KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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SCREENING OF GROUNDNUTS (*Arachis hypogaea* L.) FOR RESISTANCE TO EARLY AND LATE LEAF SPOTS

BY

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SCREENING OF GROUNDNUTS (*Arachis hypogaea* L.) FOR RESISTANCE TO EARLY AND LATE LEAF SPOTS.

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN CROP PROTECTION (PLANT PATHOLOGY)

BY

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APRIL, 2010

DECLARATION

I declare that the work in this thesis was carried out by me, and has not been submitted for a degree to any other university. Apart from the references made, which I have duly acknowledged, this thesis is the result of my own investigation.

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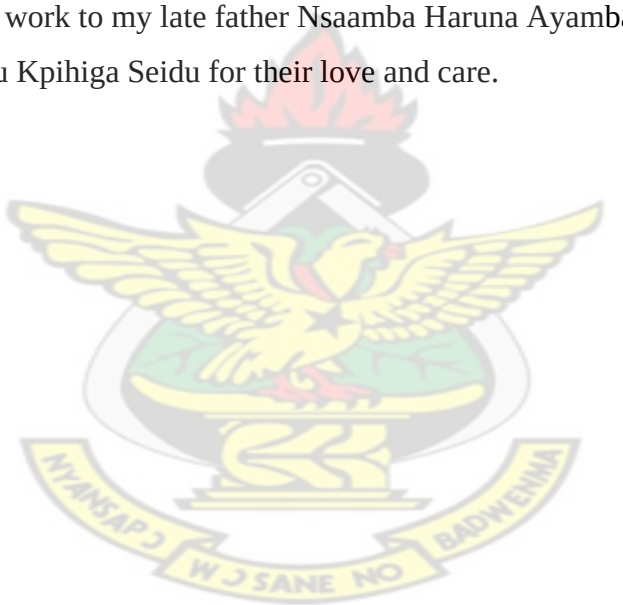
DEDICATION

I dedicate this work to my late father Nsaamba Haruna Ayamba Yussif and my Mother, Mma Ayishetu Kpihiga Seidu for their love and care.



ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important crop both in subsistence and commercial agriculture in Ghana. Early leaf spot (*Cercospora arachidicola*) and late leaf spot (*Phaeoisariopsis personata*) are major limiting factors to groundnut productivity in Ghana. The objective of the study was to determine resistant or tolerant varieties due to combined attack of both diseases. A disease-based questionnaire was administered to 100 farmers in their local language spread across 10 villages and towns selected from Tamale, Tolon-Kunbungu and Savelugu-Nanton Districts, all in the Northern Region of Ghana. The responses of the farmers showed that *Cercospora* leaf spot (ELS and LLS) is one of the major constraints to groundnut production in the area to which farmers have no solution. The severity of the disease was dependent on the cropping system adopted by the farmers. The variety Chinese turned out to be the most important commercial cultivar grown by farmers but it is susceptible to both diseases. Sixteen local groundnut varieties were field-screened from 2006 to 2008 at the Crops Research Institute, Kumasi, under the Council for Scientific and Industrial Research. The experiment was laid out in randomised complete block design (RCBD) with three replications. Early and late leaf spot ratings were recorded at 40 and 60 days after planting for early leaf spot, and 70 and 90 days after planting for late leaf spot, using a five point scale. The means of the scores were recorded. Pod and grain yields were also recorded at harvest. The results indicated that Azivivi, Nkosour, Adepa, and Jenkar had lowest score of 1.0 for both early and late leaf spot diseases. Among the four groundnut cultivars, Azivivi recorded the highest pod yield of 1086.1kg/ha and grain yield of 713.9kg/ha, followed by Nkosour with pod yield of 1011.7kg/ha and grain yield of 657.2kg/ha. Adepa had a pod yield of 929kg/ha and seed yield of 603.9kg/ha. The pod yield of Jenkaa was 842.2kg/ha and seed yield of 525.6kg/ha. All of them, except Jenkaa, recorded pod yield above 880kg/ha., a national average pod yield of groundnut.

From this study, Azivivi, Nkosour, Adepa, and Jenkaa are recommended for cultivation by farmers, since they are resistant to *Cercospora* leaf spots (ELS and LLS).

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CHAPTER ONE

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop and grain legume worldwide (Mensah and Obadoni, 2007). It is an important cash crop in subsistence and commercial farming systems, as well as an important food source (Izge *et al*., 2007). According to Asiedu (1989), groundnut is a herbaceous plant of which there are two major types, bunch and runner. Apart from the bunch and the runner types, many intermediate forms or hybrids exist (Irvine, 1974). The groundnut plant prefers rainfall of 500-1500mm, well distributed during the vegetative period of growth. Groundnut grows best in light-textured, deep, well-drained soils with no hindrance to penetration of the sharp point of the ovary (Tweneboah, 2000).

According to FAO estimates, the average world production of groundnut pods in 1999-2003 was about 34.4million t/year from 24.4million hectares of land (Ntare, 2007). The total production in sub-Saharan Africa was 8.2million t/year from 9.5million hectares of land (Ntare, 2007). The largest producers of groundnut are China and India, followed by sub-Saharan African countries and Central and South America (Johnson and Ives, 2001).

In Ghana, groundnut is grown in all agro-ecological zones. About 85% of the area under groundnut production is in the Guinea and Sudan savannah zones (Atuahene-Amankwa *et al*., 1988). However, smaller quantities are produced in all parts of the country (Tweneboah, 2000).

Groundnut cultivation is a major agricultural activity for the people of the northern regions of Ghana. It is both a commercial and subsistence venture for majority of the inhabitants (Tsigbey *et al.*, 2004).

Groundnut contains on the average 12-15% carbohydrates, 25-30% protein and 45-50 % oil (Kwarteng and Towler, 1994). The nuts may be chewed uncooked, but are usually eaten boiled or roasted (Abbiw, 1990). The nuts can also be boiled, fried, ground into groundnut butter, or crushed for oil (Porter, 1997; Owens, 1999). Groundnut butter is extensively used in the preparation of soup and as bread spread (Tsigbey *et al*., 2004). The oil which contains unsaturated fats is highly nutritious and contains between 50 - 65% oleic acid, 18-30% linoleic acid, 8-10% palmitic acid, 3-6% stearic acid as well as 7% of other fats including arachidic acid, beheric acid and lignoceric fatty acids (Oyenuga, 1967). The oil is used to make margarines, mayonnaise and for edible purposes (Garcia *et al*., 1990; Sanders *et al.,* 2003).

Groundnut protein is the cheapest source of dietary protein in places where meat is scarce and very expensive for large proportion of subsistent farming communities (Trawalley, 1998).

The groundnut hay is used as animal fodder and the shells as source of fuel and fertilizer (De Waele and Swanevelder, 2001). The cakes formed after the oil extraction are a high protein animal feed. It is also a valuable source of vitamins E, K, and B (FAO 1997). According to Marfo (1997), the crop is also an essential component in the cropping system in Northern Ghana because of its ability to fix nitrogen for associated or subsequent cereal crops.

Groundnut production in Ghana nearly tripled from 168,200 t in 1995 to 420,000 t in 2005 and was primarily due to increase in the area under cultivation which increased from 180,400 ha in 1995 to 450,000 ha in 2005 (FAO, 2006). Average yields, however, continue to remain below 1.0 t/ ha which is far below the potential yields of 2.0-3.0 t/

ha (Asibuo *et al.,* 2008). Pod yield of groundnut crops in Ghana averages only 840 kg/ha, which is low, compared to yields of 2,500 kg/ha in developed countries (FAO, 2002; Nutsugah *et al*., 2007b).

In Ghana, the major constraint to groundnut production is disease incidence, particularly, early leaf spot caused by *Cercospora arachidicola* and late leaf spot by *Phaeoisariopsis personata* (Frimpong *et al.*, 2006a). Both early and late leaf spots diseases are widely distributed and occur in epidemic proportions in northern Ghana (Nutsugah *et al*., 2007a). Epidemics of early and late leaf spots on susceptible groundnut genotypes can cause complete defoliation, which drastically can reduce yields (Shew *et al*., 1995).

Losses due to diseases can be attributed to the high percentage defoliation caused by leaf spot diseases, which thus affect pod filling and subsequent grain yield. Defoliation percentage affects hay quality of vines that are fed to animals (Tsigbey *et al.*, 2004).

In addition, fallen leaves from infected plants provide organic matter as a food source for other fungi particularly, *Sclerotium rolfsii*, and this can contribute to inoculums build-up on farms (Lucas *et al.*, 1992). Diseases of groundnut reduce yield and quality of grains and increased cost of production wherever the crop is grown (Wynne *et al.*, 1992).

Chemical control of leaf spot diseases has been reported in several production areas including Ghana. However, the principal limitation to the wider use of chemical control measures is high cost of the chemicals and the application equipment (Allen, 1983). In most developing countries, groundnut is grown mainly by resource-poor farmers who

can hardly afford chemical protection (Pande and Rao, 2002). Plant damage also occured during application of chemicals (Ihejirika *et al*., 2006a). According to Gibbons (2002), spraying chemicals against leaf spot, as against other diseases, should be kept to a minimum on health and environmental grounds. According to Tuormaa (2006), a World Health Organisation (WHO) report estimated that there were between 800,000 and 1,500,000 cases of unintentional pesticide poisoning worldwide, leading to between 3,000 and 28,000 deaths. This calls for a reduction on dependence on chemical control of disease.

