EFFECTS OF LATE LEAF SPOT INDUCED BY *PHAEIOSARIOPSIS PERSONATA* (BERK. & M. A. CURTIS VAN ARX) ON YIELD AND SOME PHYSIOLOGICAL PARAMETERS OF GROUNDNUT *(ARACHIS HYPOGAEA* L.) VARIETIES

BY

ABDULBASID KABIR

DEPARTMENT OF CROP PROTECTION

FACULTY OF AGRICULTURE

AHMADU BELLO UNIVERSITY, ZARIA

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DEPARTMENT OF CROP PROTECTION
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

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DECLARATION

I declare that the work in this dissertation titled "Effects of Late Leaf Spot Induced by *Phaeiosariopsis personata* (Berk. & M. A. Curtis Van Arx) on Yield and Some Physiological Parameters of Groundnut *(Arachis hypogaea* L.) Varieties" has been carried out by me in the Department of Crop Protection. The information derived from literature has 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.

Abdulbasid KABIR _____ _____

Signature Date

CERTIFICATION

The dissertation titled "EFFECTS OF LATE LEAF SPOT INDUCED BY *PHAEIOSARIOPSIS PERSONATA* (BERK. & M. A. CURTIS VAN ARX) ON YIELD AND SOME PHYSIOLOGICAL PARAMETERS OF GROUNDNUT *(ARACHIS HYPOGAEA* L.) VARIETIES" by Abdulbasid KABIR meets the regulations governing the award of the degree of Master of Science in Crop Protection of the Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

Prof. Olufunmilola Alabi (Chairperson, Supervisory Committee)	Signature	Date
Dr S. E. L. Alao (Member, Supervisory Committee)	Signature	Date
Prof. A. B. Zarafi (Member, Supervisory Committee)	Signature	Date
Prof. O. O. Banwo (Head, Department of Crop Protection)	Signature	Date
Prof. Sadiq Z. Abubakar (Dean, School of Postgraduate Studies)	Signature	Date

DEDICATION

This work is dedicated to my father, late Muhammad Kabir Hassan, for his parental support, prayers and encouragement in my academic pursuit.

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ABSTRACT

In 2016 cropping season, two trials were conducted to evaluate the efficacy of Funguforce® (mancozeb + carbendazim) in the management of late leaf spot of groundnut induced by (*Phaeiosariopsis personata* [Berk. & M. A. Curtis van Arx]) in Samaru, North – West Nigeria as well as to determine the effect of the disease on yield and yield parameters of groundnut varieties, and to assess the effect of late leaf spot on crude protein and chlorophyll contents of groundnut. In the first experiment, five groundnut varieties (SAMNUT 18, 21, 22, 23 and 25) were subjected to sprayed and unsprayed treatment of mancozeb + carbendazim at three – week intervals. In the second experiment, SAMNUT - 14, a variety susceptible to the disease was subjected to five [plants sprayed weekly ($T_{1)}$, plants sprayed biweekly ($T_{2)}$, plants sprayed every three weeks ($T_{3)}$, plants sprayed every four weeks ($T_{4)}$ and unsprayed plants ($T_{5)}$] different frequencies of fungicide application. The experiments were laid out in a randomized complete block design (RCBD) with three replications and were established at the Institute for Agricultural Research (IAR) Samaru, Zaria. The parameters recorded were stand count at emergence, and at harvest, disease severity at 56, 63, 70, 77, 84, 91, and 98 days after sowing (DAS) based on 1 – 9 scale, percent defoliation, pod and haulm yields. Area Under Disease Progress Curve (AUDPC), crude protein content and chlorophyll content were also computed. Results showed that, application of mancozeb + carbendazim at the rate of 2 kg ai/ha on groundnut varieties at three weeks intervals reduced disease severity by 27.29 %, defoliation by 52.57 % with an increase in pod yield of 16.89 %, haulm yield (17.94 %) and recorded a decrease in AUDPC by 43.39 % compared to the unsprayed plots. The highest yields were recorded for SAMNUT 21 and SAMNUT 22 that had lowest values for the disease parameters. Low yields were recorded in SAMNUT 18 and 25 which also had the highest severity, percent defoliation and area under disease progress curve. Weekly spray was found to

be most effective in reducing disease with minimum disease severity of 33.33 % and consequently improved pod yield by 47.91 %. Biweekly application of the fungicide was also found to be effective with decrease in disease severity by 56.41 % and increase of 45.65 % in yield over untreated; and was most economical with cost: benefit ratio of 1:69.6. For all the fungicide frequencies tested there were significant differences in crude protein and chlorophyll contents which decreased with increase in disease severity. Crude protein and chlorophyll contents increased by 29.45 % and 78.57 % in the treated plants respectively compared to the untreated. Correlation analysis showed that late leaf spot infection significantly lead to reduction in pod and haulm yields, crude protein and chlorophyll contents. It can be concluded that from this study the use of SAMNUT 21 or 22 with application of mancozeb + carbendazim at biweekly interval was the best economical management option for late leaf spot of groundnut.

