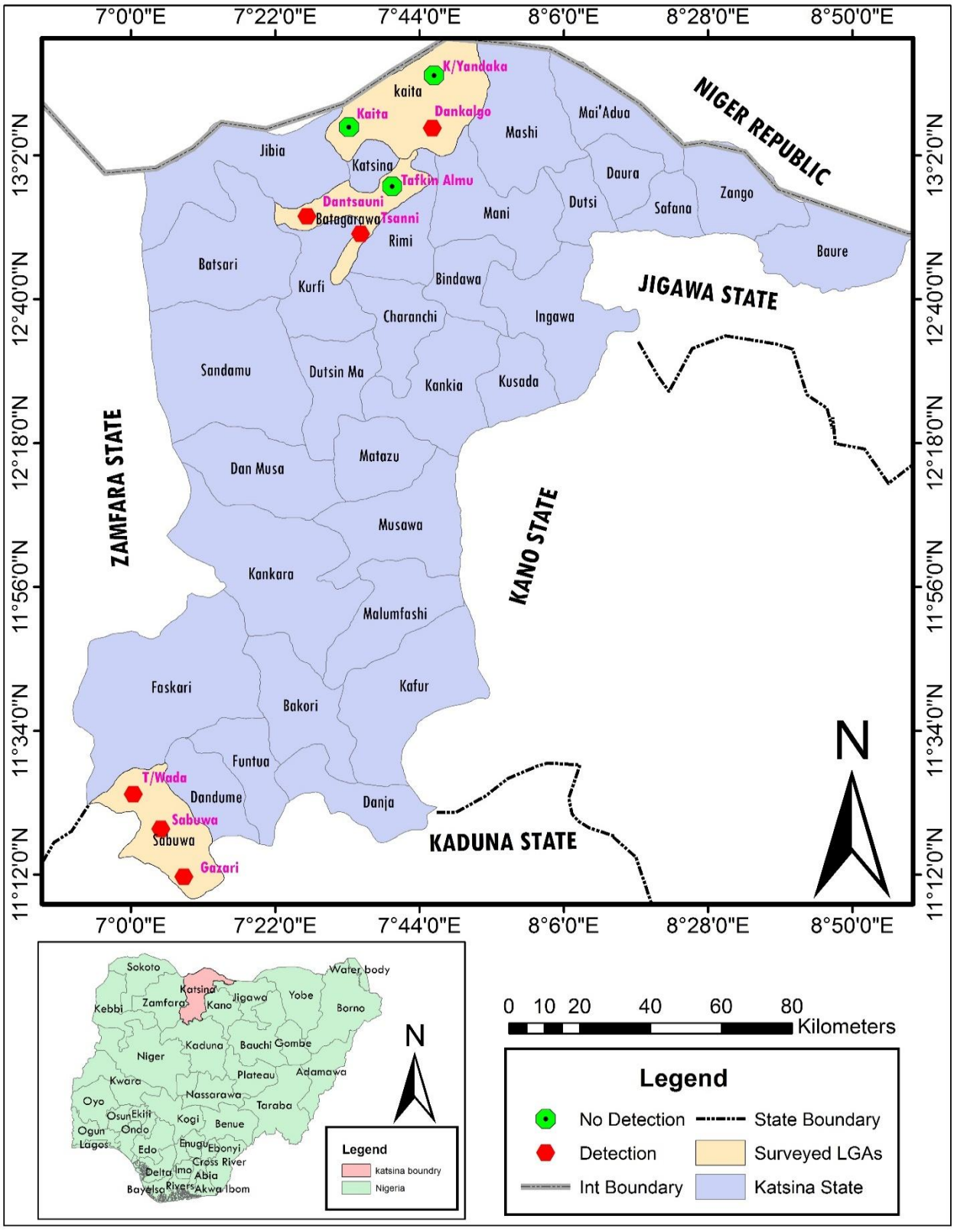


Figure 6: Distribution of cowpea stem rot in the surveyed Local Government Areas of Katsina State

Source: Modified from www.nationsonline.org

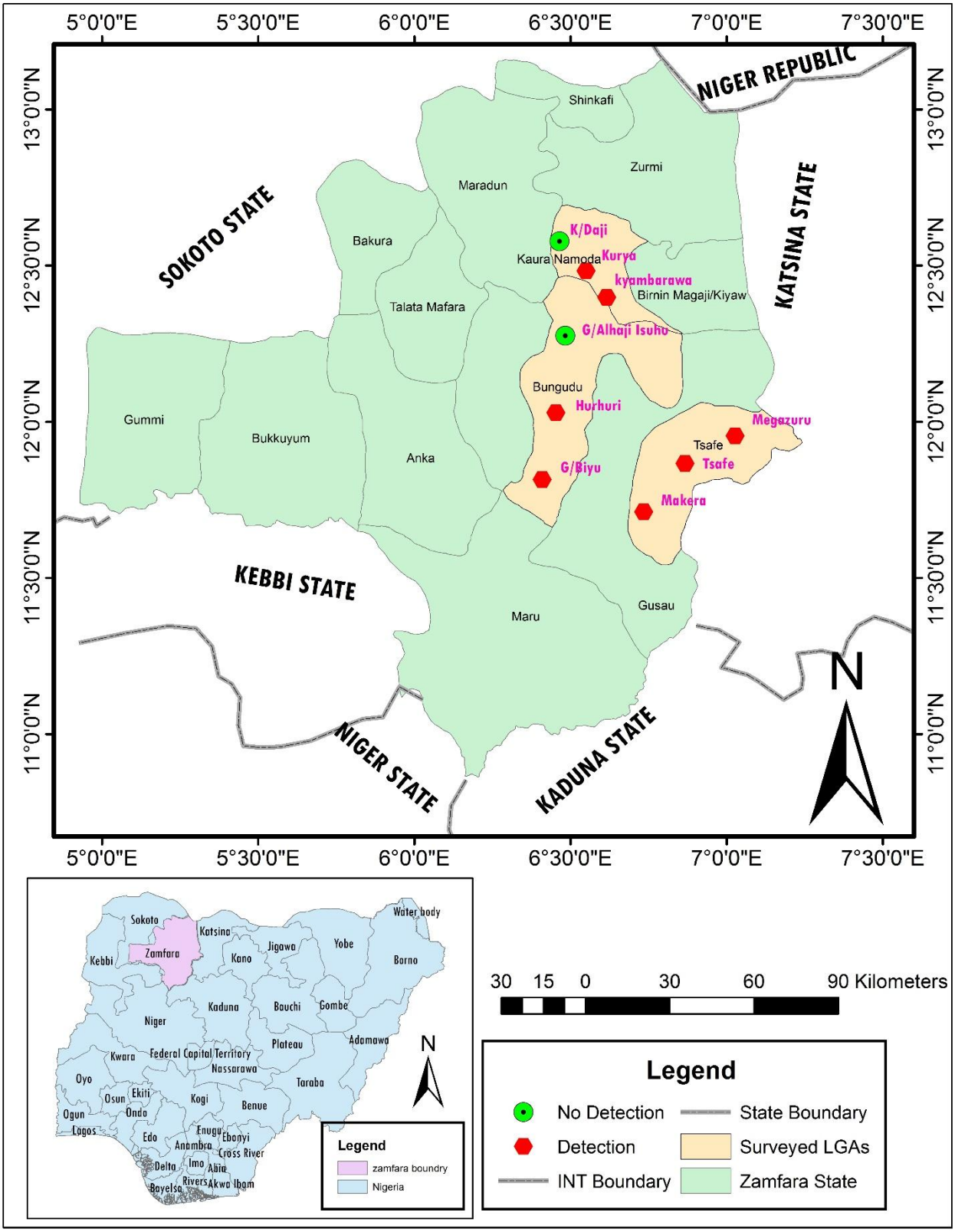


Figure 7: Distribution of cowpea stem rot in the surveyed Local Government Areas of Zamfara State

Source: Modified from www.nationsonline.org

Frequency of isolation of the fungi significantly varied (Table 4). *R. solani* had the highest frequency followed by *M. phaseolina* which did not statistically differ from that

of *F. solani*. The least frequency was recorded for *C. lunata* which did not statistically differ from that of *C. capsici* and *Sclerotium* sp. The frequency of the fungi did not significantly vary with States and years. The two ways interaction of fungi × year and year × State were not significant as well as the three ways interaction of fungi × year × State but the two ways interaction of fungi × State was highly significant (Table4). *R. solani* had the highest frequency in Kaduna, Kano and Zamfara States while *M. phaseolina* had the highest frequency in Katsina State. *Sclerotium* sp. was only isolated from Kano State, *C. capsici* from Kaduna and Kano only with higher frequency in Kaduna State. Zamfara had the highest frequency of *F. solani* followed by Kano. Katsina State had the least frequency of *F. solani* which did not differ statistically from that of Kaduna. *C. lunata* was only isolated from Kaduna and Katsina with Kaduna having the highest frequency (Table 5).

Cultures of *Rhizoctonia solani* on Potato Dextrose Agar amended with Streptomycin (PDAs) were brown in colour and covered 90 mm petri dish in four to five days at room temperature (27 ± 2^0 C). Microscopic examination shows a pale brown hyphae with nearly right - angled side branches constricted basally and no conidia were observed (Plates III A and B).*Macrophomina phaseolina* on PDAs produced black mycelia that covered 90 mm petri dish in 16 - 18 days at room temperature (27 ± 2^0 C). Sclerotia when viewed were black. Neither conidia nor pycnidia were observed (PlatesIV A and B).Culture of *Sclerotium* sp. was grey in colour which covered 90 mm petri dish in four to five days at room temperature (27 ± 2^0 C). Their appearance was dense cottony with profuse hyphae. No conidia were observed. Hyphae were hyaline, branched and constricted basally with side branches septate near the main hyphae (PlatesV A and B).