In Ghana, some of the most hazardous agrochemicals in the world were among those being used regularly by farmers who lack knowledge and training in the safe use of these chemicals. A case study finding revealed extremely disturbing levels of pesticides misuse and abuse resulting in poisoning of families and livestock (Adolpus, 2007). In addition, excessive use of broad spectrum or persistent chemicals may result in soil contamination, fungicidal resistance, or other harmful effects (Maloy, 1993).

For the reasons above, the best option to control diseases of food crops is to obtain disease-resistant cultivars (Mallikarjuna *et al.*, 2004). Jyosthna *et al*. (2004) reported that an economic and eco-friendly way to manage diseases effectively is through host-plant resistance. It is the most cost effective of all the control measures (Driscoll, 1990).

Disease resistant cultivars are the safest and the most practical way to control diseases of many crops. Also, the use of resistant cultivars requires few changes in farmers' production practices (Lucas *et al*., 1992). Resistant varieties save time, effort, and money otherwise spent controlling plant diseases. Host-plant resistance reduces or eliminates two economic losses, direct reduction of yield and additional cost of control.

The environment also benefits because there is no need for pesticide application (Maloy, 1993). Subrahmanyam *et al*., (1982) reported that some genotypes of *Arachis hypogaea* are resistant to *Cercospora* leaf spot (ELS and LLS).

This study, therefore, focused on identifying resistant varieties of groundnut through screening of genotypes in disease hotspots as an attempt of contributing towards a significant reduction of yield losses due to early and late leaf spot diseases. The study also appraised farmer's perception of early and late leaf spot diseases of groundnut.

CHAPTER TWO

LITERATURE REVIEW

Cercospora leaf spots are found on a wide range of crops, particularly in warm humid regions. Leaf spots of groundnut are one of the most important diseases of this crop worldwide with annual yield losses of 15 to 50% (Lucas *et al*., 1992). There are many pathogenic strains of *Cercospora* some of which produce toxins which are poisonous to plants and aid in attacking the plant (Lucas *et al.,* 1992).

2.1 Early and late leaf spots diseases

The groundnut foliar diseases, early leaf spot (ELS) and late leaf spot (LLS), are caused by the globally significant pathogens, *Cercospora arachidicola* and *Cercosporidium personatum* [syn. *Phaeosariopsis personata* (Berk. & Curt.) V.Arx.], respectively. The teleomorphic stages of both organisms have been placed in the class Loculoascomycetes under the order Dothideales in the Ascomycotina. The anamorphs of both organisms are classified as Hyphomycetes, according to the Saccardo system of classification of the imperfect fungi. The host range of C. *arachidicola* and C. *personatum* is confined to the genus *Arachis* (Stalker and Simpson, 1995).

Although *Phaeoisariopsis personata* develops later, it is potentially the more destructive species because of its much higher rate of spread, leading to more rapid defoliation (Hemingway, 1955; Allen, 1983).

2.1.1 Early Leaf Spot (ELS) of groundnut

Morphology of the causal organism

Early leaf spot is caused by the fungus *Cercospora arachidicola*. The perfect state (asci and septated ascospores) of the early leaf spot pathogen (*Mycosphaerella arachidicola*) described by Jenkins (1938) is rarely observed, but the imperfect state (*C. arachidicola*) is commonly present on lesions.

During the imperfect state, the dark brown stromata produce brownish septated conidiophores which are generally restricted to the upper leaf surface. The conidiophores produce colourless curved septated conidia (35-110 x 3-6µm). Dry weather influences septation (Jenkins, 1938; Gibbons, 1966).

2.1.1.1 Symptoms of ELS on groundnut

Lesions are roughly circular, dark brown on the upper leaflet surface, lighter on the adaxial surface and surrounded by a chlorotic (yellow) halo (plate 1). They may coalesce in cases of severe attack, leading to defoliation. Lesions can also develop on stems, petioles and pegs (Woodroof, 1933; Jenkins, 1938; Van Wyk and Cilliers, 2000).

Symptoms can be confused with injuries caused by soil-applied chemicals, especially insecticides. However, in the latter case, lesions are scattered along the margins of leaves (Hagan, 1998)

2.1.1.2 Survival of ELS pathogen

It has been suggested that the pathogen perpetuates from season to season on volunteer groundnut plants and infected plant debris, building up an inoculum reservoir for the following season (Subrahmanyam *et al.,* 1992). Rao *et al.* (1993a) indicated that the conidia, ascospores and mycelia could only survive for between 30-60 days on infected groundnut debris that was buried under the soil surface. However, survival increased up to 12 months when the debris was stored indoors.

2.1.2 Late Leaf Spot (LLS) of groundnut

Morphology of the causal organism

Late leaf spot (LLS) is caused by the fungus *Phaeoisariopsis personata*. The late leaf spot pathogen is seen primarily in its imperfect state known as *C. personatum*. The perfect state (*Mycosphaerella berkeleyii* Jenkins) is classified under the ascogeneous fungi and both asci and spermatogonia occur on debris where the fungus over-winters (Pattee and Young, 1982). Jenkins (1938) described the imperfect state as follows: conidiophores (10-100 x 3-6.5µm) are mostly hypophyllous arising in more or less distinctly concentric reddish-brown tufts, generally with hyaline tips. Conidia (20-70 x 4-9µm) are generally cylindrical, pale brown, with somewhat attenuated tips and one or more septa.

2.1.2.1 Symptoms of LLS on groundnuts

According to Woodroof (1933) and Jenkins (1938), the lesions are very similar in size and form when compared to those of ELS. These lesions are, however, darker brown and without a definite chlorotic halo (plate 2). On the adaxial side of the leaflets, lesions are almost

Plate. 1. Symptoms of early leaf spot caused by *Cercospora arachidicola* on groundnut leaves

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Plate. 2. Symptoms of late leaf spot caused by *Phaeoisariopsis personata* on groundnut leaves

black in contrast to the lighter coloured lesions of ELS. Late leaf spot generally occurs later in the season and are often seen as a complex with other leaf spots.

Pattee and Young (1982) reported that *C. personatum* produced cellulolytic and pectolytic enzymes that altered the starch, sugar and amino acid content of leaf tissue, resulting in reduced leaf efficiency and premature abscission. Cercosporin, a biologically active red phytotoxin, was also isolated from *C. personatum.* Mohaptra (1982) also reported that infected leaves contained higher quantities of reducing sugars than healthy ones.

Pattee and Young (1982) observed that severe leaf spot damage reduced the leaf area index by 80%, the carbon dioxide uptake by 85% and the canopy carbon exchange rate by 93%. Photosynthesis of diseased canopies was reduced not only by defoliation but also by inefficient fixation of carbon dioxide by diseased leaves. Horne *et al.* (1976) reported that the LLS fungus produced haustoria that penetrated individual plant cells and that leaves infected with the fungus showed marked increase in respiration.

2.1.2.2 Survival of LLS pathogen

The pathogen perpetuates from season to season only on volunteer groundnut plants and infected plant debris, building up an inoculum reservoir for the following season (Subrahmanyam *et al.,* 1992).

2.2 ELS and LLS disease cycles

Primary inoculum comprises of conidia or mycelia that have overwintered on crop residue such as pods, stems or petioles. Ascospores potentially serve as other sources of inoculum. Wind, splashing raindrops, and insects disseminate conidia. Multi-celled conidia land on groundnut tissue, and germinate with one to several germ tubes (Shokes and Culbreath, 1997). Infection may occur on both abaxial and adaxial leaf surfaces, and penetration pegs enter the plant through lateral surfaces of epidermal cells, or through natural openings, such as stomata (Jenkins, 1938*). C. arachidicola* is a necrotroph, as intracellular hyphae are only found in cells that have been killed by the pathogen (Fig. 1). *C. personatum*, however, remains intercellular, and is known to produce haustoria in living cells (Fig. 2) (Jenkins, 1938; Abdou *et al.*, 1974; Mims *et al*., 1989). Under ideal conditions, visible ELS symptoms develop 6 to 8 days after infection in favourable conditions, and LLS symptoms can be seen 10 to 14 days after infection (Shokes and Culbreath, 1997)