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CHAPTER ONE

1.0 INTRODUCTION

Groundnut (*Arachis hypogaea* L.) also known as peanut, earthnut or monkey-nut is a member of the family Fabaceae used for human food and animal feed (Sharma, 2005). It is an important food legume highly adapted to tropical and subtropical climates of the world (Janila *et al*., 2013). Groundnut is a key crop for small scale farmers especially in Africa and Asia where the crop serve as a valuable source of dietary protein, oil, and fodder for livestock. It contains 48-50 % oil, 26-28 % protein and a rich source of dietary fibre, minerals (calcium, potassium, phosphorus, magnesium) and vitamins (Schilling and Gibbon, 2002; Brink and Belay, 2006; Janila *et al.,* 2013). Groundnut in association with a bacterium has the ability to fix atmospheric nitrogen which helps in the maintenance of soil fertility (FAO, 2012). This crop is cultivated annually on about 24.63 million hectares worldwide with annual production of 41.27 million tons and productivity of about 1.85 t ha^{-1} (FAO, 2012). Groundnut is the 13th most important crop and the 5th most important oilseed in the world in terms of volume of oil production and is widely grown in more than 100 countries of tropical, subtropical, and warm temperate regions of the globe (Vijaya, 2007; Upadhyaya *et al.,* 2012). Yields are traditionally low in the developing countries of the tropics due to a combination of factors including unreliable rainfall, little improved technology available to small scale farmers, pests and diseases occurrence, poor seed quality, inappropriate agronomic practices (Atuahene – Amanka *et al*., 1990). The global annual increase in production was 0.4 % between 2009 and 2012 which was attributed to a 0.3 % and 0.1 % increases in cultivated land area and crop yield respectively (Janila *et al.,* 2013).

In West Africa, Nigeria is the largest producer of groundnuts with production of 3.07 million tons on about 2.4 million hectare (FAO, 2012). Major groundnut producing countries are China, India, Nigeria and USA (FAO, 2015).

Despite the economic, social and cultural importance of groundnuts, its productivity is severely constrained by several biotic and abiotic factors. Drought is the major abiotic constraint affecting groundnut production and quality worldwide. Two thirds of the global production occurs in rain-fed regions of the semi-arid tropics where rainfall is generally erratic and insufficient, causing unpredictable drought stress (Reddy *et al.,* 2003). Also, groundnut yield and quality are severely constrained by a wide range of fungi, bacteria, viruses, and nematodes. Among the fungal diseases, early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot (*Phaeiosariopsis personata* van Arx) are the most prevalent, and occur throughout all groundnut growing regions (Liu *et al.,* 2013). In Nigeria, the leaf spots and rosette virus are the most serious damaging diseases of groundnut (Alabi *et al*., 1993).

Late leaf spot induced by *Phaeiosariopsis personata* (Berk & M.A Curtis van Arx) is widely distributed throughout the world and can lead to yield loss of up to 80 % (McDonald *et al*., 1985; Miller *et al*., 1990; Grichar *et al*., 1998). Late leaf spot causes severe defoliation and reduces pod yields by more than 50 % if the crop is not protected with chemicals (fungicides) (Shew *et al*., 1988).

Although fungicides application is effective in controlling the disease, its high cost is considered uneconomical in many developing countries such as Nigeria, Ghana, Sudan, in this situation, the use of resistant cultivars of groundnut offers a better alternative (Pensuk *et al*., 2002).

1.1 Justification of the study

Late leaf spot (LLS) induced by *Phaeiosariopsis personata* (Berk. & M.A. Curtis van Arx) is commonly present wherever groundnut (*Arachis hypogaea* L.) is grown (Bharat *et al*., 2013). It is an economically important fungal disease of groundnut in Nigeria and worldwide (Pande and Rao, 2001). The fungus penetrates leaf cells and withdraws their contents causing the cells to collapse and die, forming spots. Late leaf spot lowers yield by reducing the green leaf area available for photosynthesis leading to reduction in crude protein, chlorophyll content and by stimulating abscission and extensive defoliation. The cost of yield losses due to leaf spot globally have been estimated at USD 5 million (FAO, 2011). The losses in yield due to the leaf spot vary from place to place and between seasons (Backman *et al*., 1974; Porter, 1980). Where fungicide application is normal practice for control during the crop season, pod yield losses are estimated at around 10 %. But for much of the semi – arid tropics, where fungicides are rarely used, losses in excess of 50 % are common (Pensuk *et al*., 2002). There is also no true resistant or tolerant variety to the disease which will suit the agro – climatic conditions of the tropics. It is therefore important that effective management of late leaf spot disease be developed and applied (Feakin, 1973). As a result, use of fungicide is the best alternative for effective management of the disease (Joshi, 2010). Varying fungicide spray frequency at suitable time of application will help reduce disease development thereby increasing pod and haulm yields. This study was therefore carried out to evaluate the effect of the disease on crude protein and chlorophyll contents on groundnut varieties and the use of fungicides combination and frequencies to manage the disease.