Table 4: Frequency of fungi isolated from diseased cowpea stem in 2013 and 2014

Treatment	Frequency of isolation (%)
Year	
2013	19.10
2014	17.55
SE±	2.49
Fungi	
Rhizoctonia solani	45.90[a]
Macrophomina phaseelina	29.55[b]
Sclerotium sp.	2.22[c]
Colletotrichum capsici.	2.92[c]
Fusarium solani	21.04[b]
Curvularia lunata	8.30[c]
SE±	4.31
State	
Kaduna	16.11
Kano	16.67
Katsina	16.67
Zamfara	23.84
SE±	3.52
Interactions	
Year x Fungi	NS
Fungi x State	**
Year x State	NS
Year x Fungi x State	NS

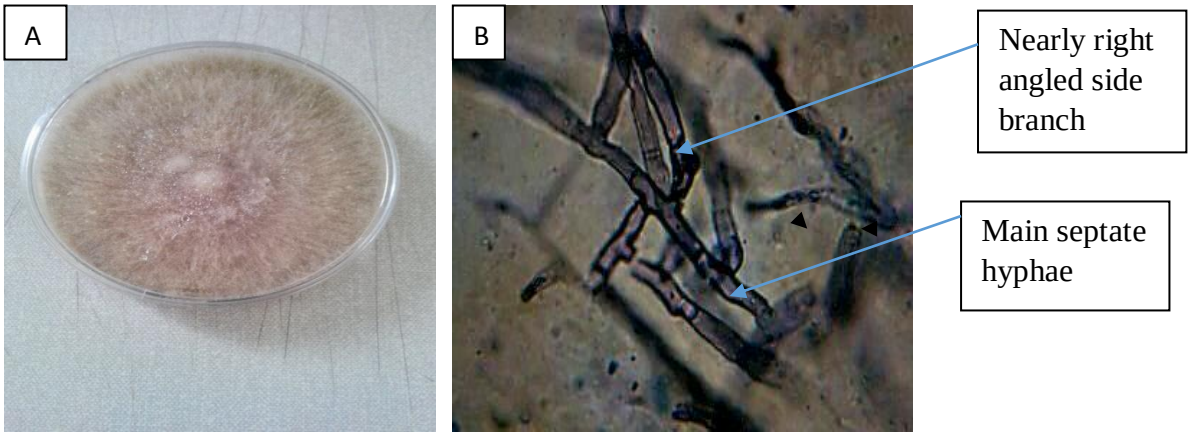
Means with the same superscript in a column are not significantly different at 5% level of significance (P≤0.05) using Duncan Multiple Range Test (DMRT).

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

Table 5: Interaction between frequency of fungi isolated from diseased cowpea and the four States surveyed

State	Frequency of isolation (%) of:					
	Rhizoctonia solani	*Macrophomina phaseolina*	*Sclerotium* sp.	*Colletotrichum capsici*	*Fusarium solani*	*Curvularia lunata*
Zamfara	52.94^{a}	11.56^{c}	0.00^{d}	0.00^{d}	35.49^{b}	0.00^{d}
Kano	50.00^{a}	10.00^{cd}	15.00^{bc}	5.00^{de}	20.00^{b}	0.00^{e}
Kaduna	40.00^{a}	10.00^{c}	0.00^{d}	10.00^{c}	13.33^{c}	26.67^{b}
Katsina	33.33^{b}	43.78^{a}	0.00^{d}	0.00^{d}	11.44^{c}	11.44^{c}
LSD	6.27					

Means with the same superscript in each row are not significantly different at 5% level of significance ($P \leq 0.05$) using Least Significant Difference (LSD)



PlateIII: A = Culture of *Rhizoctonia solani* on plate.B= *Rhizoctonia solani* hyphae.

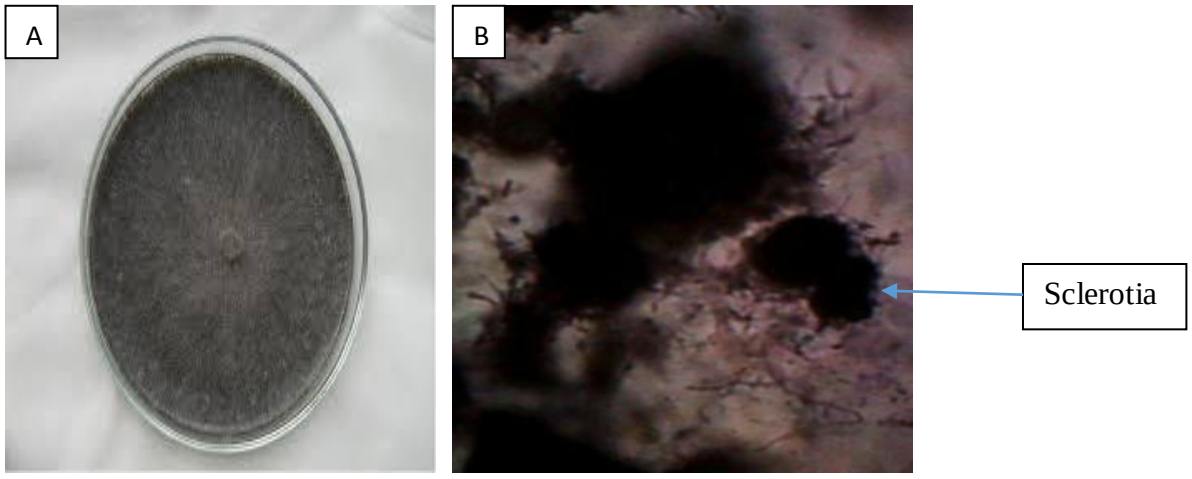


Plate IV: A = *Macrophomina phaseolina* culture on plate. B = *Macrophomina phaseolina* sclerotia

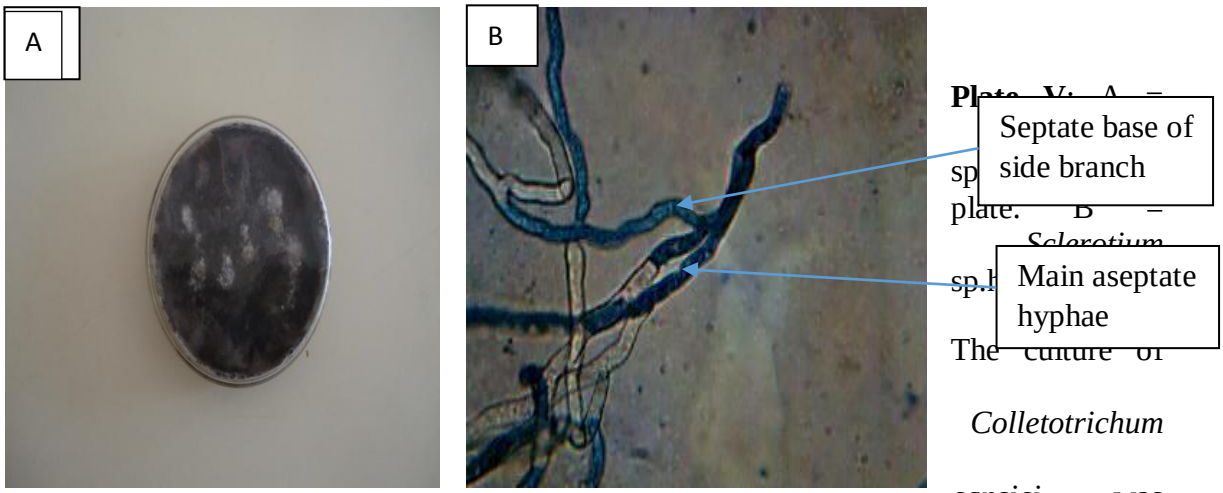


Plate V: A = *Colletotrichum capsici* sp. plate. B = *Sclerotium* sp.

The culture of *Colletotrichum capsici* was orange coloured with concentric zonations which covered 90 mm petri dish in 18 – 20

days when grown on PDAs. Conidia were, hyaline one- celled and cylindrical to sickle in shape (Plates VI A and B).

Culture of *Fusarium solani* on PDAs was pinkish and covered 90 mm petri dish in 10 - 14 days. When microscopically examined, *F. solani* produced two types of conidia: Macroconidia which were slightly curved, three to five celled; and microconidia that were cylindrical, one to two celled (Plates VII A and B).

When grown on PDAs, *Curvularia lunata* produced black coloured, hairy and rapidly growing mass of hyphae (covering 90 mm petri dish in 4 - 5 days). Conidia were dark brown, curved, four celled and larger in penultimate cells (Plates VIII A and B).

4.3 Pathogenicity Test

Cowpea plants inoculated with the six isolated fungi produced disease symptoms 5 - 7 days after inoculation in the glasshouse. The typical symptoms observed on farmers' fieldswas shown by only plants inoculated with *Rhizoctonia solani*.The symptoms were reddish brown lesions on the stem at soil level and was first observed 8 Days after Inoculation (DAI) and girdled the stem at 20 DAI (Plate X). *Macrophomina phaseolina* produced brown necrotic lesions observed 6 DAI which turned grey and the stem was covered with black sclerotia at 30 DAI (Plate XI). *Sclerotium* sp. produced dark brown lesions first observed 4 DAI that girdled the collar region and covered with white minute sclerotia at 16 DAI (Plate XII). *Colletotrichum capsici* produced purple brown lesion at stem base first observed at 12 DAI which progressed upward (Plate XIII). *Fusarium solani* produced reddish brown lesions first observed at 10 DAI which coalesce to cover the stem base at soil level at 25 DAI (Plate XIV). *Curvularia lunata* resulted in dark brown lesions first observed at 9 DAI which turned black at 28 DAI (Plate XV).