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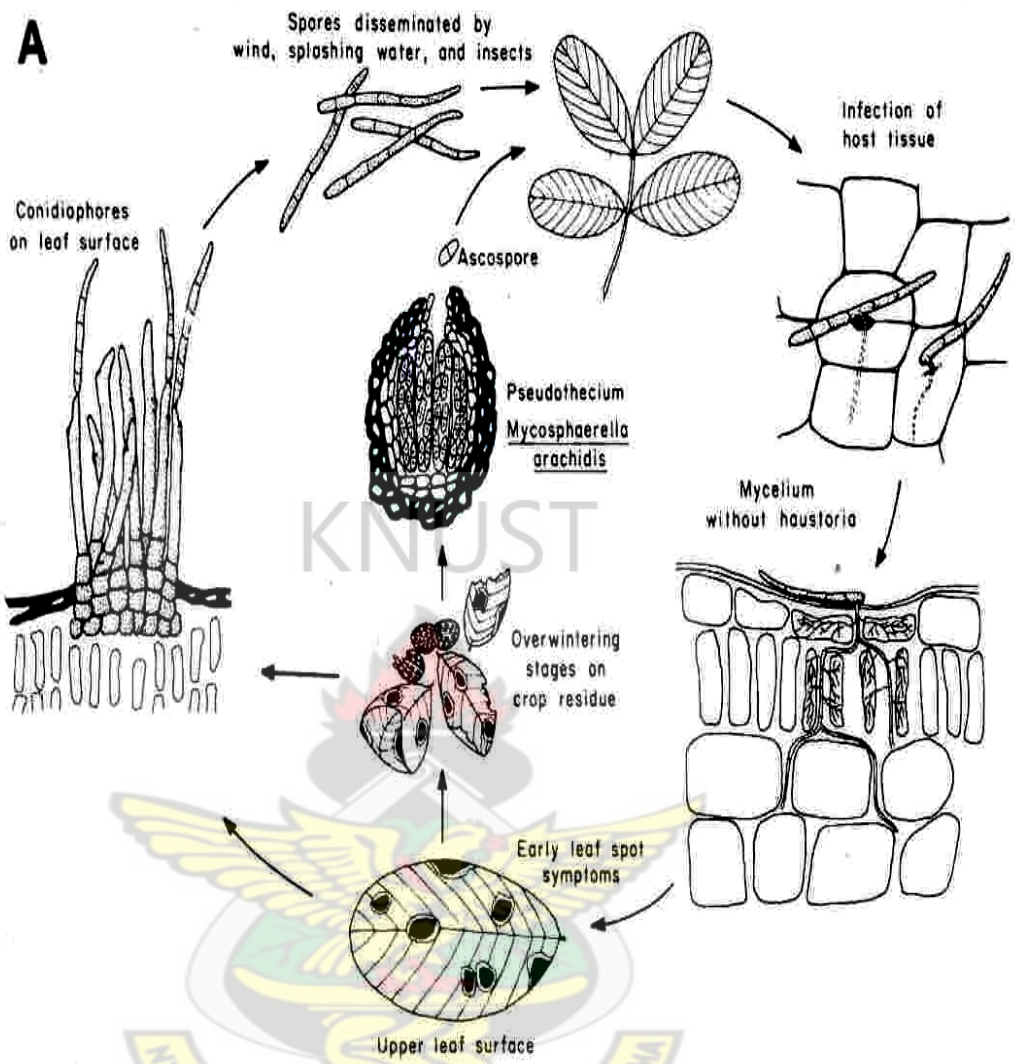

Figure 1. Disease cycle of *Cercospora arachidicola* (A).

(McDonald *et al*., 1985)

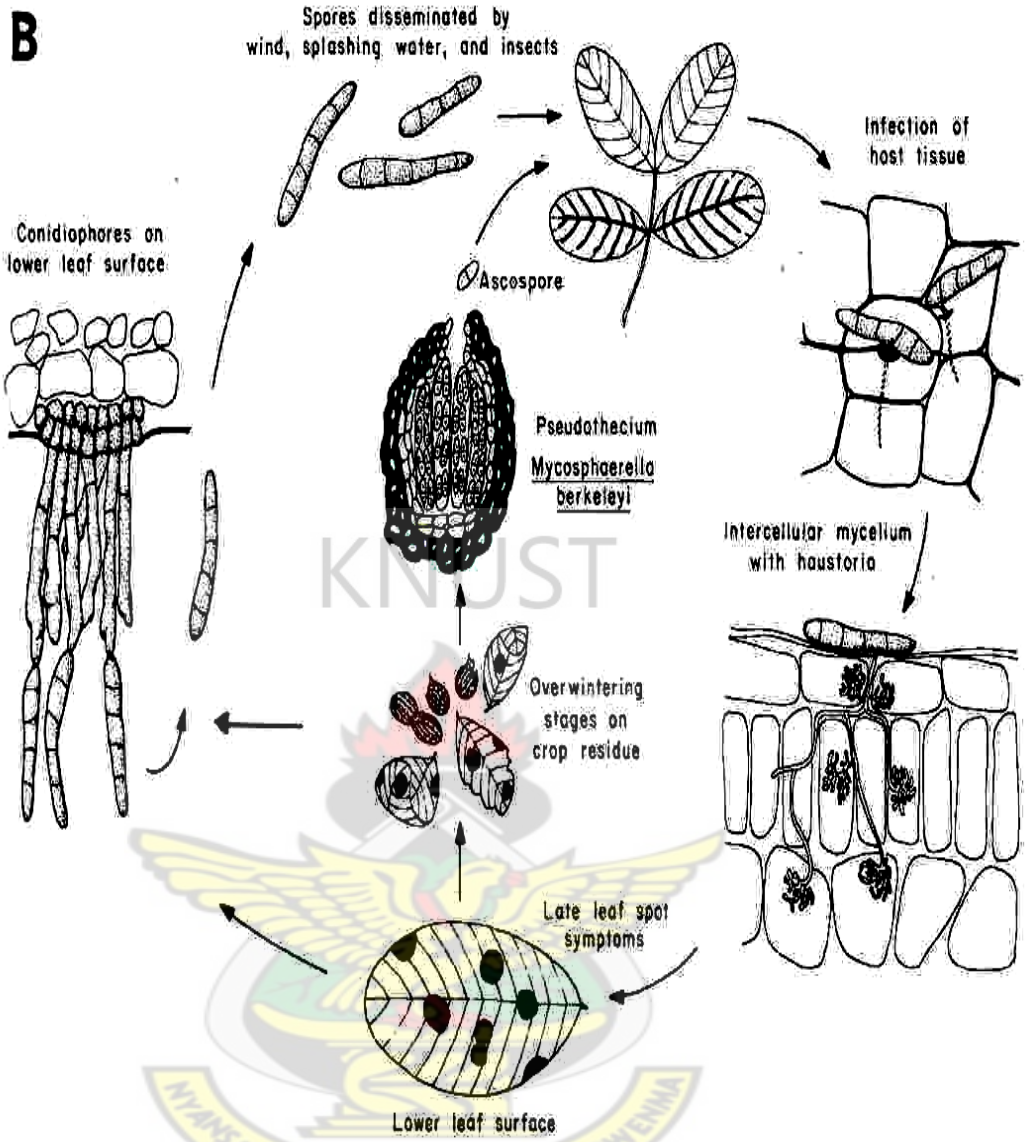

Figure 2. Disease cycle of *Phaeoisariopsis personata* (B).

(McDonald *et al.*, 1985)

2.3 Effects of *Cercospora* leaf spot diseases of groundnut

Severe infection greatly reduces the photosynthetic surface of the crop and, consequently, results in reduced potential yield. It has also been observed that the life span of the crop is generally determined by defoliation caused by *Cercospora* species (Porter, 1970; Elston *et al.,* 1976; Twumasi, 1993).

According to Bdliya (2007), *Cercospora* leaf spot causes severe damage to groundnuts, particularly towards the pod formation stage of the crop leading to lower seed and haulm yield. The disease also induces false maturity, low yields and adversely affected the quality of the groundnut (Kapooria and Zulu, 1982; Meddleton *et al.*, 1994). Premature defoliation can occur in severe cases and petioles and stems may also become infected (Pretorius, 2006).

2.4 Management of *Cercospora* leaf spot diseases of groundnut

2.4.1 Cultural control

The basic approach with cultural control is to use crop husbandry that promotes sound crop growth and inhibits or obstructs the growth of the pathogen. It also aims at changing the environment that is encountered by the pathogens, either inside or outside the host, thereby providing conditions conducive to host growth but adverse to the pathogen. These controls act largely in a preventive manner and are applied in advance of invasion (Dixon, 1984). The fungus is carried over from one season to the next on infected debris from the previous crop; hence all trash should be burnt or ploughed under as soon as possible. Crop rotation also should be used to prevent inoculum build-up (Lucas *et al.*, 1992). Growers are encouraged to rotate groundnut fields on a three-year cycle with cotton, corn and soybean (Shokes and Culbreath, 1997). Significant control of early leaf spot has been achieved by crop rotation with bahia grass (Brenneman *et al*., 1995). Deep ploughing of crop residue suppresses the spore-forming ability of the pathogen (Weeks *et al.*, 2000; Brenneman and Culbreath, 2005).

Volunteer crops should be removed as soon as they appear as they provide primary inoculum sources for early infections and act as hosts to other diseases and insect pests (Feakin, 1973). Growers should also follow sanitary measures, including removal of

volunteer groundnut and burial of groundnut residue using a mouldboard plough (Shokes and Culbreath, 1997). Planting groundnut in residues of previous rotational or cover crops suppressed early leaf spot development (Monfort *et al*., 2001). Early planting dates in Florida shortened the time the crop was exposed to both ELS and LLS pathogens, thus significantly reducing severity and defoliation, and resulting in higher yields (Shokes *et al.,* 1982).

2.4.2 Biological control.

It is the reduction or elimination of plant pests by means of parasitic organisms that prey on them (Maloy, 1993).

Mycoparasites, *Dicyma pulvinata* (Berk. & Curt.) v. Arx (= *Hansfordia pulvinata* (Berk. & Curt.) Hughes) and *Verticillium lecanii* (Zimmerm.) Viegas, have been observed to parasitise the early and late leaf spot pathogens of groundnut. These were found to be effective in controlling leaf spots in greenhouse studies, but no attempts have been made to use them at the field level (McDonald *et al.,* 1985).