1.2 Objectives of the study

The objectives of this research are:

i. To determine the effect of late leaf spot on yield and some yield parameters of six groundnut varieties.

ii. To assess the effect of late leaf spot on crude protein of seeds and chlorophyll contents of leaves of groundnut.

CHAPTER TWO

2. 0 LITERATURE REVIEW

2. 1 Groundnut (*Arachis hypogaea L.*)

2. 1. 1 Botanical description of groundnut

Groundnut *(Arachis hypogaea* L.) is an annual or perennial plant that is distinguished from most other crops by producing aerial flowers, but fruits below the soil level. *Arachis* belongs to the family *Fabaceae,* subfamily *Faboideae* tribe *Dalbergieae. Arachis hypogaea* (L.) is the only domesticated species in the genus (Tillman and Stalker, 2009). It is also known as peanut, Pindar, monkey-nut, earthnut, etc (Martin *et al*., 2006; Brink and Belay, 2006). The binomial designation *Arachis hypogaea* describes the most peculiar trait of the species – subterranean fruit formation (*hypo*, meaning under and *gaea* meaning ground) (Chapman and Carter, 2000). Kochhar (1986) noted that like bambara groundnut of West Africa, all species of *Arachis* are geocarpic, forming their fruits underground.

Two major types of groundnut are cultivated – the bunch or erect types and the runner or trailing types. The groundnut plant has a central, upright stem and many lateral branches. When these lateral branches are upright, the plant is designated bunch or erect type (Anonymous, 2009). However, when horizontal, the plant is referred to as a runner or trailing type. The Valencia and Spanish groundnut are bunch types, while the Virginia groundnut consists of both the bunch and runner types (Chapman and Carter, 2000).

The leaves are pinnate normally with two pairs of leaflets and are green or dark green in colour. Darker leaves are found in Virginia groundnut, whereas Spanish and Valencia groundnut tend to have lighter leaves (Schilling and Gibbon, 2002). The flowers are sometimes white, but more often yellow to orange, borne on inflorescence in the leaf

axils, sessile and attached to the leaf axils either singly or in groups up to three and are self – pollinated (Chapman and Carter, 2000). Natural cross pollination occurs at the rates of less than 1% to greater than 6% (< 1% > 6%) due to atypical flowers and action of bees (Coffelt, 1989). After fertilization, the aerial flowers grow downwards and the ovary at the end of the elongated stalk (peg) enters the soil in a positive geotropic manner where the ovary at the tip of the peg grows into a pod containing the seeds (Tweneboah, 2000). At the end of the ovary grows a meristematic region that becomes the stalk-like structure (the gynophore) that bends downwards (a geotropic reaction) and forces the ovary into the soil. The gynophore is commonly referred to as peg and the stage of the plant development at which the gynophore is activated and elongates is referred to as pegging (Chapman and Carter, 2000). Groundnut plants have taproots with abundantly branched lateral roots on which globular, often dark brown nodules are usually present (Gregory and Gregory, 1986).

Nodulation in groundnut is very essential as it has the benefit of symbiotically (e.g. Rhizobium) fixing Nitrogen (N_2) which can be made available to crops that succeed the groundnut. The ability to nodulate and fix N_2 is a genetic factor affected by environmental conditions and requires large amount of dry matter (Dakora *et al*., 1987; Giller and Wilson, 1991). The differences in the number of nodules per plant is attributed to plant factors that affect dry matter production and partitioning; environmental factors which affect crop growth and development, as well as soil factors that affect the process of nodulation and N_2 fixation (Banerjee *et al*., 2005; Ahmad *et al.*, 2007).

2. 1. 2. Origin and distribution of groundnut

Groundnut (*Arachis hypogaea* L.) is believed to have originated in South America and was domesticated in the area covered by Brazil, Argentina, Paraguay, Peru and Bolivia

(Tweneboah, 2000; De Waele and Swanevelder, 2001). The Portuguese apparently took the seeds from Brazil to the West Coast of Africa in the 16th Century. Groundnut was cultivated by the Incas in Peru, from there, it spread to Mexico and then to the West Indies before the arrival of the Europeans in South America (De Waele and Swanevelder, 2001).