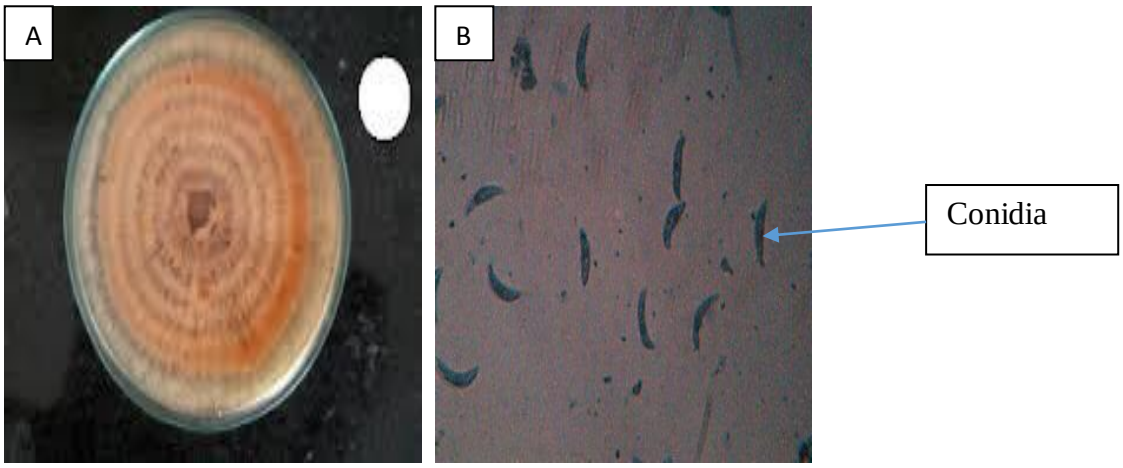


Plate VI: A = *Colletotrichum capsici* culture on plate. B = *Colletotrichum capsici* conidia

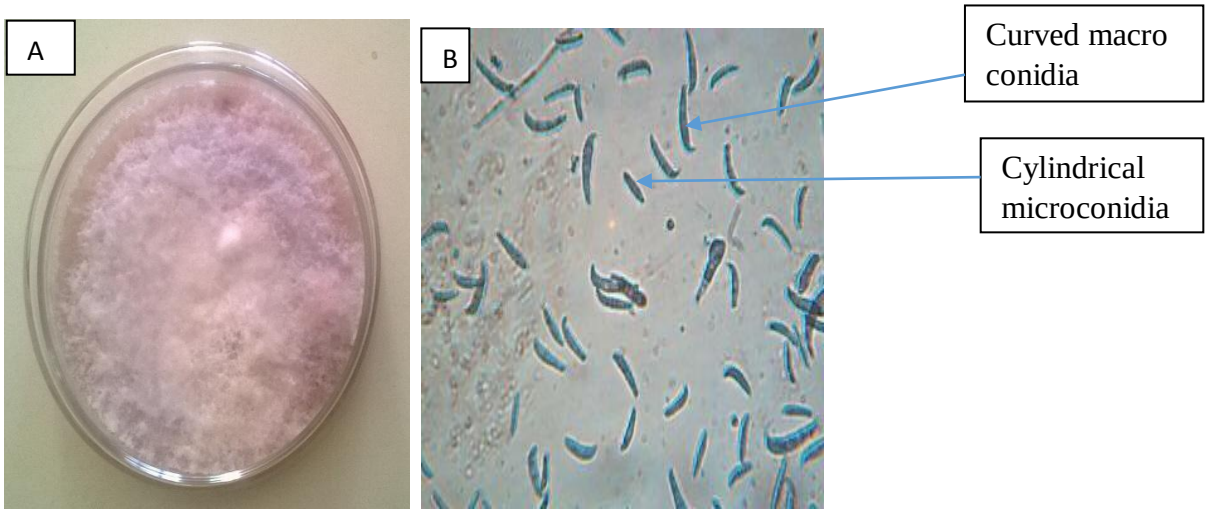


Plate VII: A = *Fusarium solani* culture on plate. B = *Fusarium solani*conidia

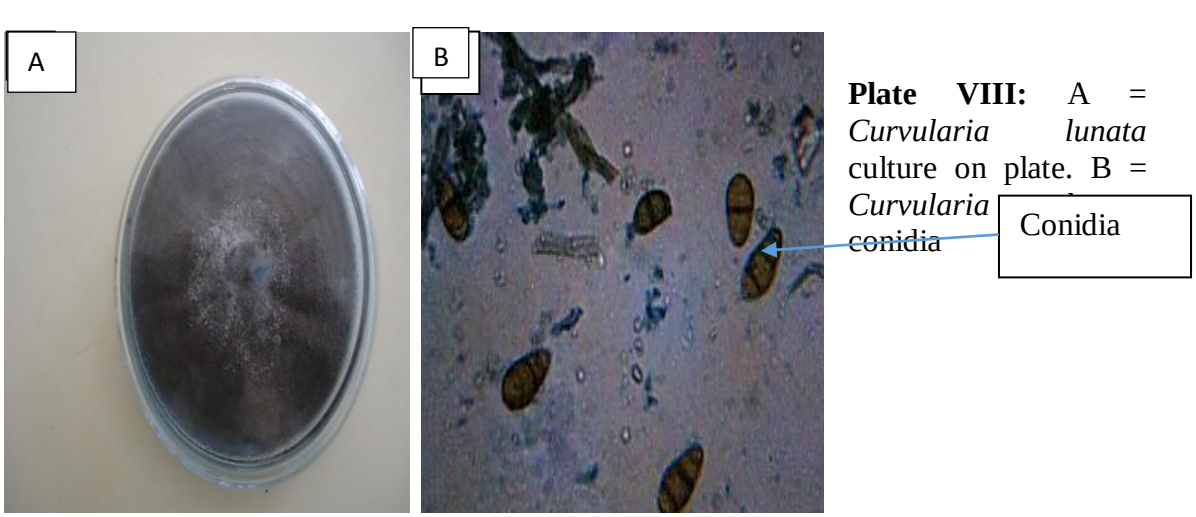


Plate VIII: A = *Curvularia lunata* culture on plate. B = *Curvularia* conidia



Plate IX: Healthy cowpea plants at 28 days after inoculation



Plate X: Symptoms observed on cowpea inoculated with *Rhizoctonia solani* at 35 days after inoculation



Plate XI: Symptoms observed on cowpea inoculated with *Macrophomina phaseolina* at 28 days after inoculation



Plate XII: Symptoms observed on cowpea inoculatedwith *Sclerotium* sp. at 14 days after inoculation



Plate XIII: Symptoms observed on cowpeaplants inoculated with *Colletotrichum capsici* at 35days after inoculation



Plate XIV: Symptoms observed on cowpea plantsinoculated with *Fusarium solani* at 21 days after inoculation



Plate XV: Symptoms observed on cowpea plantsinoculated with *Curvularia lunata* at 28 days after inoculation

4. 4 Evaluation of Different Inoculation Methods on the Development of Cowpea Stem Rot in the Glasshouse

Disease incidence of cowpea inoculated with *R. solani*using different inoculation methods significantly varied. For injury pinprick inoculation, symptoms were first observed 1 day after inoculation (DAI). Disease reached 60.2, 87.6, and 91.67 % at 1, 2, and 3 weeks after inoculation (WAI) respectively, and from then it did not increase significantly. For millet grain soil inoculation, symptoms were first observed 1 WAI. Disease incidence was 8.33 % at 1 WAI, 16.67 % at 2 WAI, and then it increased rapidly to 100 % at 5 WAI. For soil drench inoculation, symptoms were first observed 4 DAI. Disease incidence reached 16.67 % at 1 WAI, 20.84 % at 2 WAI, 63.43 % at 3 WAI, and 83.33 % at 4 WAI from which it did not increase significantly. Cowpea inoculated using spray method had no symptoms of the disease(Figure 8).

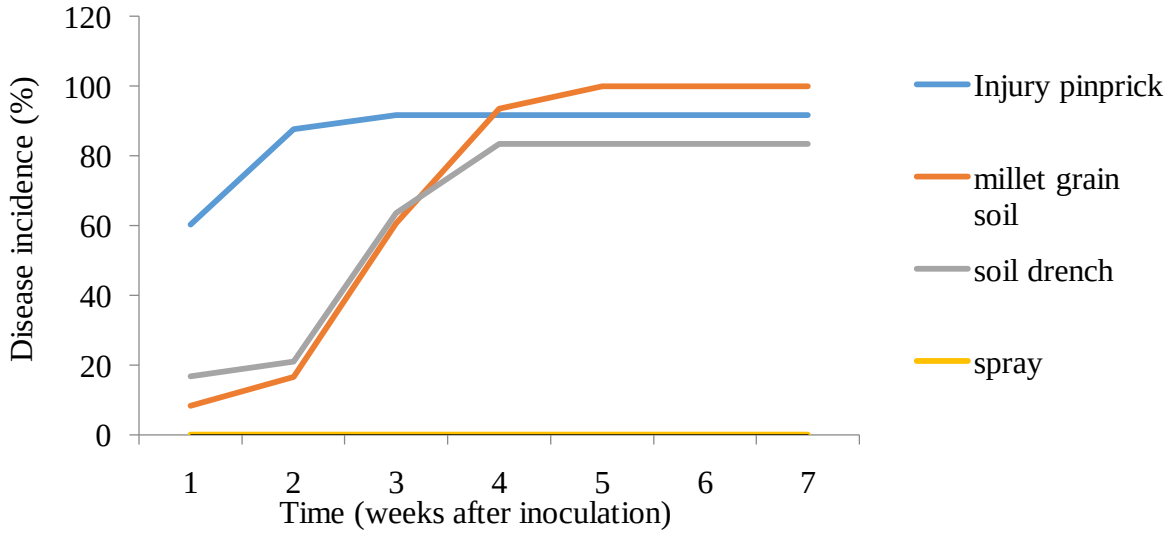


Figure 8: Diseaseincidence on cowpea inoculated with *Rhizoctonia solani*using four inoculation methods at 1 – 7 weeks after sowing

Disease severity for the different inoculation methods also significantly varied. Injury pinprick inoculation had severity of 37.14 % at 1 WAI, 42.57 % at 2 WAI and 70.46 %

at 3 WAI from which it did not increase significantly. For millet grain soil inoculation disease severity reached 5.62 % at 1 WAI, 10.56 % at 2 WAI, 40.61 % at 3 WAI, 48.98 % at 4 WAI and 50.48 % at 5 WAI from where it did not increase significantly. For soil drench inoculation, disease severity reached 10.30 % at 1WAI, 18.24 % at 2 WAI, 38.00 % at 3 WAI, 50.51 % at 4 WAI and 65.4 % at 5 WAI and then it did not increase significantly. Disease severity for spray inoculation was 0.00 % at 1 – 7 WAI (Figure 9).