Kokalis-Burelle *et al.* (1992) reported positive results after treatment of groundnut leaves with chitin and the bacterium *Bacillus cereus.* Knudsen *et al.* (1987) obtained more effective control using *Pseudomonas cepacia* on groundnut. *Verticillium lecanii* has been reported as a parasite on several groundnut pathogens in India, including *C. arachidicola* (Subrahmanyam *et al.,* 1990).

The hyperparasitic fungus, *Dicyma pulvanata* (Berk. and Curtis) fed on leaf spot fungi, but this fungus has not been tested for the control of ELS in field trials (Brenneman and Culbreath, 2005).

According to Kishore *et al.* (2005), biocontrol agents for the control of foliar diseases are available, but inconsistent performance of the introduced agents on aerial plant parts poses a limitation for their extensive adoption.

According to Parry (1990), it is difficult to predict soil environmental interactions where biological control agents are frequently introduced. Hence, many very promising antagonists in the laboratory or glasshouse gave inconsistent results in the field. Also, biological control is slower to take effect than fungicidal control. There are also problems regarding the production and storage of antagonists as living organisms in sufficient quantities for large scale field use.

Effective biological control of plant diseases usually requires the application of multiple procedures, each operating in a different way or time. It has also been difficult to ensure survival of biological control agents in sufficient numbers to be effective on the plant where the disease might occur (Lucas *et al* 1992). According to Youdeowei *et al*. (1986), biological control requires thorough knowledge of the ecosystem, the ecology and behaviour of the target pest and the biocontrol agent.

2.4.3 Chemical control

The early and late leaf spot diseases can be controlled with multiple applications of fungicidal sprays. Benomyl, captafol, chlorothalonil, copper hydroxide, mancozeb, maneb, and sulphur are examples of fungicides that have been used for management of early and late leaf spots (Porter *et al*., 1984). According to Smith and Littrel (1980), leaf spot can be managed by applying fungicides during the most vulnerable periods of fungal infection, especially when excessive moisture and humidity occur.

Control is currently achieved primarily through fungicidal sprays, which should be applied beginning approximately 30 to 40 days after planting and continuing at 10 to 14 day intervals (Smith and Littrell, 1980; Melouk and Shokes, 1995). Although chlorothalonil and tebuconazole are the most commonly used compounds, many other fungicides also are used to control ELS (Melouk and Shokes 1995; Baily 2002). Hagan (1998) reported that LLS can be controlled by a flusilazool/carbendazim (systemic) compound. The fluzilazool molecule rapidly penetrates the lipid layer on the leaf surface, becoming effective within three hours after application. This is particularly important in wet weather, when groundnuts are at risk from LLS. Hagan *et al.* (2005) reported that tebuconazole and tebuconazole+chlorothalonil both had protective and curative activity against leaf spot fungi while chlorothalonil fungicides were only protective.

Under conditions of low rainfall and/or erratic rainfall distribution, fungicidal control of ELS was found to be ineffective. A study conducted in Malawi by Subrahmanyam and Hildebrand (1997) illustrated this phenomenon. Rao *et al.* (1993b) reported that *C. arachidicola* had developed tolerance to benomyl (benzimidazole) in France.

However, difficulties in obtaining fungicides and application machinery, their high cost for small-scale farmers, have made it almost impossible for farmers to effectively use chemical control. This is also coupled with the side effects of the chemicals on other plants, non-target organisms and the environment (Tovigan *et al*., 2001; Ihejirika *et al*., 2006a).

According to Horsfall and Cowling (1977), fungicides have fairly unspecific modes of action. They are inherently toxic for a broad spectrum of organisms including higher plants and animals. Application of chemicals to impart resistance has been tried many times but with little success (Maloy, 1993). Driscoll (1990) reported that some chemicals enter the food chain for long periods rather than being broken down into simpler compounds.

2.4.4 Host Plant resistance

A resistant plant is one which possesses qualities which hinder the development of a given pathogen (Parry, 1990). Host plant resistance to early leaf and late leaf spots is an important component of disease management programmes. This involves heritable changes in the plant that will render it resistant or immune to diseases (Driscoll, 1990).

2.4.4.1 Types of resistance

Disease resistance that is genetically controlled by the presence of one, a few, or many genes for resistance in the plant is known as true resistance. In true resistance, the host and the pathogen are more or less incompatible with one another, either because of lack of chemical recognition between the host and the pathogen or because the host plant can defend itself against the pathogen by the various defence mechanisms either already present or activated in response to infection by the pathogen. There are two kinds of true resistance; horizontal and vertical.

Horizontal resistance is controlled by many genes. Each of these genes alone may be rather ineffective against the pathogen and may play a minor role in the total horizontal resistance.

Vertical resistance is always controlled by one or a few genes. These genes control a major step in the recognition of the pathogen by the host plant and therefore play a major role in the expression of resistance. In the presence of vertical resistance, the host and pathogen appear incompatible. The host may respond with a hypersensitive reaction, may appear immune, or may slow pathogen reproduction. Often, vertical resistance inhibits the initial establishment of pathogens that arrive at a field from host plants that lack, or have different, major genes for resistance. Vertical resistance inhibits the development of epidemics by limiting the initial inocula or by limiting reproduction after infection (Agrios, 1997).

Susceptible plants may remain free from infection or symptoms and thus appear resistant. The apparent resistance to disease of plants known to be susceptible is generally a result of disease escape or tolerance to disease. Disease escape occurs

whenever genetically susceptible plants do not become infected because the three factors, susceptible host, virulent pathogen, and favourable environment necessary for disease do not coincide and interact at the proper time or for sufficient duration (Agrios, 1997).

Tolerance to disease is the ability of plants to become diseased and possibly show it, but not have yields appreciably or proportionately affected (Maloy, 1993). Tolerance results from specific, heritable characteristics of the host plant that allow the pathogen to develop and multiply in the host while the host, either by lacking receptor sites for or by inactivating or compensating for the irritant excretions of the pathogen, still manages to produce a good crop. Tolerant plants are susceptible to the pathogen, but they are not killed by it and generally show little damage (Agrios, 1997).

2.4.4.2 Mechanism of resistance

The major mechanisms of resistance that have been proposed are either passive or active. These proposed mechanisms can be combined into three simple categories, mechanical, chemical, and functional (Maloy, 1993).

Mechanical barriers include the cuticle, epidermal tissues, cork layers in bark and thickened cell walls in many tissues (Waller and Lenne, 2002). Thickened cuticle was reported to resist penetration and rendered older leaves of citrus more resistant to anthracnose than younger leaves (Maloy, 1993). Thick cuticle is also associated with resistance to direct penetration by powdery mildews, some rusts, gray mold, and coffee berry pathogen (Maloy, 1993).

Waxes on leaf and fruit surfaces form a water-repellent surface and thereby prevent the formation of a film of water on which pathogens might be deposited or germinate (Agrios, 1997).

Post-infection resistance to both ELS and LLS was related to thickening of cell walls and deposition of pectic substances around the site of infection (Abdou *et al*., 1974).

Chemical barriers include the gums, tannins and other substances present in the outer tissues of some plant organs (Waller and Lenne, 2002). The defensive role of gums is that they are quickly deposited in the intercellular spaces and within the cells surrounding the locus of infection, thus forming an impenetrable barrier that completely encloses the pathogen. Some of the compounds released by some plants have inhibitory action against certain pathogens. Fungitoxic exudates on the leaves of some plants, for example, tomato and sugar beet, were present in sufficient concentrations to inhibit the germination of spores of the fungi, *Botrytis* and *Cercospora*, respectively, that may be present in dew or rain droplets on these leaves (Agrios, 1997).

Borbonol is a preformed fungitoxic, nonphenolic ring compound in avocado species that are resistant to *Phytophthora* root rot present in resistant *Persea borbonica* and *Persea caerula* but not in susceptible *Persea indica* or only in small amounts in *Persea americana* (Maloy, 1993). Resistant genotypes of groundnuts contained higher levels of total phenols, ortho-dihydroxy-phenols and non-reducing sugars than the susceptible genotypes (Karunakaran and Raj, 1980). Ascorbic acid accumulates around the infected areas of the leaves of resistant lines of groundnuts and reduced growth of the ELS pathogen within the necrotic region (Karunakaran and Raj, 1980).

Hemingway (1957) found a relationship between riboflavin content of the groundnut seed and LLS resistance and reported that thick dark green palisade layers and small stomata were associated with disease resistance. According to Cook (1981), cultivars resistant to LLS had fewer lesions on mature leaves.

Hypersensitive response was thought to be responsible for limiting the growth of the pathogen and, in that way, is capable of providing resistance to the host plant against the pathogen (Agrios, 1997). A necrotic defense reaction appeared to be operative on resistant cultivars of groundnut in response to infection by the LLS pathogen (Pattee and Young, 1982).

Abdou *et al*. (1974) found that pre-infection resistance to both ELS and LLS could be attributed to non-directional germ tube growth. Conversely, germ tubes on susceptible plants display directed growth toward open stomata.

Systemic acquired resistance can occur in susceptible plants in response to localised infections (Stitcher *et al*., 1997). This resistance is apparently non-specific and effective against a wide range of pathogens, but declines with time. It is dependent on the translocation of some signal within the plant (Waller and Lenne, 2002).

Reddy *et al.* (1997) field-tested 33 groundnut entries and concluded that, seven genotypes were moderately resistant to both ELS and LLS and the genotype ICGV86252/JL24-3 was resistant to LLS.