In Africa, groundnut is a major cash crop in Senegal, Gambia, Nigeria, Niger and Sudan (Brink and Belay, 2006; Martin *et al.*, 2006). Six million tons are produced in Africa and about 80% comes from the savanna zone, south of the Sahara of which Nigeria, Senegal, Niger, Gambia and Sudan are the largest producers in the zone (Tweneboah, 2000). Production levels during the 2008 to 2009 season for Nigeria, Sudan, Senegal and Ghana, were 15.5, 8.5, 7.5 and 4.4 × 10^5 million metric tons, respectively (Anonymous, 2009).

2.1.3 Importance and uses of groundnut

Groundnut is a principal source of digestible protein (26 – 28%), cooking oil (48 – 50%) and vitamins like thiamine, riboflavin and niacin (Savage and Keenan, 1994; Janila *et al*., 2013). Groundnut is also a good source of minerals like P, Ca, Mg and K as well as vitamin E, K and B (Schilling and Gibbon, 2002). The bulk of the production is used for extracting oil while the cake is fried to make a local food called "kulikuli". Groundnut paste from roasted kernel is used to thicken stews, soups and as bread spread (Atuahene-Amankwa *et al*., 1990). In many countries, groundnut cake and haulms are also used as livestock feed. Oil extracted from the nuts is used in the manufacture of soap, lubricant and illuminants and the production of detergents (Danquah *et al*., 2000; Kochhar, 1986).

As a legume, groundnuts improve soil fertility by fixing nitrogen (N_2) thereby increasing productivity of the semi-arid cereal cropping system (Smart, 1994).

The seeds are eaten boiled and salted to improve flavour and taste, or are processed into butter and used in sandwiches, mixed into candies, cookies, pies and other bakery products (Anonymous, 1990). In Africa, groundnut is eaten fresh or roasted and also in the preparation of soup (De Waele and Swanevelder, 2001).

In countries such as Senegal, Gambia and Nigeria oil extraction has been an important cottage industry for years. The use of groundnut in confectionery and for oil and meal production is increasing, and there is gradual shift taking place from oil and meal to confectionery use, especially in Latin America and the Caribbean and the seeds are fermented into alcoholic drinks (Smart, 1994). The cake from oil extraction is a feed rich in protein, but it is also made into groundnut flour, which is used in many human foods. Fermented groundnut cake is eaten fried in Indonesia. The cake finds industrial application in the production of glues, sizes for paper and starches for laundering and textile manufacture (Danquah *et al*., 2000). Protein from groundnut cake is made into a wool-like fibre, which can be blended with wool or rayon. Groundnut shells are used as roughage in fodder, as fuel, fertilizer, mulch, in the manufacture of particle board and building blocks, and can be used as a source of activated carbon, combustible gases, organic chemicals, reducing sugars and alcohol. Young groundnut pods and leaves are consumed as a vegetable, in West Africa the leaves are added to soups. Groundnut has a range of uses in traditional African medicine. Pod extracts are taken as a galactagogue, and used as eye-drops to treat conjunctivis. Macerations of peeled seeds are drunk to treat gonorrhoea, macerations of the seed coats against syphilis, while macerations of the seed coats and shells are applied against ophthalmia (De Waele and Swanevelder, 2001). Sap of ground leaves and seeds is used for ear-drops against ear discharge. Leaf macerations are drunk as a diuretic. Leaf infusions are drunk against female infertility, and used for eye-drops to treat eye injuries and cataract. Plant ash with salt is applied in

case of caries. Pod extracts and young plants are credited with aphrodisiac properties. The plant is also used to relieve cough and is considered emollient and demulcent; emulsions are taken to treat pleurisy, enteritis (including colitis), and dysuria. Agglutinins (lectins) from groundnut seeds are often used in medical research for histochemical investigations (De Waele and Swanevelder, 2001).

2.2 Production and Yield of Groundnut

World groundnut production was estimated to be 37.196 million metric tons (MT) in 2012/2013, with a drop of 2% on the year-on-year basis (FAO, 2013). The top four producers are China, India, Nigeria and USA whose groundnut production was estimated to be 13,336,860 million MT, 7,156,448 million MT, 2,755,649 million metric ton (MT) and 1,837,519 million MT, respectively (FAO, 2015). The top ten producers of groundnut in the world are presented in Table 1 as presented in appendix 1.

2.3 Production Constraints of Groundnut

2.3.1 Pests and diseases of groundnut

Groundnut is susceptible to a number of diseases the most important being early leaf spot (*Cercospora arachidicola*), late leaf spot (*Phaeiosariopsis personata*), rust (*Puccinia arachidis*), groundnut rosette, *Aspergillus flavus* and *A. parasiticus* infection of seeds and aflatoxin contamination. Aflatoxin is produced by the two fungi (*Aspergillus flavus* and *A. parasiticus*), it occurs at both pre-harvest, and post-harvest stages. Aflatoxin is harmful to the health of humans and animals. Aflatoxin contamination can be managed by avoiding damage to seeds during weeding, harvesting and storage. Soil amendment with lime and farm yard manure, proper and prompt drying and storing of pods or seeds at low temperature and under moisture-free conditions also help reduce aflatoxin contamination in groundnut (Brink and Belay, 2006).