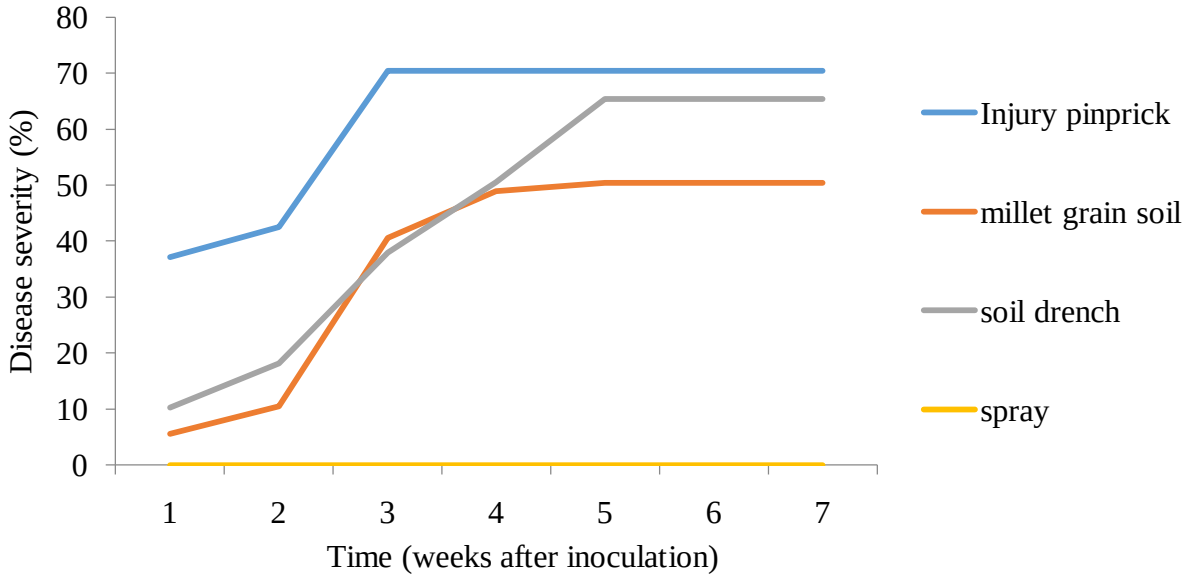


Figure 9: Disease severity on cowpea inoculated with *Rhizoctonia solani*using four inoculation methods at 1 – 7 weeks after sowing

4.5 Evaluation of Cowpea Varieties for their Reactions to the Causal Organism

The incidence of stem rot on cowpea varieties inoculated with *Rhizoctonia solani* in the glasshouse significantly varied (Table 6) with time.At 2 Weeks After Sowing (WAS), highest disease incidence (75.00 %) was recorded on SAMPEA 10 which did not differ statistically from that of Biu local and IAR-07-1050. Dansokoto, IAR-00-1074, SAMPEA 11 and SAMPEA 12 were disease free.

Table 6: Incidence of stem rot on cowpea varieties inoculated with *Rhizoctonia solani* in the glasshouse at 2 – 8 weeks after sowing in 2014

Variety	Disease incidence (%) at:						
	2WAS	3WAS	4WAS	5WAS	6WAS	7WAS	8WAS
SAMPEA 10	75.00^{a}	75.00^{a}	91.67^{a}	91.67^{a}	100.00^{a}	100.00^{a}	100.00^{a}
IAR- 07- 1050	70.83^{a}	79.17^{a}	87.50^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Biu local	54.17^{a}	70.83^{a}	91.67^{a}	95.83^{a}	100.00^{a}	100.00^{a}	100.00^{a}
SAMPEA 8	23.33^{b}	8.33^{bc}	15.00^{cd}	25.00^{bcd}	33.33^{cd}	33.33^{cd}	33.33^{cd}
SAMPEA 9	20.83^{b}	29.17^{b}	45.83^{b}	50.00^{b}	79.17^{b}	79.17^{b}	79.17^{b}
Kanannado	15.00^{b}	15.83^{bc}	37.50^{bc}	37.50^{bc}	37.50^{cd}	37.50^{cd}	37.50^{cd}
SAMPEA 7	8.33^{b}	25.00^{bc}	30.17^{bcd}	34.33^{bc}	45.83^{cd}	45.83^{cd}	45.83^{cd}
Maifarin hanci	7.50^{b}	23.33^{bc}	33.33^{bc}	33.33^{bc}	33.33^{cd}	33.33^{cd}	33.33^{cd}
SAMPEA 11	0.00^{b}	15.83^{bc}	15.83^{cd}	27.50^{bcd}	27.50^{de}	27.50^{de}	27.50^{de}
SAMPEA 12	0.00^{b}	15.83^{bc}	37.50^{bc}	41.67^{bc}	50.00c	50.00c	50.00^{c}
IAR- 00- 1074	0.00^{b}	7.50^{bc}	15.00^{cd}	22.50^{cd}	27.50^{de}	27.50^{de}	27.50^{de}
Dansokoto	0.00^{b}	0.00^{c}	7.50^{d}	8.33^{d}	8.33^{e}	8.33^{e}	8.33^{e}
SE±	7.47	7.92	7.62	7.87	6.29	6.29	6.29

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT)

WAS = Weeks after sowing

At 3 WAS, IAR-07-1050 recorded the highest incidence (79.17 %) which did not differ statistically from that of SAMPEA 10 and Biu local. Dansokoto recorded the least incidence (0.00 %) but did not differ statistically from that of IAR-00-1074, SAMPEA 8, SAMPEA 11, SAMPEA 12, Kanannado, Maifarin hanci and SAMPEA 7.At 4 WAS, Biu local and SAMPEA 10 recorded the highest incidence (91.67 %) which did not differ statistically from that of IAR- 07-1050. Dansokoto recorded the least incidence (7.50 %).At 5 WAS, IAR-07-1050 recorded the highest incidence (100 %) which did not differ statistically from that of Biu local and SAMPEA 10. Dansokoto recorded the least incidence (8.33 %) which did not statistically differ from that of IAR-00-1074, SAMPEA 8 and SAMPEA 11.At 6 WAS, IAR-07-1050, Biu local and SAMPEA 10 recorded the highest incidence (100 %) followed by SAMPEA 9. Dansokoto recorded the least incidence (8.33 %) which did not statistically differ from that of IAR-00-1074 and SAMPEA 11. No significant increase in incidence was recorded at 7 and 8 WAS.

The severity of stem rot on cowpea varieties inoculated with *R. solani* in the glasshouse also significantly varied (Table 7) with time.At 2 WAS, highest disease severity (40.76 %) was recorded on Biu local which did not differ statistically from that of IAR-07-1050. Dansokoto, IAR-00-1074, SAMPEA 11 and SAMPEA 12 had the least severity (0.00 %) which did not differ statistically from that of Maifarin hanci and SAMPEA 7.At 3 WAS, Biu local recorded the highest severity (49.52 %) which did not differ statistically from that of IAR-07-1050. Dansokoto recorded the least severity (0.00 %) though it did not statistically differ from that of SAMPEA 8, SAMPEA 12, Kanannado and SAMPEA 11.At 4 WAS, Biu local recorded the highest severity (58.09 %) which did not differ statistically from that of IAR- 07-1050. Dansokoto recorded the least severity (5.71 %) which did not differ statistically from that of IAR-00-1074, SAMPEA 8 and SAMPEA 11.

Table 7: Severity of stem rot on cowpea varieties inoculated with *Rhizoctonia solani* in the glasshouse at 2 – 8 weeks after sowing in 2014

Variety	Disease severity (%) at:						
	2WAS	3WAS	4WAS	5WAS	6WAS	7WAS	8WAS
Biu local	40.76^{a}	49.52^{a}	58.09^{a}	58.09^{a}	62.86^{a}	62.86^{a}	62.86^{a}
IAR- 07- 1050	35.24^{ab}	45.62^{a}	55.24^{a}	56.24^{a}	60.95^{a}	60.95^{a}	60.95^{a}
SAMPEA 10	29.52^{bc}	31.43^{b}	32.38^{b}	53.33^{a}	55.71^{b}	55.71^{b}	55.71^{b}
SAMPEA 8	19.05^{cd}	6.67d^{e}	13.33^{d-g}	19.05^{c}	24.76^{cde}	24.76^{cde}	24.76^{cde}
SAMPEA 9	19.05^{cd}	20.95^{bc}	24.76^{bcd}	25.71^{bc}	39.81^{bc}	39.81^{1bc}	39.81^{bc}
Kanannado	11.43^{de}	11.43^{cde}	23.81^{b-e}	23.81b^{c}	23.81^{de}	23.81^{de}	23.81^{de}
SAMPEA 11	0.00^{f}	12.38^{cde}	12.38^{efg}	19.05^{c}	22.86^{de}	22.86^{de}	22.86^{de}
SAMPEA 12	0.00^{f}	11.43^{cde}	20.00^{c-f}	24.72^{bc}	28.53^{cde}	28.53^{cde}	28.53^{cde}
IAR- 00- 1074	0.00^{f}	5.71^{de}	11.43^{fg}	15.24^{cd}	17.14^{ef}	17.14^{ef}	17.14^{ef}
Dansokoto	0.00^{f}	0.00^{e}	5.71^{g}	6.67^{d}	6.67^{f}	6.67^{f}	6.67^{f}
SAMPEA 7	6.67^{ef}	19.51^{bcd}	20.95^{b-e}	24.76^{bc}	37.14b^{cd}	37.14^{bcd}	37.14^{bcd}
Maifarin hanci	5.71^{ef}	18.09^{bcd}	31.43^{bc}	31.43^{b}	31.43^{b-e}	31.43^{b-e}	31.43^{b-e}
SE±	3.53	4.33	3.82	3.62	4.88	4.88	4.88

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT)

WAS = Weeks after sowing

At 5 WAS, Biu local recorded the highest severity (62.86 %) which did not differ statistically from that of IAR-07-1050 and SAMPEA 10. Dansokoto recorded the least severity (6.67 %) which did not statistically differ from that of IAR-00-1074.At 6 WAS, Biu local recorded the highest severity (62.86 %) which did not differ statistically from that of IAR-07-1050. Dansokoto recorded the least severity (6.67 %) which did not statistically differ from that of IAR-00-1074.No significant increase in severity was recorded at 7 and 8 WAS.