CHAPTER THREE

MATERIALS AND METHODS

The study involved surveys, laboratory studies and field experimentation.

3.1 Survey of groundnut production areas in Tamale and surrounding towns and villages

One hundred groundnut farmers in towns and villages around Tamale were interviewed, using structured questionnaires to document farmers' knowledge of groundnut diseases, particularly, leaf spot diseases (Appendix 1). The survey also gathered information on farmers' practices that could affect disease incidence and severity on the field.

Villages and farmers covered in the survey were selected with the help of CSIR-Savanna Agriculture Research Institute (CSIR-SARI) and some Extension staff from Ministry of Food and Agriculture (MOFA). Majority of the farmers were clustered within ten villages namely; Dindo, Savelugu, Tingoli, Kpalsorgor, Worborgor, Datoyilli, Tolon, Kunbungu, Chanayili, Cheyorhe, and the rest at the outskirts of Tamale Metropolis. Tamale, Datoyili, and chanayili were selected from Tamale district, Savelugu from Savelugu-Nanton district, and the rest of the towns and villages from Tolon –Kunbungu district all in the Northern region of Ghana. Each farmer was interviewed in the local Dagbani language. Of the one hundred farmers interviewed, 25 were women and the rest men. The questionnaires were self – administered. Statistical Package for Social Scientist (SPSS) version 15.0 was used to analyse the data.

3.2. Sources of groundnut genotypes

Sixteen (16) groundnut varieties namely; Adepa, Aprewa, Azivivi, Chinese, Edorpo-Munikpa, Fmix, Jenkaa, Jusie Balin, Kpalneil, Kumawu early, Manipinta, Nkate kokoo, Nkatepa, Nkosour, Shitaochi and Sinkazie obtained from Savanna Agriculture Research Institute and Crops Research Institute, all of Council for Scientific and Industrial Research were used for the study. The cultivar Chinese was the control.

Adepa, Azivivi, Nkosour and Jenkaa are varieties released by CSIR-Crops Research Institute in 2006. Manipintar was released in Ghana in 1960 for commercial production. Adepa, Azivivi, Nkosour Jenkaa, Chinese, Edorpo-Munikpa, Kumawu early, Jusie Balin, are early maturing but Kpalneil, Manipinta, Fmix, Nkatepa, Nkate kokoo, and Sinkazie are late maturing.

3.3. Location of experiment

The field experiments were carried out at a site with a long history of groundnut cultivation at the Crops Research Institute, Fumesua station (under the Council for Scientific and Industrial Research). The site is a noted hot spot for leaf spot diseases of groundnuts. The Fumesua station is in the rain forest zone.

3.3.1. Field experiment and design

The land was ploughed, harrowed and divided into plots of size 5m x 3.6m with 1m interval between plots. The experiments were laid out in a randomized complete block design with three times replications.

A seed each was sown per hole at a depth of about 5cm. The inter- and intra-row distances were 60cm and 20cm, respectively. Each plot consisted of six rows and the two median rows were used for disease assessment and yield records.

Weeds on the experimental plots were managed by hand weeding, when necessary. The groundnut varieties were exposed to natural infection. The plants were observed for disease symptoms development of either early or late leaf spots.

Early leaf spot was scored 40 and 60 days after sowing and late leaf spot at 70 and 90 days using a five-point scale by Crops Research Institute, Kumasi where;

1 = no visible symptom of disease;

2 = low disease level in which single lesion - 25% of total leaf area is covered by lesions;

3 = intermediate disease level in which 26-50% of the total leaf area is covered by spots, with some defoliation in the first branch;

4 = high level of disease in which spots cover 51-75% of total leaf area of the whole plant, with increasing defoliation in the first and second branches; and

5 = very high disease level in which over 75% of the leaf area of the whole plant is spotted, and/ or more than 50% of the total number of leaves is defoliated.

Means of the disease scores for both early and late leaf spots for the 16 varieties were computered. Harvesting of the two inner rows was done at maturity. Data on pod yield, grain yield, 100 seed weight and 100 pod weight were collected. The pods were dried, shelled, and the seeds weighed. The values were recorded for each treatment. Data collected were subjected to statistical analysis using Genstat package. Correlation (r) was used to identify relations between disease scores and grain and pod yields.

3.4. Laboratory studies

Laboratory studies involved media preparation, isolation and characterization of causal organism of *Cercospora* leaf spot of groundnut. An identification manual was used to identify the isolation.

3.4.1 Preparation of culture media

Petri dishes (9cm in diameter) were thoroughly washed and dried and then packed into canisters and sterilized by autoclaving at 160^{o}C in an oven for about three hours. The media was prepared by putting 39g of Potato Dextrose Agar (PDA) by Difco in a litre of distilled water a two litre conical flask and shaken thoroughly. The mixture was poured into conical flasks and plugged with non-absorbent cotton wool and then autoclaved at 100 psi and 121^{o}C for 15 minutes. The laminar flow was switched on for 30 minutes and the working surface was sterilised with 90% ethanol. The PDA was then poured into the sterilised Petri plates in the laminar flow. The poured plates were stored at refrigeration temperature and used when needed.

3.4.2 Isolation from diseased leaves

Leaves with lesions of the early and late leaf spot diseases were collected from different parts of the experimental field. Margins of these infected leaves were cut with a pair of scissors into small pieces that contained both diseased lesions and healthy uninfected tissues.

The small cut pieces of the diseased-leaf tissues were surface sterilised in 5% sodium hypochlorite solution (1% available chlorine) for five minutes to eliminate saprophytes. The cut pieces were immediately rinsed in sterile distilled water three times and

blottered dry with tissue paper in the laminar flow. The dried diseased leaf tissues were then plated on Potato Dextrose Agar in Petri dishes and incubated at room temperature.

3.4.3. Subculturing of fungi

The fungal tissues that grew from the plated-diseased tissues were sub-cultured onto fresh PDA medium. A needle sterilized by dipping in absolute alcohol followed by flaming was used in the transfer of fungal tissues onto the fresh media plates. Further sub-culturing was carried out until pure colonies of single species were obtained.

3.5 Identification

The identification of the isolate was done using identification manual (Barnett and Hunter, 1972) where the conidiophores and conidia of the isolate were compared with the drawings and pictorial descriptions of the fungi.

CHAPTER FOUR

RESULTS

4.1. Farmers' perception and the effect of early and late leaf spot diseases on groundnut production

One hundred groundnut farmers were interviewed and 20% of them have been cultivating groundnuts between one to three years, 37% of them between four to six years, 36% of them seven to nine years and seven percent of them have been cultivating groundnuts for over 10 years. In all 43% out of the groundnut farmers interviewed have been cultivating groundnuts for seven years and above, implying that the farmers are experienced in groundnut production. (Table 1).

Table 1. Years of experience of groundnut cultivation by farmers interviewed in Tamale and selected towns and villages

Experience of farmers in groundnut cultivation (yr)	Percent of farmers (%)
1-3	20.0
4-6	37.0
7-9	36.0
above 10	7.0

Of the farmers interviewed, 41% of them cultivated groundnuts on one hectare or less, 43% of them between one and half to two hectares, 14% of them between two and half to three and half hectares and two percent of them cultivate four hectares or more every year (Table 2).

Table 2. Hectares of groundnut farms cultivated per farmer interviewed in Tamale and selected towns and villages

Hectares	Percent of farmers
0-1.0	41.0
1.5-2.0	43.0
2.5-3.5	14.0
Above 4.0	2.0

Most of the groundnut farmers cultivate groundnuts on the same piece of land year after year. Fifty four percent of the groundnut farmers cultivate groundnut as a sole crop while the rest intercrop groundnuts with maize and guinea corn. Thirty-nine percent of the farmers grow maize in their groundnut farms, two percent intercrop groundnuts with guinea corn and six percent cultivate both maize and guinea corn in their groundnut farms (Table 3).

The groundnut variety, Chinese, is cultivated by 80% of the groundnut farmers while 12% cultivate Abban and or Chinese and 8% cultivate other groundnut varieties. Fifty one (51) percent of the groundnut farmers said they cultivate Chinese because it is marketable, 40% of them cited early maturity and marketability and nine percent cited early maturity as the reason for cultivating the variety (Table 3).

Table 3. Cropping system, list of intercrops, groundnut varieties grown and reasons for variety choice

Cropping system	Percent of farmers
Sole cropping	54.0
Intercropping	46.0
Intercrops of groundnut	
Maize	39.0
Guinea corn	2.0
Maize and guinea corn	6.0
No intercrop	53.0
Varieties of groundnut cultivated	
Chinese	80.0
Chinese / Abban	12.0
Others	8.0
Reasons for cultivating 'Chinese'	
Matures early	9.0
Marketable	51.0
Matures early and marketable	40.0

Seventy nine (79) percent of the groundnut farmers perceived early and late leaf spots as their main problem while 21% of them reported that it was the combination of early and late leaf spot diseases and credit to meet the cost of production that are their main contraints. All the groundnut farmers interviewed agreed that they encountered the early and late leaf spot diseases on their fields (Table 4).