Aflatoxin contamination is another important fungal disease of groundnut and a name for a group of toxins known as B1, B2, G1, G2, M1 and M2 (carcinogenic compounds) that are produced mainly by two fungi called *Aspergillus flavus* and *A. parasiticus*. These toxins occur naturally and have been found in a wide range of commodities used for animal and human consumption. Depending on their levels, toxins can severely affect the liver and induce a human carcinogen, i.e., causes cancer. In many developing countries, aflatoxin is a major health risk to both humans and animals due to the high levels of the contaminated products consumed (Wright *et al*., 2002).

The causative agents grow on food and feed grains at moisture level of 15% or greater in the presence of warm temperatures (21°C - 37°C). The toxin can be found in a variety of grains but most often occurs in groundnut and maize. Contamination can occur while the grain is standing in the field, soon after harvesting and during storage, before or after the grain is processed into food or feed (Allen, 2003).

Foliar diseases of groundnut, early leaf spot, late leaf spot and rust can collectively cause up to 70% yield losses (Schilling and Gibbon, 2002) if left uncontrolled. Early and late leaf spots attack can cause 50% yield losses in groundnut (De Waele and Swanevelder, 2001). Recommended control methods for these foliar diseases include planting resistant varieties, removal of volunteer plants from the field, adopting cereal-groundnut rotation, application of broad-spectrum fungicides and early planting (De Waele and Swanevelder, 2001; Schilling and Gibbon, 2002; Anonymous, 2009).

Groundnut rosette virus disease (GRVD) is an important disease of groundnut (De Waele and Swanevelder, 2001). Groundnut rosette virus transmitted by aphids is endemic to Sub-Saharan Africa and widely prevalent in Nigeria, Ghana, Malawi and Zambia causing yield losses of 30 to 100% (Schilling and Gibbon, 2002). Control of the disease is by early sowing in the rains, high density planting, planting resistant varieties,

biological control using the adult ladybird beetle that feeds on aphids (Anonymous, 2009). Removal of diseased plants from within crop stand (roguing) is a well-known means of controlling viral diseases by eliminating initial sources of infection from which further spread can occur (Thresh, 1988).

Other diseases of groundnut include Aspergillus crown rot (*Aspergillus niger*), a fungal disease that causes rot of both seeds and crowns of seedlings hence reducing plant stand. Mature plants can also be infected leading to permanent wilt of branches or the entire plant (Schilling and Gibbon, 2002; Anonymous, 2009). Sclerotium blight (*Sclerotium rolfsii*) is another destructive disease that affects all parts of the groundnut plant with stem infection being the most common. Different types of pests attack and destroy groundnut in the field and in storage. Globally, the most important groundnut pests include aphids (*Aphis craccivora*), thrips (*Frankliniella schultzei*), white grubs (*Schyzonycha spp.*) and termites. The groundnut leaf miner (*Aproaerema modecella*) a caterpillar, causes more than 50 % yield losses in Africa where they have reached epidemic densities in some farms (Kenis and Cugala, 2006; Schilling and Gibbon, 2002). The impact of leafminer could be reduced by using tolerant varieties. For example, Egola-1 a groundnut variety in Uganda has shown relative resistance to leafminer (Anonymous, 2009).

Pest attacking stored groundnut pods and seeds include the bruchid beetles (*Caryedon serratus, Callosobruchus* spp*., Tribolium castenium*) with *Caryedon serratus* being the major storage pest in West Africa (Schilling and Gibbon, 2002).

2. 3. 2. Late Leaf Spot

Late leaf spot is one of the two diseases (early and late) commonly referred to as cercospora leaf spots, although they are induced by two different pathogens. The two pathogens induce similar symptoms, they form necrotic lesions on leaves and petioles

and less frequently on stems, stipules and pegs. Early leaf spot produces yellow halos around the lesions which are usually absent in late leaf spot. Under field conditions, however, yellow halos may be altered by genetics or nutritional status of host or weather conditions therefore, both the diseases are considered as one (Holiday, 1980). Late leaf spot induced by *Phaeiosariopsis personata* is the most common, wide spread, destructive and consistent in occurrence.

The host range of *P. personata* is confined to the genus *Arachis* (Stalker and Simpson, 1995). Epidemics of Late Leaf Spot have frequently led to yield losses of 50% on unsprayed groundnuts (Melouk and Shokes, 1995). The pathogen often forms necrotic lesions on leaves and petioles and less frequently on stems, stipules and pegs.