Pod number and grain weight of varieties inoculated with *R. solani* in the glasshouse varied significantly (Table 8).Dansokoto produced highest number of pods (32.67) which did not statistically differ from that of SAMPEA 12, IAR-00-1074 and Kanannado.IAR-07-1050 produced least number of pods (6.33) though it did not differ statistically from that of SAMPEA 7, SAMPEA 9, SAMPEA 10 and Biu local. Highest grain weight on inoculated cowpea was recorded on SAMPEA 8 (53.53 g) which did not differ statistically from that of IAR-00-74, Dansokoto, Maifarin hanci and Kanannado. Least grain weight (11.53 g) was recorded on IAR-07-1050 which did not differ statistically from that of Biu local, SAMPEA 10, SAMPEA 9, SAMPEA 11, SAMPEA 7, SAMPEA 12, Kanannado and Maifarin hanci.

Table 9 shows the correlation between disease incidence, disease severity, number of pods and grain weight of inoculated cowpea recorded in the glasshouse in 2014. Disease incidence is positively and not significantly correlated (0.077) with disease severity, it however correlated negatively and not significant with number of pods (- 0.09) and grain weight (- 0.21). Disease severity on the other hand was negatively and significantly correlated with number of pods (- 0.76) and grain weight (- 0.57). Number of pods correlated positively and significantly with grain weight (0.63).

Table 8: Pod Number and grain weight of cowpea varieties inoculated with *Rhizoctonia solani* in the glasshouse in 2014

	Inoculated		Non inoculated	
Variety	Number of pods/plant	Grain weight (g)/plant	Number of pods/plant	Grain weight (g)/plant
Dansokoto	32.67^{a}	36.06^{abc}	34.00^{ab}	42.50^{cd}
IAR-00-1074	29.67^{ab}	38.03^{ab}	32.41^{ab}	42.50^{cd}
Kanannado	25.00^{abc}	31.97^{a-d}	35.43^{a}	48.35^{bc}
SAMPEA 12	22.33^{a-d}	24.87^{bcd}	29.91^{abc}	39.24^{d}
SAMPEA 8	21.33^{bcd}	53.53^{a}	23.58^{cde}	80.21^{a}
Maifarin hanci	21.33^{bcd}	34.07^{a-d}	28.45^{bc}	52.57^{b}
SAMPEA 11	20.67^{bcd}	22.40^{bcd}	23.52^{cde}	26.32^{e}
SAMPEA 7	16.67^{cde}	22.57^{bcd}	17.57^{ef}	30.30^{e}
SAMPEA 10	15.67^{cde}	14.29^{bcd}	20.32^{def}	28.52^{e}
SAMPEA 9	13.67^{de}	21.50^{bcd}	15.33^{f}	29.00^{e}
IAR-07-1050	6.33^{e}	11.53^{d}	18.92^{def}	29.68^{e}
Biu local	7.33^{e}	12.37^{cd}	24.47^{cd}	38.94^{d}
SE±	3.38	7.27	2.06	2.09

Means with the same superscript in a column are not significantly different at 5% level of significance (P≤0.05) using Duncan Multiple Range Test (DMRT)

Table 9: Correlation between disease incidence, disease severity, number of pods and grain weight of cowpea varieties inoculated with *Rhizoctonia solani* in the glasshouse in 2014

	Disease incidence	Disease severity	Number of pods	Grain weight
Disease incidence	1.00			
Disease severity	0.077	1.00		
Number of pods	- 0.092	- 0.76**	1.00	
Grain weight	- 0.21	- 0.57**	0.63**	1.00

NS = Not significant at 5%
** = Significant at 1%

The incidence of stem rot on cowpea varieties inoculated with *R. solani* on the field significantly varied (Table 10).At 2 WAS, highest disease incidence (14.79 %) was recorded on SAMPEA 10 which did not differ statistically from that of IAR-00-1074, SAMPEA 12, IAR-07-1050 and Biu local. SAMPEA 7, AMPEA 8, SAMPEA 11, Dansokoto, Kanannado, Maifarin hanci and SAMPEA 9 recorded the least incidence (0.00 %) which did not differ statistically from that of Biu local, SAMPEA 12, IAR-07-1050 and IAR-00-1074.At 3 WAS, SAMPEA 10 recorded the highest incidence (18.24 %) which did not differ statistically from that of Biu local, IAR-00-1074, IAR-07-1050 and SAMPEA 12. SAMPEA 7, SAMPEA 8, SAMPEA 11, SAMPEA 9, Maifarin hanci, Kanannado and Dansokoto recorded the least incidence (0.00 %) though it did not statistically differ from that of SAMPEA 12, IAR-00-1074 and IAR-07-1050.At 4 WAS, SAMPEA 11 recorded the highest incidence (42.94 %) which did not differ statistically from that of SAMPEA 10, Maifarin hanci and SAMPEA 9. Dansokoto recorded the least incidence (21.67 %) which did not differ statistically from that of SAMPEA 8, IAR-00-1074, Kanannado, IAR-07-1050, Biu local, SAMPEA 7 and SAMPEA 9.At 5 WAS, SAMPEA 10 recorded the highest incidence (64.13 %). Dansokoto recorded the least incidence (21.67 %) which did not statistically differ from that of Kanannado, SAMPEA 12, IAR-00-1074 and SAMPEA 8.At 6 WAS, SAMPEA 10 recorded the highest incidence (75.41 %) followed by Biu local which did not statistically differ from that of IAR-07-1050. Dansokoto recorded the least incidence (21.67 %) which did not statistically differ from that of Kanannado and SAMPEA 12. No significant increase in incidence was recorded at 7 and 8 WAS.

The severity of stem rot on cowpea varieties inoculated with *R. solani* on the field also significantly varied (Table 11).

Table 10: Incidence of stem rot on cowpea varieties inoculated with *Rhizoctonia solani* on the field from 2 – 8 weeks after sowing in 2014 rainy season

Variety	Disease incidence (%) at:						
	2WAS	3WAS	4WAS	5WAS	6WAS	7WAS	8WAS
SAMPEA 10	14.79^{a}	18.24^{a}	36.90^{ab}	64.13^{a}	75.41^{a}	75.41^{a}	75.41^{a}
IAR-00-1074	6.86^{ab}	13.53^{ab}	24.95^{cd}	31.93^{cde}	48.93^{c}	48.93^{c}	48.93^{c}
SAMPEA 12	6.00^{ab}	12.00^{ab}	24.17^{cd}	28.86^{de}	30.28^{d}	30.28^{d}	30.28^{d}
IAR-07-1050	6.00^{ab}	13.50^{ab}	26.23^{bcd}	50.81^{b}	57.91^{bc}	57.91^{bc}	57.91^{bc}
Biu local	4.19^{ab}	18.17^{a}	28.97^{bcd}	49.73^{b}	64.62^{b}	64.62^{b}	64.62^{b}
SAMPEA 7	0.00^{b}	0.00^{b}	30.81^{bcd}	41.27^{bc}	50.71^{c}	50.71^{c}	50.71^{c}
SAMPEA 8	0.00^{b}	0.00^{b}	22.43^{d}	32.39^{cde}	51.21^{c}	51.21^{c}	51.21^{c}
SAMPEA 9	0.00^{b}	0.00^{b}	32.58^{a-d}	49.05^{b}	53.49^{c}	53.49^{c}	53.49^{c}
SAMPEA 11	0.00^{b}	0.00^{b}	42.94^{a}	45.56^{b}	51.74^{c}	51.74^{c}	51.74^{c}
Maifarin hanci	0.00^{b}	0.00^{b}	34.77^{abc}	49.05^{b}	53.49^{c}	53.49^{c}	53.49^{c}
Kanannado	0.00^{b}	0.00^{b}	25.29^{cd}	25.29^{e}	25.29^{d}	25.29^{d}	25.29^{d}
Dansokoto	0.00^{b}	0.00^{b}	21.67^{d}	21.67^{e}	21.67^{d}	21.67^{d}	21.67^{d}
SE±	3.66	4.36	3.56	3.64	2.99	2.99	2.99

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT)

WAS = Weeks after sowing

Table 11: Severity of stem rot on cowpea varieties inoculated with *Rhizoctonia solani* on the field from 2 – 8 weeks after sowing in 2014 rainy season