Table 4. Farmers' problems associated with groundnut cultivation in the areas surveyed

Groundnut Problems	Percent of farmers
Disease (ELS and LLS)	79.0
Disease (ELS and LLS) and credit	21.0

Forty seven (47) percent of the groundnut farmers reported that ELS and LLS diseases affected about 30% of the groundnut plants on their farms, 11% of them said ELS and LLS diseases affected about 40% of the groundnut plants on their farms, 41% of them said 50% of the groundnut plants on their farms were lost to ELS and LLS diseases and one percent of the farmers reported that 60% of the groundnut plants on their farm were lost to ELS and LLS diseases. Ninety seven (97) percent of the groundnut farmers said they observe ELS and LLS disease symptoms every season and three percent of them said they observe them every year (Table 5).

Table 5. Proportion of diseased groundnut plants and disease (ELS and LLS) occurrence

Proportion of diseased groundnut plants on farm	**percent of farmers**
30%	47.0
40%	11.0
50%	41.0
60%	1.0
Disease (ELS and LLS) occurrence	
Every season	97.0
Every year	3.0

Sixty five (65) percent of the groundnut farmers were able to show some leaves with either ELS or LLS symptoms or both while 35% of them showed a whole defoliated plant with early and late leaf spots (Table 6).

Ninety (90) percent of the groundnut farmers said they see the leaf spot disease symptoms after flowering, seven percent of them said before flowering and three percent of them said at flowering stage (Table 6).

All the groundnut farmers interviewed do nothing to control early and late leaf spot diseases (Table 6).

Table 6. Farmers' knowledge of disease (ELS and LLS), symptoms appearance and disease (ELS and LLS) intervention

Disease sample	Percent of farmers
Leaves	65.0
Whole plant	35.0
Symptom appearance	
Before flowering	7.0
At flowering	3.0
After flowering	90.0
Disease (ELS and LLS) intervention	
No intervention	100.0

Thirty nine (39) out of fifty-four (54) groundnut farmers who cultivate groundnut as a sole crop reported that 50% of the groundnut plants on their farms were attacked by both early and late leaf spot diseases, four of them said 30% of the groundnut plants, 10 of them said 40% while only one farmer said 60% of the groundnut plants on their farms were devastated by the disease (Table 7a).

Forty three (43) out of the forty six (46) groundnut farmers who intercrop groundnut with other crops reported that 30% of the groundnut plants on their farms were lost to early and late leaf spots, two of them said 50% of the groundnut plants and only one farmer said 40% of groundnut plants on their farms were lost to both early and late leaf spot diseases (Table 7a).

Table 7a. Effect of cropping system on diseases (ELS and LLS) observed by farmers

Proportion of diseased groundnut plants on farm	Response of farmers who practiced sole cropping	Response of farmers who practiced intercropping	Total
30%	4.0	43.0	47.0
40%	10.0	1.0	11.0
50%	39.0	2.0	41.0
60%	1.0	0.0	1.0
Total	54.0	46.0	100

Almost all the farmers cultivate groundnuts on the same piece of land year after year. Forty-four (44) of them said they lost 30% of groundnut plants on their farms to early and late leaf spot , 11 of them said 40% of groundnut plants, 41 of them said 50% of groundnut plants on their farms and only one of them said 60% of groundnut plants on their farms (Table 7b).

Only three farmers said every year they cultivate groundnut at different places. All of them said they lost 30% of groundnut plants on their farms to early and late leaf spot (Table 7b).

Table 7b. Effect of cropping system on diseases (ELS and LLS) observed by farmers

Proportion of groundnut plants diseased	Response of farmers who practiced continuous cropping	Response of farmers who practiced land rotation	Total
30%	44.0	3.0	47.0
40%	11.0	0.0	11.0
50%	41.0	0.0	41.0
60%	1.0	0.0	1.0
Total	97.0	3.0	100.0

4.2 Disease score and yield data

Table 8. Early and late leaf spot diseases scores of the groundnut varieties

Groundnut varieties	Early leaf spot score (1-5)	Late leaf spot score (1-5)
Adepa	1.0	1.0
Aprewa	2.6	3.1
Azivivi	1.0	1.0
Chinese (control)	3.1	4.0
Edorpo Munipka	2.4	2.5
F-mix	2.2	3.0
Jenkaa	1.0	1.0
Jusie Balin	1.0	1.7
Kpalneil	2.0	2.3
Kumawu arly	2.3	2.8
Manipinta	2.3	2.4
Nkatepa	2.2	2.9
Nkate Kokoo	2.1	2.2
Nkosuor	1.0	1.0
Shitaochi	2.0	2.7
Sinkazie	1.4	2.0

On a scale of 1 to 5 (where 1 = no disease and 5 = very high disease level in which over 75% of the leaf area of the whole plant is spotted with more than 50% of the total number of leaves defoliated), Azivivi, Adepa, Jenkaa, Jusie Balin and Nkosuor had an ELS score of 1.0 and LLS score 1.0 except Jusie Balin which had a LLS score of 1.7 (Table 8). Aprewa had ELS score of 2.6 and LLS score of 3.1; Chinese had ELS score of 3.1 and LLS score of 4.0; Edorpo Munikpa scored 2.4 for ELS and 2.5 for LLS; F-

mix had 2.2 and 3.0; Kpalniel had 2.0 and 2.3; Kumawu Early had 2.3 and 2.8; Manipinta had 2.3 and 2.4; Nkatepa had 2.2 and 2.9; Nkate kokoo had 2.1 and 2.2; Shitaochi had 2.0 and 2.7 and Sinkazie had 1.4 and 2.0 for ELS and LLS, respectively (Table 8).

Table. 9. Means of pod yield, seed yield, 100 seed weight and 100 pods weight

Groundnut varieties	Pod yield/ha(kg)	Seed yield/ha(kg)	100 seed wt.(g)	100 pods wt.(g)
Adepa	929.4	603.9	34.3	91.7
Aprewa	1201.1	820.1	35.0	89.3
Azivivi	1086.1	713.9	37.0	95.0
Chinese (control)	1168.3	820.0	33.3	89.0
Edorpomunikpa	681.7	455.6	39.7	89.7
F. Mix	1004.9	652.8	31.0	85.3
Jenkaa	842.2	525.6	31.0	80.3
Jusie Balin	1043.3	639.4	39.3	94.3
Kpalneil	1211.3	835.0	39.7	77.3
Kumawu early	1109.4	768.3	30.3	80.0
Manipinta	665.0	425.9	34.0	96.3
Nkate Pa	904.4	632.8	35.0	98.0
Nkate kokoo	1078.8	719.4	31.3	103.3
Nkosuor	1011.7	657.2	37.7	94.3
Shitaochi	1200.3	825.0	29.7	85.7
Sinkazie	1213.1	835.8	44.7	114.3
Lsd(5%)	570.01	415.03	5.62	19.98
CV%	42.41	41.03	9.58	13.09

For the pod and seed yields of the 16 varieties (Table 9), Adepa recorded pod yield of 929.4kg/ha and seed yield of 603kg/ha; Azivivi 1086.1kg/ha pod yield and 713.9kg/ha seed yield, Jenkaa 842.2kg/ha pod yield and 525.6kg/ha seed yield, Nkosour 1011.7kg/ha pod yield and 657.2kg/ha seed yield, Jusie Balin 1043.3kg/ha pod yield

and 639.4 seed yield, Sinkazie recorded the pod yield of 1213.1kg/ha and 835.8kg/ha seed yield and Chinese 1168.3kg/ha pod yield and 820kg/ha seed yield.

For 100 seed weights of the 16 varieties (Table 9), Adepa recorded 34.33g, Azivivi 37.00g, Chinese 33.33g, Edorpo Munikpa 39.67g, F-mix 31.00g, Jenkaa 31.00g, Jusie Balin 39.33g, Kpalneil 39.67g, Kumawu early 30.33g, Manipinta 34.00g, Nkatepa 35.00g, Nkate kokoo 31.33g, Nkosour 37.67g, Shitaochi 29.67g and Sinkazie of 44.67g. Sinkarzie recorded the highest 100 seed weight of 44.67g and Shitaochi recorded the lowest value of 29.67g.

For 100 pod weights of the 16 varieties (Table 9), Adepa 91.67g, Azivivi 95g.00, Chinese 89.00g, Jenkaa 80.33g, Jusie Balin 94.33g, Nkosour 94.33g, Kumawu early 80.0g Shitaochi 85.7g and Sinkazie 114.00g. Sinkazie recorded the highest weight of 114.00g.

Table 10. Correlation between disease (ELS and LLS) score and other traits

	Disease score	100seed wt.(g)	Pod yield/ha (kg)	Seed yield/ha (kg)	100pods wt.(g)
Disease score	1				
100seed wt.	-0.3	1			
Pod yield	-0.01	0.3	1		
Seed yield	0.1	0.2	0.9**	1	
100pods wt.	-0.2	0.4	0.4	0.5	1

There is a negative correlation between disease score and 100 seed weight, pod yield and 100 pods weight. There is significantly positive correlation between pod yield and seed yield.

Plate 3. The conidiophores of *Cercospora* spp.

The conidiophores of the isolated pathogen are dark, simple, arising in clusters and bursting out of leaf tissues (Barnett and Hunter, 1972) as shown above.