2. 3.2.1 Description of late leaf spot pathogen

Mycelium of *Phaeiosariopsis personata* Van Arx is septate and exclusively intercellular. Its haustoria puncture into the palisade and mesophyll tissue. Dense, globular, brown to black stromata measuring diameter of 20 µ to 30 µ are produced. Conidiophores mostly are hypophyllous (growing on the undersurface of leaves) but some time amphigenous (occurring on both sides of the leaf). In later stages of disease development, conidiophores arise in clearly concentric tufts from heavy stromatic base. These are fasciculate, geniculate, reddish brown in colour with mostly hyaline tips and non-or severally septate. Conidiophore size range from 24 µ to 54 µ x 2 µ to 8.2 µ. Conidia of the fungus are obclavate with attenuated tips and pale brown dilutely olivaceous colour measuring 18 µ to 60 µ × 5 µ to 11 µ with one to nine septa and bluntly rounded top cells. Perithecia, asci and ascospores of teleomorphic stage of *P. personata* only differ from *C. arachidicola* in size. The teleomorphic stage of the LLS pathogen is rarely seen on groundnut (Shokes and Culbreath, 1997).

2. 3. 2. 2 Survival of the pathogen

Conidia of *P. personata* produced on crop residue in soil are the main source of initial inoculum. Mycelium in spots on stems, petioles, and pegs are more likely to over season than that on leaflets (Shokes and Culbreath, 1997).

Survival of *Phaeiosariopsis personata* as a pathogen on crop debris is influenced by weather conditions at time of harvest or the growing season of crop. The late leaf spot fungus remained viable for 60 days on crop residue kept under field conditions and it may remained viable for 30 days on residue of post rainy season crop, when residue was kept on soil surface during both the seasons (Rao *et al*., 1993). The pathogen remained viable for more than one year when the fungus was stored indoor on a susceptible variety. On a resistant genotype it retained viability only for 135 days (Rao *et al*., 1993).

2.4. Symptoms

The fungal pathogen attacks any above-ground portion of the plant, but leaf spots are the most conspicuous symptom. Depending upon weather conditions and cropping history, leaf symptoms usually appear between 30 to 50 days after planting. Symptoms of late leaf spot first appear as brown or black, pinpoint-size dots on the upper leaf surface (McDonald *et al*., 1985). Late leaf spots typically appear as black, circular spots lacking or with a less pronounced yellow halo. The spots then develop in about 5 days into mature, sporulating lesions. On the abaxial surfaces, where most sporulation occurs, the lesions are black with a slightly rough appearance. The distributions of fruiting structures are in circular rings on the abaxial surfaces which is a useful character for distinguishing between early and late leaf spots in the field. *P. personata* produces haustoria within host cells and lesions on petioles, stems, and pegs. The symptoms are oval to elongate and have more distinct margins than the leaflet lesions. When disease

attack is severe, the affected leaflets first become chlorotic, then necrotic, lesion often coalesce and leaflets are shed (McDonald *et al*., 1985).

2.5 Epidemiology

Maximum temperature range of 31 to 35^{o}C and minimum temperature range of 18 to 23^{o}C favour Cercospora leaf spot outbreak on groundnut (Sulaiman and Agashe, 1965; Vankataraman and Kazi, 1979; Pande *et al*., 2004). When precipitation of rains makes a film of water over the leaves or a relative humidity of >90 % prevails with a temperature of 20 to 29^{o}C for six to seven days, the groundnut crop is severely affected by Tikka disease (Cercospora leaf spot) (Chohan, 1974). The influence of climatic elements, temperature and relative humidity, on development of cercospora leaf spot in groundnut have been extensively studied (Jensen and Boyle, 1965; Vale and Zambolim, 1996; Wu *et al*., 1999). A model was developed by taking in consideration the relative humidity more than 95% and temperature minimum 22^{o}C and maximum 30^{o}C. This model was used to compare with calendar-based schedule in Argentina, America (Smith, 1986) and Brazil (Moraes *et al*., 1997). In field conditions and particularly in dry land agriculture, rainfall is the main source of humidity that makes leaves to become wet. The rainfall, for cercospora leaf spot epidemic, is a real alternative to relative humidity (Johnson *et al*., 1986; Davis *et al*., 1993). Generally, during the growth period of groundnut, temperature is favorable for host as well as for pathogen (Paul and Munkvold, 2005). Similar approaches have been used for forecasting the incidence of other host pathogen systems (Jhorar *et al*., 1997). Higher Humid Thermal Ratio (HTR) values observed when maximum temperature was less than 22^{o}C, and less disease progress was observed at lower HTR values at temperature more than 27^{o}C (Riaz, 2006). Disease evaluations were made by severity indexes, in leaflet samples at weekly intervals starting at the 30th day after sowing. Disease severity was calculated by

AUDPCs and the results showed that when onset of rainfall (minimum of 2.5 mm) on 2nd, 4th or 6th day fungicide application compared with four applications of 14 day fixed schedule fungicide sprays on 2nd and 4th day of rainfall have same effect as the fixed schedule of 14 sprays (Pezzopane *et al*., 1998).