Variety	Disease severity (%) at:						
	2WAS	3WAS	4WAS	5WAS	6WAS	7WAS	8WAS
SAMPEA 10	9.99^{a}	11.43^{a}	30.48^{a}	55.24^{a}	66.19^{a}	66.19^{a}	66.19^{a}
SAMPEA 12	5.71^{ab}	11.43^{a}	20.00^{bcd}	21.91^{fg}	26.67^{e}	26.67^{e}	26.67^{e}
IAR-07-1050	5.71^{ab}	11.43^{a}	23.81^{bc}	34.29^{bc}	49.52^{b}	49.52^{b}	49.52^{b}
IAR-00-1074	3.56^{ab}	12.38^{a}	21.90^{bcd}	25.71^{ef}	36.19^{cd}	36.19^{cd}	36.19^{cd}
Biu local	3.18^{ab}	17.97^{a}	23.81^{bc}	39.90^{b}	62.86^{a}	62.86^{a}	62.86^{a}
SAMPEA 7	0.00^{b}	0.00^{b}	20.00^{bcd}	29.52^{cde}	41.90^{cd}	41.90^{cd}	41.90^{cd}
SAMPEA 8	0.00^{b}	0.00^{b}	20.95^{bcd}	27.14^{def}	36.19^{cd}	36.19^{cd}	36.19^{cd}
SAMPEA 9	0.00^{b}	0.00^{b}	19.05^{cd}	32.28^{cde}	43.62^{bc}	43.62^{bc}	43.62^{bc}
SAMPEA 11	0.00^{b}	0.00^{b}	31.43^{a}	31.43^{cde}	35.24^{d}	35.24^{d}	35.24^{d}
Maifarin hanci	0.00^{b}	0.00^{b}	24.76^{b}	33.33^{bcd}	39.05^{cd}	39.05^{cd}	39.05^{cd}
Kanannado	0.00^{b}	0.00^{b}	18.09^{d}	19.05^{g}	19.05^{f}	19.05^{f}	19.05^{f}
Dansokoto	0.00^{b}	0.00^{b}	17.14^{d}	17.14^{g}	17.14^{f}	17.14^{f}	17.14^{f}
SE±	2.78	3.41	1.74	2.20	2.40	2.40	2.40

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT)

WAS = Weeks after sowing

At 2 WAS, highest disease severity (9.99 %) was recorded on SAMPEA 10 which did not differ statistically from that of SAMPEA 12, IAR-07-1050 IAR-00-1074, and Biu local. SAMPEA 7, SAMPEA 8, SAMPEA 9 and SAMPEA 11. Dansokoto, Kanannado, and Maifarin hanci recorded the least severity (0.00 %) which did not differ statistically from that of Biu local, IAR-00-1074, SAMPEA 12 and IAR-07-1050.At 3 WAS, Biu local recorded the highest severity (17.97 %) which did not differ statistically from that of IAR-00-1074, SAMPEA 10, IAR-07-1050 and SAMPEA 12. SAMPEA 7, SAMPEA 8, SAMPEA 11, SAMPEA 9, Maifarin hanci, Kanannado and Dansokoto recorded the least severity (0.00 %).At 4 WAS, SAMPEA 11 recorded the highest severity (31.43 %) which did not differ statistically from that of SAMPEA 10. Dansokoto recorded the least severity (17.14 %) which did not differ statistically from that of Kanannado, Biu local, IAR-07-1050, SAMPEA 7, SAMPEA 8 and IAR-00-1074.At 5 WAS, SAMPEA 10 recorded the highest severity (55.24 %) followed by Biu local which did not differ statistically from that of IAR-07-1050 and Maifarin hanci. Dansokoto recorded the least severity (17.14 %) which did not statistically differ from that of Kanannado and SAMPEA 12.At 6 WAS, SAMPEA 10 recorded the highest severity (66.19 %) which did not differ statistically from that of Biu local. Dansokoto recorded the least severity (17.14 %) which did not statistically differ from that of Kanannado but at par with SAMPEA 12. No significant increase in severity was recorded at 7 and 8 WAS.

Number of pods significantly varied. Dansokoto produced highest number of pods (238.67) which did not statistically differ from that of Kanannado, IAR-00-1074, SAMPEA 7 and SAMPEA 12. Biu local recorded least number of pods (95.33) though it did not statistically differ from that of SAMPEA 10, SAMPEA 8, SAMPEA 9, IAR-07-1050, Maifarin hanci and SAMPEA 12.

Highest grain weight was obtained on SAMPEA 7 (564.94 Kg/ha) which did not statistically differ from that of IAR-00-74, Dansokoto, SAMPEA8, Kanannado, SAMPEA 11, SAMPEA 12 and Maifarin hanci (Table 12). Least grain weight (220.14 Kg/ha) was recorded on SAMPEA 9 which did not statistically differ from that of SAMPEA 10, IAR-07-1050, Biu local, Maifarin hanci, SAMPEA 12 and SAMPEA 11.

Table 13 shows the correlation between disease incidence, disease severity, number of pods and grain weight recorded on the field in 2014. Disease incidence correlated positively and highly significant (0.914) with disease severity, it correlated negatively and significant with number of pods (- 0.42) and grain weight (- 0.40).

Disease severity on the other hand correlated negatively and highly significant with number of pods (- 0.47) and grain weight (-0.47). Number of pods however correlated positively and highly significant with grain weight (0.67).

The inoculated cowpea varieties were separated into different host reaction groups based on the scale described earlier. The glasshouse evaluation result showed that SAMPEA 7, SAMPEA 9 and Maifarin hanci were moderately susceptible; SAMPEA 8, SAMPEA 11, SAMPEA 12, IAR-00-1074, and Kanannado were moderately resistant; SAMPEA 10, IAR-07-1050 and Biu local were found to be highly susceptible while Dansokoto was highly resistant. The field evaluation result however showed that SAPEA 7, SAMPEA 8, SAMPEA 9, SAMPEA 11, IAR-00-1074 and Maifarin hanci were moderately susceptible; SAMPEA 10, IAR-07-1050 and Biu local were highly susceptible while SAMPEA 12, Kanannado and Dansokoto were moderately resistant (Table 14).

Table 12: Pod Number and grain weight of cowpea varieties inoculated with *Rhizoctonia solani* on the field in 2014 rainy season

	Inoculated		Non inoculated	
Variety	Number of pods/plot	Grain weight (Kg/ha)	Number of pods/plot	Grain weight (Kg/ha)
Dansokoto	238.67[a]	509.13[ab]	243.80[a]	537.68[b]
Kanannado	231.33[ab]	493.17[ab]	243.67[a]	494.42[cd]
IAR- 00- 1074	214.67[abc]	523.72[ab]	222.00[bc]	573.51[a]
SAMPEA 7	211.67[abc]	564.95[a]	235.33[ab]	548.59[a]
SAMPEA 11	204.33[abc]	435.90[abc]	210.60[c]	484.40[cd]
SAMPEA 12	168.33[a-d]	398.62[abc]	169.60[e]	432.22[e]
Maifarin hanci	144.00[bcd]	347.12[abc]	162.26[e]	395.89[f]
IAR- 07- 1050	126.67[cd]	302.19[bc]	134.36[f]	489.31[cd]
SAMPEA 9	116.33[d]	220.14[c]	134.50[f]	245.58[g]
SAMPEA 8	113.00[d]	500.32[ab]	122.00[f]	505.43[c]
SAMPEA 10	106.67[d]	262.98[c]	193.34[d]	471.53[d]
Biu local	95.33[d]	309.69[bc]	106.42[g]	408.08[f]
SE±	27.85	6.58	3.61	8.02

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Duncan Multiple Range Test (DMRT)

Table 13: Correlation between disease incidence, disease severity, number of pods and grain weight of cowpea varieties inoculated with *Rhizoctonia Solani* on the field in 2014

	Disease incidence	Disease severity	Number of pods	Grain weight
Disease incidence	1.00			
Disease severity	0.914**	1.00		
Number of pods	- 0.42*	- 0.47**	1.00	
Grain weight	- 0.40*	- 0.47**	0.67**	1.00

* = significant at 5%
** = significant at 1%

Table 14: Host reaction groups of cowpea varieties evaluated for their reaction to stem rot in the glasshouse and on the field in 2014

Varieties	Host Reaction Group	
	Glasshouse	Field
SAMPEA 7	MS	MS
SAMPEA 8	MR	MS
SAMPEA 9	MS	MS
SAMPEA 10	HS	HS
SAMPEA 11	MR	MS
SAMPEA 12	MR	MR
IAR- 00- 1074	MR	MS
IAR- 07- 1050	HS	HS
Biu local	HS	HS
Maifarin hanci	MS	MS
Kanannado	MR	MR
Dansokoto	HR	MR

MS = moderately susceptible. MR = moderately resistant. HS = highly susceptible.
HR = highly resistant

CHAPTER FIVE

5.0 DISCUSSION

5.1 Incidence and Severity of Cowpea Stem Rot in the Surveyed Locations

The uneven distribution of the disease observed indicates that rainfall and relative humidity influence the disease in the surveyed areas, as evidenced by high incidence and severity recorded in Lere LGA in Northern Guinea Savannah with high rainfall and relative humidity while lowest incidence and severity were recorded in Kaita LGA in Sahel savannah with low rainfall and relative humidity (Appendix 2).Also the year 2013 with higher incidence and severity of the disease recorded higher rainfall than 2014 (Appendix 3).This conforms to the report by Dorrance *et al*. (2003), that soil moisture and relative humidity favour *R. solani* disease development.According to a work by Adandonon *et al*. (2004),disease incidence of cowpea stem rot was higher in the south and central zones of Benin Republic than its Northern zone as a result of different amount of rainfall received by each zone.

In Kaduna State where highest disease incidence and severity were recorded, even though the cowpea is planted in relay with maize but the maize is harvested at an early stage of the cowpea making it a sole crop on the field,thiscauses the pathogen to easily spread to nearby plants. In the intercrop system observed in Kano, Katsina and Zamfara States, the disease develop slowly as the cereal serve as a barrier between cowpea stands. This Agrees with Singh *et al*. (1997) who reported that in an intercropping or mixed crop system, the populations of several pests and disease incidence are reduced and yields increased accordingly.Adandonon *et al*. (2004), also recorded high incidence and severity of cowpea stem rot in sole crop cowpea fields than in cowpea fields intercropped with cereals in Benin.