CHAPTER FIVE

DISCUSSION

5.1 Farmers' perception and the effect of early and late leaf spots on groundnut production.

All the 100 farmers who were interviewed are groundnut farmers. In a typical farming community in the north, more than 90% of farm families cultivate groundnut (Tsigbey *et al*, 2004). For the women living in rural northern Ghana, a major source of income and, therefore, economic sustenance is groundnut production (Millar and Yeboah, 2006). According to Quaye (2008), there is a strong correlation between crops cultivated and consumption patterns, and groundnut is the second most important crop cultivated in Northern region of Ghana. According to a survey conducted by Jolly *et al*. (2008) on groundnut consumption frequency in Ghana, 80% of respondents consume groundnut and/or its products at least once a week and 32% consume it three times a week. Groundnuts provide a vital source of cash income and nutritious, high protein food which could prevent child malnutrition (Kenny and Finn, 2004). Groundnut is a major cash crop and also plays a major role in the diet of many people in Ghana. Groundnut hay is used as livestock feed especially during the long dry season and also serves as an additional source of income. This explains the concentration of groundnut cultivation in northern Ghana (Tsigbey *et al*, 2004). Al-hassan and Poulton (2009) reported that groundnut production has been increasing rapidly in Northern Ghana in recent years.

Land ownership and size of holdings determine the number of fields a farmer has access to and rotation cycles vary between two and nine years (Tsigbey *et al*., 2004). Majority of groundnut farmers have been cultivating groundnuts for between 4 and 9 years (Table 1).

Areas of land cultivated by groundnut farmers ranged from zero (less than a hectare) to over four hectares of land (Table 2). This is in consonance with findings that areas of land cultivated by groundnut farmers in the north ranged between less than a hectare to more than 6 hectares (Tsigbey *et al*., 2004).

On the farms, about 46% of the groundnut farmers interviewed mixed groundnut with other crops while the rest had sole groundnut farms (Table 3). The mixed cropping is a method of crop intensification commonly practiced by traditional farmers in many small farms. The benefits that may be derived from intercropping are many and include maximised land utilization, increased farm profits, better income distribution, better labour use, production of more food crops, reduction of weed growth and cost of weed control and improvement of soil physical characteristics and fertility (Paner, 1975; Mercado *et al*., 1976). Although the yield of peanut could be reduced by 20-30% when intercropped with maize (Obordo and Onia, 1970), the combined productivity of the two crops is 30-50% higher than their monoculture yields (Herrera *et al.*, 1975).

Majority of the groundnut farmers use maize as the main intercrop (Table 3). The predominant cropping pattern is a mixture of cereal/legume because maize is one of the major staple foods (Tsigbey *et al.*, 2004). According to Marfo (1997), groundnut is an essential component in the cropping system in Northern Ghana because of its ability to fix nitrogen for associated or subsequent cereal crops. Legumes are commonly grown in intercrops because of the nitrogen they make available to other crops, and have been shown to increase maize yields in Kenya (Rao and Mathuva, 2000).

Overwhelming majority of the groundnut farmers cultivate Chinese variety because it is the most commercially important cultivar in northern Ghana (Frimpong *et al.*, 2006b).

According to the farmers, the Chinese variety matures early and it is also highly marketable. Chinese variety is erect, and early-maturing and has a kernel yield of 1.8 tons/ha (CSIR, 2007) (Table 3).

The early and late leaf spot diseases were the major problems encountered by majority of the groundnut farmers (79%) interviewed (Table 4). This is because the disease has been reported to be endemic in all the groundnut production areas, and yield loss close to 100% has forced farmers to abandon harvesting their farms because of poor yields (Tsigbey *et al*., 2004).

Fifty three percent of the groundnut farmers lost between 40% - 60% of their farms to both early and late leaf spot diseases (Table 5). According to Tsigbey (1996), seed yield loss from leaf spot alone occured in more than 40% of yield potential of groundnut in northern Ghana. Pod loss due to *Cercospora* leaf spot was as high as 78% on-farm (Tsigbey *et al*., 2004). Combined infection of both ELS and LLS diseases caused yield losses between 50% - 70%, and adversely affected the quality of the kernel (Mehan and Hong, 1991). Hence, groundnut disease control in order to increase yields has become imperative in northern Ghana (Brandenburg, 2003). Efficient control of groundnut diseases is a prerequisite to the attainment of food security, poverty alleviation and increased farm household (Tsigbey *et al*., 2004).

Almost all the groundnut farmers interviewed encountered both ELS and LLS every season. ELS and LLS incidence was 100% in all groundnut growing regions in northern Ghana. One of the most devastating leaf diseases is *Cercospora* leaf spot and the most predominant form is late leaf spot found throughout all locations of Northern Ghana

(Brandenburg, 2003). Both early and late leaf spot diseases are widely distributed and occur in epidemic proportions in northern Ghana (Nutsugah, *et al*., 2007a) (Table 5).

All the farmers in the survey area were able to identify and show infected leaves or whole groundnut plant infected with both ELS and LLS. Therefore, they perceived ELS and LLS as disease problem. Ninety (90) percent of the groundnut farmers reported that they observed the disease after flowering. This was so because depending on genotype and environment, flowering starts at about 25 days after emergence (Rao and Murty, 1994). However, lesions induced by *Cercospora arachidicola* normally first appear three-four weeks after sowing, *Phaeoisariopsis personata* appearing some two-four weeks later (Allen, 1983). Under ideal conditions, visible ELS symptoms develop six to eight days after infection in favourable conditions, and LLS symptoms can be seen 10 to 14 days after infection (Shokes and Culbreath, 1997) (Table 6).

All the groundnut farmers interviewed do nothing control early and late leaf spots diseases. No form of disease control was practiced by the farmers in Northern Ghana (Tsigbey *et al*., 2004). According to Naab *et al*. (2005), traditionally, farmers in northern Ghana do not use any management practices to control leaf spot diseases.

The diseases (ELS and LLS) were more devastating when groundnut was cultivated as sole crop, compared to where groundnut was intercropped with corn and other crops (Table 7a). A review of studies on intercropping and leaf spot diseases indicated that the general trend is toward less disease incidence in intercrops, compared to monocrops (Duffie, 2003). It has been observed that barrier rows of corn between groundnut test plots were very effective at preventing spread of early leaf spot and late leaf spot between adjacent plots (Johnson *et al*., 1986).

The disease is more devastating where groundnut was cultivated on the same land season after season, compared to where groundnut was cultivated on different pieces of land at different seasons (Table 7b). Gibbons (2002) reported that leaf spot-infected fallen leaves of groundnut carried over the disease to the next crop when groundnut was followed by groundnut on the same land. Groundnut should not follow groundnut, as pods break off and stay behind in the soil with plant residue. The fungi may over-winter on these materials and provide inocula in the following season (Pretorius, 2006).

5.2 Early and late leaf spot diseases scores of the groundnut varieties

The early and late leaf spots were present during the cropping season but in different proportions among the various cultivars.

Among the sixteen (16) varieties, evaluated (Table 8), Azivivi, Adepa, Nkosour, and Jenkaa recorded the lowest score of 1.0 for both ELS and LLS diseases. Jusie Balin also had a score of 1.0 for ELS and score of 1.7 for LLS. Azivivi, Adepa, Nkosour, and Jenkaa are resistant to both ELS and LLS. This confirms an earlier report (CSIR, 2007) that, Azivivi, Adepa, Jenkaa and Nkosour are resistant to *Cercospora* leaf spot. Jackson (2006) reported that Azivivi, Nkosour, Adepa, and Jenkaa are all resistant to *Cercospora* leaf spot. Jusie Balin which had a similar reaction as Azivivi, Adepa, Jenkaa, and Nkosour had a LLS score of 1.7. Frimpong *et al*. (2006a) reported that Jusie-Balin is early maturing and resistant to ELS and LLS.

Sinkazie, Kpalneil, and Nkate kokoo expressed low levels to both the ELS and LLS.

Shitaochi, Nkatepa, Kumawu early, F-mix, Manipinta, Edorpo Munikpa, and Aprewa expressed intermediate disease level with some defoliation to LLS and low disease

level to ELS. Chinese recorded the highest disease score of 3.1 for ELS and 4.0 for LLS on a scale of 1 to 5.

Chinese expressed intermediate disease level with some defoliation to ELS and high disease level with increasing defoliation to LLS. Chinese, among all the varieties, is the most susceptible variety to both ELS and LLS diseases. Frimpong *et al.* (2006a) reported that on scale of 1 to 9 (where 1 = no leaf spot and 9 = complete defoliation due to leaf spot) scores for reaction to *Cercospora* leaf spots (ELS and LLS), Chinese recorded between seven and nine, the highest on the scale. The variety Chinese is the most cultivated but very susceptible to early and late leaf spot diseases hence some of the varieties identified to have resistance, that is, Azivivi, Adepa, Nkosour and Jenkaa can be introduced into endemic areas of early and late leaf spots to reduce losses.

5.3 Pod yield, seed yield, 100 seed weight and 100 pod weight

For pod yield, no significant difference ($p>0.05$) was observed among the varieties for this trait. However, there was a negative correlation ($r = -0.02$) between the disease score and the pod yield. For example, Azivivi, Adepa, Nkosuor and Jenkaa recorded a disease score of 1.0 for both ELS and LLS and had pod yields of 1086.1kg/ha., 929.4kg/ha.,1011kg/ha and 842kg/ha., respectively, whereas Edorpomunikpa with a higher disease score of 2.4 and 2.5 for ELS and LLS, respectively, had a pod yield of 681.7kg/ha.