2.6 Disease Management in Groundnut

2.6.1 Cultural Control Measures

Crop rotation is one of the cultural methods aimed at eradicating or reducing the amount of foliar pathogen from a field. Late leaf spot of groundnut passes dry season in crop debris. Host range of this pathogen is very limited to only groundnut crop. Amount of disease inoculum in soil may decrease if groundnut crop is rotated with any other crop for one or two or three years (Mazzani and Allievi, 1971; Kucharek, 1975). Crops selected for rotation, should be resistant to soil borne pathogens like fungi, bacteria, viruses and nematodes. Suitable crop rotation will decrease the disease progress rate in terms of disease severity and defoliation (Nutter and Shokes, 1995). Plant debris should be removed from the field after harvest, burned *in situ*, fed to animals or deep-buried. Volunteer groundnut plants and 'ground-keepers' should be eradicated. Weeds should be kept under control because their heavy growth may encourage disease development through modification of the crop microclimate (McDonald *et al*., 1985).

In on-farm IPM studies, sowing time, plant density and cultivar interaction illustrated significant difference for late leaf spot disease incidence. In early sown crop, disease values were higher than intermediate sowing, but still yields were higher than intermediate sowing dates. The late sown treatments also showed high disease incidence and pest infestation ultimately resulting into minimum yields (Adipala *et al*., 2000). Groundnut cultivars were collected from southern parts of India and evaluated under early and late season rainfall, late leaf spot incidence has more standard error of the

mean (SE m ±) and percent coefficient of variation under late season than in early season (Prakash and Halaswamy, 2003). Adverse effects of late leaf spot on early sown groundnut are less apparent than on late sown (Kucharek, 2003). The crop sown in early March and April does not need fungicidal spray till 60 days of age but the crop sown in May or June is sprayed within 25 to 30 days of emergence. In case the crop is not rotated with a non-host crop and wet moist weather prevails, late leaf spot epidemic may occur earlier in season (Kucharek, 2003).

Irrespective of weather conditions the crop is grown under rainfed or irrigation conditions, the popular cultivars comprising of spreading and semi spreading types matures late and become vulnerable to foliar diseases, which are impediments in obtaining peanut productivity. Depending upon length of the growing season and cultivars grown, the time of sowing may be adjusted to avoid infection of crop from outside source and to avoid environmental conditions conducive to disease build-up (McDonald *et al*., 1985)

2.6. 2 Host Resistance

In field experiments, disease progress curve has been found best criterion for evaluating varietal resistance (Johnson *et al*., 1986). Vanderplank (1968) used AUDPC to describe the resistance level and types of resistance in potato and wheat varieties. He dealt with vertical or horizontal resistance but the principles set for resistance that slow the epidemic with time scale remained the same.

In the Cercospora and groundnut pathogen - host relationship, several biological rate reducing components of partial resistance have been proposed (Johnson *et al*., 1986). These rate reducing components include number of lesions per leaf, small lesion diameter, long latent period, less diseased leaf area and decreased maximum percentage of lesions sporulating (MPLS) (Ricker *et al*., 1985; Johnson *et al*., 1986). Cultivars

having same response to a particular biological phase are blocked together. Two different isolate - variety combinations with same infection efficiency may be grouped in the same block at different stages of infection processes. Test lines may be classified according to decreasing infection ratio, increasing latent period, and decreasing infection period (Zadoks and Schein, 1979).

2. 6. 3 Chemical Treatments

In Asia where groundnuts are cultivated under rainfed conditions, farmers generally avoid to invest on disease control interventions. Cercospora leaf spot reduces yield by 5.50 - 6.08 g $plot^{-1}$ (4 m^2) for every unit increase in disease severity (Das and Roy, 1995) and this disease is responsible for reduction in protein content and oil recovery (Gupta *et al*., 1987). Disease management techniques/practices rather than control measures are adopted to address this disease problem effectively. Improving levels of resistance along with foliar application of fungicides to manage the disease in locally adapted varieties would substantially increase groundnut yields in developing countries. There are only a few varieties possessing tolerance to foliar diseases. However one to two sprays depending upon the suitable time of application increase the pod yield significantly (Waliyar *et al*., 1998).