5.2 Isolation and Identification of Fungi

Rhizoctonia solani was the organism most frequently isolated from the naturally infected plants obtained from the surveyed locations. In earlier works, of all the isolated organisms from this study, only *C. capsici* and *C. lunata* were not implicated as causal organisms of cowpea stem rot but causes Cowpea brown blotch and *Curvularia* leaf spots of maize respectively (Adegbite and Amusa, 2008; Shigang *et al*., 2014). Adandonon *et al*. (2004) isolated*S. rolfsii, Fusarium* spp., *Pythium ultimum, R. solani, Phoma* spp., and *Trichoderma harzianum* from diseased cowpea stem collected from all ecological zones of Benin. But contrary to Adandonon findings that consider *S. rolfsii* as the causal agent of stem rot, *R. solani* based on this study is considered the causal agent of stem rot in North West Nigeria having produced typical disease symptoms on artificially inoculated plants and also being the most frequently isolated from all the surveyed locations. Though this is contrary to Onuorah (1973) and Suleiman (2010) who reported *Pythium aphanidermatum* as causal agent of cowpea stem rot in Ibadan and Kogi State of Nigeria respectively. The isolation of *C. lunata* only from Kaduna and Katsina states might be as a result of cowpea maize relay that predominates in the state, because *C. lunata* is a major maize foliar fungal pathogen that is found widely in maize growing areas (Shigang *et al*., 2014).

5.3 Pathogenicity Test

Pathogenicity test showed that only *Rhizoctonia solani* induced typical symptom observed on the field even though all the isolated organisms produced disease symptoms. This agreed with findings of Adandonon *et al*. (2001) that damping off and stem rot of cowpea in South Africa is caused by complex of *Pythium ultimum* and *Rhizoctonia solani.* According to report ofSiriwardana, and Amarasingha (1982), root and stem rot of

cowpea may be caused by various fungi most notable of which are *Rhizoctonia solani, Fusarium solani, Pythium* sp. and *Sclerotium rolfsii*. Amusa *et al*. (2007) reported that isolates of *Macrophomina phaseolina* from different host induced stem necrotic lesions on stem of two cowpea varieties, this also agrees with findings of this study.

R. solani produced reddish brown lesions on the stem at soil level which girdled the stem, this agrees with the report of Olsen and Young (2001) that seedling infected with *R. solani* have reddish brown lesions and cankers on the stem and roots. *M. phaseolina* produced brown necrotic lesions which turned grey and the stem was covered with black sclerotia, this agrees with the report of Ndiaye (2007) that *M. phaseolina* causes beige lesion on stems which become grey and covered with abundant minute black punctuations. *Sclerotium* sp. produced dark brown lesions that girdled the collar region which moves acropetally and covered with white minute sclerotia. This agrees with the findings of Adejumo and Ikotun(2003) thatthe fungus *S. rolfsii* infects the cowpea stems at the base, producing a fan of silking myceliumand large round sclerotia which are initially white andgradually darken.*C. capsici* produced purple brown lesion at stem base which progressed upward. This agrees with the report of Emechebe (1981) that signs of *C. capsici* infection include hypocotyl lesions which are purplish brown and occur at above soil level. *F. solani* produced reddish brown lesions which coalesce to cover the stem near the soil level. This agrees with the findings of Nelson *et al*. (1981) that symptoms of *F. solani* infection are brown discoloration on the stem and tap root which coalesce to cover the entire below ground stem and root system. This is the first report of *C. lunata*beingassociated withfield cowpea in Nigeria.

5.4 Effect of Different Inoculation Methods on Disease Incidence and Severity on Cowpea Inoculated with *Rhizoctonia solani*

Symptoms development on the cowpea inoculated with *R. solani*using soil drench and millet grain soil inoculationmethods indicates that they are better inoculation methods than spray inoculation method. Khalil (2008) reported that high disease incidence and severity of stem canker disease caused by *Rhizoctonia solani* were recorded on potatoes inoculated with *R. solani* using soil drench and organic rye seeds soil inoculations. Adandonon *et al*. (2004) also reported Sclerotiumstem rot on cowpea inoculated with *Sclerotium rolfsii* using millet grain soil inoculation. Ndiaye (2007) and Mayek-perez*et al*. (2001) also reported high severity of charcoal rot on cowpea inoculated with *Macrophomina phaseolina* using millet grain soil inoculation. Millet grain soil appears to be the best method of inoculation for the tested fungus as it resulted in highest incidence and severity of the disease. The development of symptoms on inoculated plants using pinprick method shows the possibility of easier plant penetration and infection by the fungus when entrance such as wound is created. This is because when plant organ is wounded, it allows even the weak plant pathogenic fungi to easily enter through the wounds and cause disease, the wounded plants are also weakened greatly, especially in their ability to mobilize their defences against pathogens and to protect themselves from becoming diseased. This agreed with the report of Brown *et al.* (1994) that transgenic varieties of pea and canola inoculated with *Rhizoctonia solani* using pinprick method recorded high severity of stem diseases.

5.5 Evaluation of Cowpea Varieties for their Reactions to the Causal Organism

The results of the present study have shown that the 12 cowpea varieties evaluated produced stem rot symptoms when artificially inoculated with *Rhizoctonia solani* in both glasshouse and on the field.No cowpea variety tested was immune to the disease even

though some varieties showed different level of resistance to the disease. Higher incidences and severities were recorded on the field than in the glasshouse. The differences are probably attributable to the fact that in the glasshouse experiment, the soil was sterilised and infection was only due to the fungi inoculated; in the field however as the soil was not sterilised, activities of other soil pathogens aggravated the disease making a disease complex that is more severe than single pathogen infection. Adandonon *et al*. (2001) reported that cowpea stem rot is caused by complex of soil fungi which include *S. rolsii*, *R. solani* and *Pythium ultimum*. Onuorah (1973) also showed that cowpea stem rot caused by complex of soil borne fungi is more severe than that caused by single fungus.

SAMPEA 10, Biu local and IAR-07-1050 are the most susceptible of the 12 cowpea varieties tested. SAMPEA 12, Dansokoto and Kanannado were resistant in both glasshouse and field. With the exception of Biu local, the local varieties recorded relatively lower incidence and severity than the improved varieties, this indicates that the local cowpea varieties tested are more tolerant to stem rot than the improved varieties used in this study. According to Anonymous (2015), SAMPEA 10 is resistant to striga/alectra and tolerant to major insect pests. SAMPEA 7 is susceptible to scab, bacterial blight, septoria leaf spot and brown blotch. It is also susceptible to beetles, thrips, pod borer, pod sucking bugs and bruchids. SAMPEA 8 and SAMPEA 9 are tolerant to major insect pests. SAMPEA 11 is resistant to nematodes and major insect pests. SAMPEA 12 is field tolerant to major insect pests. None of the varieties was earlier evaluated against stem rot.

The result showed that number of pods produced and grain weight significantly decreased with increase in incidence or severity. This shows that cowpea stem rot caused

significant yield reduction. This agrees with Mbong *et al.* (2010) and Mungo (1991) who reported negative and significant correlation between cowpea scab severity and grain yield in Samaru Zaria. Soonthornpoct *et al.* (2000) reported significant negative correlation between yield of maize and severity of root and basal stem rots incited by *Rhizoctonia solani*inMississipi, USA. Yield of cowpea was also found to be correlated negatively with damping off and brown blotch of cowpea in Zaria (Okpala, 1981).

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The incidence and severity of cowpea stem rot in farmers' fields was assessed in four cowpea producing states of North - West Nigeria in 2013 and 2014 rainy seasons. Cowpea fields in Kaduna state had significantly higher incidence and severity than those in Kano, Katsina and Zamfara State for the two seasons surveyed. Katsina State had the lowest incidence and severity of the disease. In each of the States, incidence and severity of the disease increases from north to south. In Kaduna State, Lere L. G. A. had the highest disease incidence and severity while Sabongari L. G. A. had the lowest incidence and severity. Gezawa L. G. A. had the highest incidence and severity in Kano State while Minjibir L. G. A. had the lowest. In Katsina State, Sabuwa L. G. A. had the highest incidence and severity while Kaita had the lowest. In Zamfara State, highest incidence and severity were recorded in Bungudu while Tsafe recorded the lowest.

The fungi isolated from diseased cowpea stem were identified as *Rhizoctonia solani,Macrophomina phaseolina*, *Sclerotium* sp., *Colletotrichum capsici, Fusarium solani* and *Curvularialunata*.*Rhizoctonia solani*incited typical stem rot symptoms on artificially inoculated cowpea plants.

Four inoculation methods: soil drench, injury pinprick, spray and millet grain soilinoculations were used to test the progress of the disease. *R. solani* produced symptoms using injury pinprick, soil drench and soil millet grain inoculations but failed to produce symptoms with spray inoculation method.

Six improved cowpea varieties (SAMPEA 7, SAMPEA 8, SAMPEA 9, SAMPEA 10, SAMPEA 11andSAMPEA 12), two accessions (IAR–00–1074 and IAR–07–1050) and four local varieties (Biu local, Maifarin hanci, Kanannado and Dansokoto) were evaluated in the glasshouse and on field for reaction to *R. solani* infection. The *R. solani* induced symptoms of varying incidence and severity on all the 12 cowpea varieties with SAMPEA 10, IAR-07-1050 and Biu local recording the highest incidence and severity while Dansokoto recorded the least incidence and severity in both glasshouse and field. Correlation analysis showed that stem rot incidence and severity significantly reduced number of pods produced and grain yield.

6.2 Conclusions

The following conclusions can be made from the study:

Cowpea stem rot induced by *Rhizoctonia solani* was found on all cowpea growing areas surveyed but its incidence and severity were influenced by agro ecological location with highest in the Northern Guinea Savannah and lowest in the Sahel Savannah.

Dansokoto, Kanannado and SAMPEA 12 were resistant in both glasshouse and field, they could therefore form part of Integrated Pest Management (IPM) strategy for cowpea stem rot in areas where the disease is reported to cause yield loss.