There was also no significant difference ($p>0.05$) for the seed yield among the varieties. There was a positive correlation ($r = 0.9$) between pod yield and seed yield, hence the higher the pod yield the higher the seed yield. Azivivi also recorded 1086kg/ha pod yield and 713.9kg/ha seed yield.

One hundred (100) seed weight of the 16 varieties registered significant difference ($p < 0.05$). There was no significant difference among Nkosour, Azivivi, and Adepa, but there was a significant diference between them and Jenkaa, Chinese, Sinkazie and Jusie Balin. There was also no significant difference in 100 seed weight of Adepa, Azivivi, Nkosour and Jusie Balin, but there was significant difference between them and Sinkazie, Chinese and Jenkaa. There was also no significant difference among Nkosour, Azivivi, Adepa and Chinese, but the difference between them and Jenkaa, Jusie Balin and Sinkazie was significant.

There was also no significant difference among Jenkaa, Adepa and Chinese however there was significant difference between them and Azivivi, Jusie Balin, Sinkazie and Nkosour. There was also no significant difference among Adepa, Azivivi, Nkosuor and Jusie Balin but the difference between them and Chinese, Jenkaa and Sinkazie was significant.

The one hundred (100) seed weight correlated ($r = -0.3$) negatively with the disease score. For example, Nkosuor and Azivivi with a lower disease score of 1.0 for both ELS and LLS recorded a 100 seed weight of 37.7g and 37.0g, respectively, as against Shitaochi which recorded 29.7g with higher disease score of 2.0 and 2.7 for ELS and LLS respectively.

There was no significant difference ($p > 0.05$) in 100 pods weights among the sixteen varieties. However, disease score correlated ($r = -0.2$) negatively with the 100 pods weight. Azivivi with a lower disease score of 1.0 for both ELS and LLS recorded 95.0g of 100 pods weight as against Kumawu early which recorded 80.0g of 100 pods weight with a higher disease score of 2.3 for ELS and 2.8 for LLS.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

From the study, farmers perceived both early and late leaf spot diseases as major constraints to groundnut cultivation in Northern Ghana and farmers could easily identify the disease. The study has also revealed that the cultivation of groundnuts as a sole crop on the same land year after year makes the early and late leaf spots more devastating than in situations where groundnut is cultivated with other crops or rotated from one place to another. Farmers in Northern Ghana do not have any solution to the disease problem and are likely to adopt varieties resistant to early and late leaf spot diseases.

Azivivi, Adepa, Nkosour, and Jenkaa in this study were found to be resistant to both early and late leaf spot diseases. Jusie Balin was less resistant to late leaf spot than early leaf spot with early leaf spot score of 1 and late leaf score of 1.7.

The resistant varieties, Azivivi, Adepa, and Nkosour, could not record the highest yield but their yields were well above the average yield of groundnut in Ghana. Azivivi recorded a pod yield of 1086.1kg/ha, Adepa 929.4kg/ha and Nkosour 1011.7kg/ha compared to the national average yield which ranges from 610 to 880kg/ha (MOFA, 2007). Jenkaa recorded 842.2kg/ha. Azivivi, Adepa, Nkosour and Jenkaa are early maturing and they all have fresh seed dormancy. They have the potential of yielding between 2000 to 2500kg/ha (CSIR, 2007).

I recommend that Azivivi, Adepa, Nkosour and Jenkaa should be screened further at different parts of the country, especially in Northern Ghana. Disease reaction and biomass yields of these varieties should be evaluated on-farm with farmers. Farmers

naturally will adopt any of these varieties which they consider good, once they can compare them with what they have.

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APPENDIX I

Questionnaire

Farmers' perception and the effect of *Cercospora* leaf spot on groundnuts.

Name of farmer.....No. of farmers.....Age.....Sex.....

Town/Village.....District.....Region.....

1. Do you cultivate groundnuts?

a. Yes b. No.

2. How long have you been cultivating groundnuts?

a. 1-3years. b. 4-6years. c. 7-9years. d. 10years and above.

3. How many acres do you normally cultivate?

a. 1-2acres b. 3-5acres. c. 6-9acres. d. 10acres and above.

4. Do you grow groundnuts on the same land every year?

a. Yes. b. No.

5. Do you plant as a sole crop or intercrop.

a. Sole crop. b. intercrop.

6. What varieties do you grow?

a. Chinese. b.' Abban'. c. Others.....

7. Why?

a. Matures early. b. easy to harvest. c. marketable. d. Low production cost.

e. Good yield. f. Matures early and marketable.

8. List the intercrops.

a. Maize. b. Guinea corn. c. maize/guinea corn.

d. Others.....

9. What do you do to the seeds before sowing?

a. Nothing b. Dress the seeds. c. others.....

10. Why?

a. No reason. b. To control the disease.

c. others.....

11. What problems do you encounter in cultivating groundnuts?

a. Disease. b. Capital. c. marketability. d. Disease and capital.

e. others.....

12. Where do you encounter the disease problems?

a. Field. b. storage. c. others.....

13. Can you show me some diseased samples/examples.

a. Leaves with symptoms. b. Diseased whole plant. c. others.....

14. What is the percentage of the disease problem?

a. 30%. b.40%. c.50%. d 60%. e. above 60%.

15. How often do you see the disease problem?

a. Every season. b. Every year. c. once a while.

16. What time and stage of growth do you encounter the disease?

a. Before flowering. b. at flowering. c. after flowering. d. Others.....

17. How do you solve the disease problems?

a. Do nothing. b. Ever reported to AEAs. c. others.....

Notes:

APPENDIX II

SUMMARY OF DATA USING SPSS

Do you cultivate groundnuts	
Response	Percent of farmers
yes	100.0
No	0.0

How long have you been cultivating groundnuts?	
Years of groundnut production	Percent of farmers
1-3	20.0
4-6	37.0
7-9	36.0
above 10	7.0
Total	100.0

How many hectares do you normally cultivate?	
Hectares of groundnut cultivation	Percent of farmers
1-2	41.0
3-5	43.0
6-9	14.0
above 10	2.0
Total	100.0

Do you grow groundnuts on the same piece of land every year?	
Response	Percent of farmers
yes	97.0
no	3.0
Total	100.0

Do you plant as a sole crop or intercrop?	
Cropping system	Percent of farmers
sole crop	54.0
intercrop	46.0
Total	100.0

What varieties do you grow?	
Varieties grown	Percent of farmers
china	80.0
china and abban	12.0
others	8.0
Total	100.0

why?	
Reasons of variety choice	Percent of farmers
matures early	9.0
marketable	51.0
matures early and marketable	40.0
Total	100.0

List the intercrops.	
intercrops	Percent of farmers
maize	39.0
guinea corn	2.0
maize and guinea corn	6.0
no intercrop	53.0
Total	100.0

What do you do to the seeds before sowing?	
	Percent of farmers
nothing	100.0

Why?	
	Percent of farmers
no reason	100.0

Can you show me some example or samples?	
Diseased samples	Percent of farmers
leaves	65.0
whole plant	35.0
Total	100.0

What problems do you encounter in groundnuts?	
problems	Percent of farmers
disease	79.0
disease and capital	21.0
Total	100.0

Where do you encounter the disease problems	
	Percent of farmers
on the field	100.0

What is the percentage of the disease problem?	
% of groundnut plants diseased	Percent of farmers
30%	47.0
40%	11.0
50%	41.0
60%	1.0
Total	100.0

How often do you see the disease problem?	
Disease occurence	Percent of farmers
every season	97.0
every year	3.0
Total	100.0

What time and stage of growth do you encounter the disease?	
Disease symptom appearance	Percent of farmers
before flowering	7.0
at flowering stage	3.0
after flowering	90.0
Total	100.0

How do you solve the various disease problems?	
Disease intervention	Percent of farmers
nothing	100.0
Total	100.0

Proportion of groundnut plants diseased	Percent of farmers who practiced sole cropping	Percent of farmers who practiced intercropping	Total
30%	4	43	47
40%	10	1	11
50%	39	2	41
60%	1	0	1
Total	54	46	100

Proportion of groundnut plants diseased	Percent of farmers who practiced monocropping	Percent of farmers who practiced land rotation	Total
30%	44	3	47
40%	11	0	11
50%	41	0	41
60%	1	0	1
Total	97	3	100

APPENDIX III

ANOVA TABLES OF POD YIELD, SEED YIELD, 100 SEED WEIGHTS AND 100 POD WEIGHTS

Anova Table for Pod yield/ha(kg).

Source	DF	SS	MS	F	P
Rep	2	1218139	609070		
Trt	15	2906034	193736	0.3902	0.4915
Error	30	5888457	196282		
Total	47	1.001E+07			

Anova Table for Seed yield/ha(kg).

Source	DF	SS	MS	F	P
Rep	2	657058	3285		
Trt	15	1504827	100322	1.23	1.3018
Error	30	2439585	81320		
Total	47	4601471			

Anova Table for 100 pods weight(g).

Source	DF	SS	MS	F	P
Rep	2	393.50	196.750		
Trt	15	3898.00	259.867	1.81	1.9812
Error	30	4306	143.550		
Total	47	8598.00			

Anova Table for 100 seed weight

Source	DF	SS	MS	F	P
Rep	2	73.50	36.7500		
Trt	15	798.65	53.2431	4.68	0.0002
Error	30	341.17	11.3722		
Total	47	1213.31			