6.3 Recommendations

Based on the findings of this study, the following recommendations were drawn:

1. Farming operations such as mechanical weeding should be carefully conducted to avoid injuring the plant at stem base as inoculated tissues artificially wounded by pinprick produced disease on all inoculated cowpea.
2. Cowpea varieties Dansokoto, Kanannado and SAMPEA 12 should be further evaluated and a more detailed work should be conducted to identify the genes or

polyphenols associated with resistance to introduce them into more preferred large seeded cowpea varieties

3. Further studies should be conducted to establish the relationship between *C. lunata* and cowpea.

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APPENDICES

Appendix 1:

CABI IDENTIFICATION REPORT

Our ref.:4A/14/A004

Your ref:

Your number	IMI number	Identification and comments
SA 1	141080	***Macrophomina phaseolina*.**(Tassi.) Goidan. This sample was identified as *Macrophomina phaseolina*, for information see Holliday, P & Punithlingam, E. (1980). CMI Descriptions pathogenic fungi and Bacteria No. 275 and Punithalingam, E. (1992). A dried example of this isolate.
SA 2	141081	***Colletotrichum capsici*** (H.sydow) E. Butler & Bisby . this sample wasprocessed usingITS and DNA sequencing which shows features andcolony characteristics of *Colletotrichum capsic*i. This sample has been placed in the IMI herbarium.
SA 3	141082	***Sclerotium sp.*** This is a mixed culture containing several species of fungi including speciaes of **Alternaria**. It is not posible to separate the other fungi in pure culture.
SA 4	141083	***Fusarium solani*** (Mart.) Sacc. This sample was identified from exami-nation of its mophology and shows microscopic features and colony chracteristics of ***F. solani***.
SA 5	141084	***Rhizoctonia solani***. This sample was identified using ITS and DNA sequencing which shows a colony characteristics of ***R. solani.***
SA 6	141086	***Curvularia lunata*** (Wakker) Boedi jn anamorph of *Cochliobolus lunatus*Nelson & Haasis (discarded)

Appendix 2: Agro Ecological Zones, Mean Annual Rainfall and Relative Humidity of the Surveyed Local Government Areas in 2014

State	LGA	Agro ecological Location	Rainfall (mm)	Relative Humidity (%)
Kaduna	Lere	Northern Guinea Savannah	1051.7	70.50
	Soba	Northern Guinea Savannah	1051.7	70.50
	Sabongari	Northern Guinea Savannah	1051.7	70.50
Kano	Dawakin kudu	Sudan Savannah	657.3	65.65
	Gezawa	Sudan Savannah	657.3	65.65
	Minjibir	Sudan Savannah	657.3	65.65
Katsina	Sabuwa	Northern Guinea Savannah	1051.7	70.50
	Batagarawa	Sudan Savannah	657.3	65.65
	Kaita	Sahel Savannah	450.6	56.00
Zamfara	Tsafe	Sudan Savannah	657.3	65.65
	Bungudu	Sudan Savannah	657.3	65.65
	Kauran namoda	Sudan Savannah	657.3	65.65

Source: KADP, KNARDA and KTARDA Crop and Weather Reports (2014)

Appendix 3:Total Annual Rainfall andMean Temperature of the Surveyed States, 2013 and 2014.

State	Raninfall (mm)		Mean Temperature (^{0}C)	
	2013	2014	2013	2014
Kaduna	1739.80	1623.60	32.30	32.10
Kano	1376.00	1009.30	34.40	33.40
Katsina	648.00	481.50	34.40	34.20
Zamfara	761.80	705.60	34.80	34.50

Source: NAERLS and FDAE (2014)

Appendix 4: ANOVA Tables

ANOVA for Cowpea stem rot incidence in four states during 2013 and 2014

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	158.469	79.235	2.25	0.1417
State	3	1410.892	470.297	13.38	0.0002
Year	1	299.344	299.344	8.52	0.0112
State*year	3	53.535	17.845	0.51	0.6833
Error	14	492.119	35.151		
Corrected total	23	2414.359			

ANOVA for Cowpea stem rot severityin four states during 2013 and 2014

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	49.844	24.921	1.27	0.3119
State	3	661.559	220.520	11.22	0.0005
Year	1	92.945	92.945	4.73	0.0473
State*year	3	20.267	6.876	0.35	0.7900
Error	14	275.268	19.662		
Corrected total	23	1100.242			

ANOVA for cowpea stem rot incidence in twelve LGAs surveyed during 2013 and 2014

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	82.203	41.102	2.63	0.0826
LGA	11	5969.955	542.723	34.79	< 0.0001
Year	1	879.062	879.062	56.35	< 0.0111
LGA*year	11	362.202	32.927	2.11	0.0385
Error	46	717.628	15.600		
Corrected total	71	8011.050			

ANOVA for cowpea stem rot severityin twelve LGAs surveyed during 2013 and 2014

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	10.966	5.483	0.62	0.5371
LGA	11	2782.652	252.968	29.07	< 0.0001
Year	1	269.662	269.662	30.99	< 0.0111
LGA*year	11	222.605	20.237	2.33	0.0228
Error	46	400.286	8.702		
Corrected total	71	3686.170			

ANOVA for frequency of the fungi isolated from diseased cowpea in 2013 and 2014

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	21.566	10.783	0.02	0.9768
Organism	5	35786.745	7157.349	15.60	< 0.0001
State	3	1470.645	490.215	1.07	0.3663
Year	1	86.583	86.583	0.19	0.6650
Organism*State	15	14301.980	953.465	2.08	0.0175
Organism*year	5	706.422	141.284	0.31	0.9070
State*year	3	157.916	52.639	0.11	0.9513
Organism*state*year	15	6180.625	412.042	0.90	0.5684
Error	94	43121.888	458.744		
Corrected total	143	101834.369			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 2WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	13217.188	1201.563	12.77	< 0.0001
Error	24	2257.500	94.063		
Corrected Total	35	15479.688			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 3WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	25810.417	2346.402	12.42	< 0.0001
Error	24	4533.334	188.889		
Corrected Total	35	30343.750			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 4WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	25964.410	2360.401	13.28	< 0.0001
Error	24	4083.333	170.139		
Corrected Total	35	30047.743			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 5WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	31816.188	2892.381	18.94	< 0.0001
Error	24	3668.500	152.854		
Corrected Total	35	35484.688			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 6, 7 and 8WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	31866.639	2896.967	16.78	< 0.0001
Error	24	4143.500	172.646		
Corrected Total	35	36010.139			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 2WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	4389.896	399.081	11.95	< 0.0001
Error	24	801.489	33.395		
Corrected Total	35	5191.384			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 3WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	7116.341	646.940	18.70	< 0.0001
Error	24	830.392	34.600		
Corrected Total	35	7946.733			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 4WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	7937.256	721.569	14.36	< 0.0001
Error	24	1205.726	50.239		
Corrected Total	35	9142.982			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 5WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	8977.088	816.099	20.81	< 0.0001
Error	24	941.329	39.222		
Corrected Total	35	9918.410			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* in the glasshouse at 6, 7 and 8WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	8253.885	750.353	14.87	< 0.0001
Error	24	1211.394	50.475		
Corrected Total	35	9465.280			

ANOVA for pod number of cowpea inoculated with *Rhizoctonia solani* in the glasshouse

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	2103.222	191.202	5.64	0.0002
Error	24	813.333	33.889		
Corrected Total	35	2916.556			

ANOVA for grain weight of cowpea inoculated with *Rhizoctonia solani* in the glasshouse

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Variety	11	5020.818	456.438	3.28	0.0126
Error	24	3336.654	139.027		
Corrected Total	35	8357.472			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* on the field at 2WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	11	339.5004	169.750	4.48	0.0233
Variety	2	707.860	64.351	1.70	0.1395
Error	22	832.916	37.860		
Corrected Total	35	1880.276			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* on the field at 3WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	228.736	114.368	2.12	0.1437
Variety	11	2093.052	190.277	3.53	0.0057
Error	22	1185.831	53.901		
Corrected Total	35	3507.619			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* on the field at 4WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	2.806	1.403	0.04	0.9617
Variety	11	1389.239	126.294	3.52	0.0058
Error	22	789.079	35.867		
Corrected Total	35	2181.124			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* on the field at 5WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	57.560	28.800	0.77	0.4768
Variety	11	5124.673	465.879	12.39	< 0.0001
Error	22	827.046	37.593		
Corrected Total	35	6009.319			

ANOVA for incidence of stem rot on cowpea inoculated with *R. solani* on the field at 6WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	244.555	122.278	4.83	0.0182
Variety	11	8134.111	739.465	49.23	< 0.0001
Error	22	556.583	25.299		
Corrected Total	35	8935.249			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* on the field at 2WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	203.929	101.965	4.64	0.0208
Variety	11	365.242	33.204	1.51	0.1970
Error	22	483.297	21.968		
Corrected Total	35	1052.469			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* on the field at 3WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	98.254	49.127	1.49	0.2468
Variety	11	1559.163	141.742	4.30	0.0017
Error	22	724.431	32.929		
Corrected Total	35	2381.849			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* on the field at 4WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	17.703	8.852	1.03	0.3739
Variety	11	681.195	61.927	7.20	< 0.0001
Error	22	189.208	8.600		
Corrected Total	35	888.107			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* on the field at 5WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	137.520	68.760	5.02	0.0160
Variety	11	3436.436	312.403	22.80	< 0.0001
Error	22	301.496	13.704		
Corrected Total	35	3875.451			

ANOVA for severity of stem rot on cowpea inoculated with *R. solani* on the field at 6, 7 and 8WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	66.421	33.210	2.03	0.1556
Variety	11	7512.740	682.976	41.69	< 0.0001
Error	22	360.392	16.381		
Corrected Total	35	7939.5531			

ANOVA for pod number of cowpea inoculated with *Rhizoctonia solani* on the field

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	12391.167	6195.583	2.82	0.0812
Variety	11	93786.083	8526.008	3.88	0.0033
Error	22	48327.500	2196.705		
Corrected Total	35	154504.750			

ANOVA for grain weight of cowpea inoculated with *Rhizoctonia solani* on the field

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Rep	2	3173.812	1586.910	0.56	0.5779
Variety	11	88704.311	8064.028	2.86	0.0173
Error	22	62083.863	2821.994		
Corrected Total	35	153961.985			

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