Fungicide application on different varieties with different levels of resistance improved yield and biomass production about two fold when compared with non-treated plots of same varieties (Pande *et al.*, 1998). In long duration lines like 28-206 and 47-16, it is better to apply fungicides at later stages of growth, both of these lines produced 3.16 and 2.94 t/ ha pod yield when fungicide was applied at 70 DAS (Days After Sowing) (Waliyar *et al*., 1998). Groundnut lines with different levels of resistance exhibits significant difference to disease incidence either defoliation or number of lesions per leaflet. Florunner, a susceptible variety to leaf spot fungus responded positively to Chlorothalonil application for lesion count and for defoliation (Gorbet *et al.,* 1982). Georgia green and C-99R

responded positively to chlorothalonil applications with reduced disease score and increased yield with increase in number of sprays per season. Chlorothalonil application at 14 days interval gave more yields in both varieties (Culbreath *et al*., 2000).

Several systemic and non-systemic fungicides are used to control late leaf spot and other diseases of groundnut throughout the world. Ali and Ali (1959) reported that Bordeaux mixture at 4:4:50, Zerlate, Fermate, Parzate and Perenox at rate of 2lb per hundred gallons of water on groundnut was used in Sindh. All chemicals gave better results over control. Bordeaux mixture was most effective and produced more yield.

A single spray of carbendazim + mancozeb applied once in different treatments and spray timings varied from 30 DAS to 80 DAS at 10 days intervals reduced the percent disease index in all treatments. The sprays conducted up to 50 DAS produced significantly more yield than later applications (Chandra *et al*., 1998). In an unprotected field 100% leaf area may be damaged due to disease. In fungicide applications, number and time of sprays are very significant (Waliyar *et al*., 1998).

Every intervention aimed at reducing initial inoculum or to increase span between two epidemiological events decreases the AUDPC. MDR-98 and C-99 cultivars planted under strip tillage and conventional practices along with fungicides applications like Chlorothalonil, Tebuconazole, and azoxystrobin were applied with different doses at different intervals. Conventional practices are more conducive for disease development although higher yields were obtained in conventional practice treatments (Monfort *et al*., 2004).

2.6.4 Biological Control

Biological control of fungal diseases of plants is eco-friendly and is a potential component of integrated disease management. Biological control of foliar diseases has received less attention, owing to the poor establishment of the introduced biocontrol agents and resulting variations in disease control. Biocontrol agents in the phylloplane are continuously subjected to rapid and extreme variations in moisture and temperature, exposure to ultraviolet radiation, and limited nutrient availability (Blakeman, 1982). Maintenance of threshold populations of the introduced biocontrol agents on the phylloplane has remained the focus of biocontrol research. Nutrient-supplemented application of biocontrol agents augments the rate and time of survival of the introduced biocontrol agent in the phylloplane. Chitin, a linear polymer of *N*-acetyl glucosamine (NAG), is selectively degraded by the chitinolytic organisms and used as a carbon source for their growth and multiplication. Chitinolytic microorganisms can be applied with chitin for better survival of the introduced agents in the phylloplane to control fungal diseases (Yuen *et al*., 2001).

Parasitism of pathogenic fungi, facilitated by the production of hydrolytic enzymes, is involved in biological control of fungal diseases. Among the hydrolytic enzymes, chitinases are of prime importance since chitin is a major cell wall constituent in the majority of phytopathogenic fungi. Chitinases inhibit fungal spore germination and germ tube elongation (Manjula *et al*., 2004), and lyse hyphal tips (Mathivanan *et al*., 1998). Purified chitinases of *Trichoderma harzianum* (El Katatny *et al*., 2001), *Gliocladium virens* (Dipetro *et al.,* 1993), *Serratia marcescens* (Mathivanan *et al*., 1998), *Serratia plymuthica* (Frankowski *et al*., 2001), and *Streptomyces* sp. (Gomes *et al*., 2001) were highly antifungal.

2.7 Cost Benefit Analysis

Cost benefit analysis (CBA) is an analytical tool for judging the economic advantages or disadvantages of an investment decision by assessing its costs and benefits in order to assess the welfare change attributable to it. It is an indicator of the relative economic performance of the treatments (Aziz *et al*., 2012). A ratio of one indicates the venture neither making profit nor loss, it is breaking even, while a ration of less than one means a loss, but a ratio of more than one indicates a profit and the economic viability of the treatment compared with the untreated.

FAOSTAT (2014) reported that the highest usable yields of tomato with greater financial benefits obtained in chlorothalonil or mancozeb at 7 and 10 days interval was primarily due to suppression of *Alternaria sp*. and other fruit rot. Prior *et al.* (1994) reported that three sprays of mancozeb reduces the disease severity significantly in groundnut compared to other chemicals and botanicals and gave the highest economic benefit.

CHAPTER THREE

3. 0 MATERIALS AND METHODS

3.1 Experimental Site

This study was conducted in the screen house of the Department of Crop Protection, Faculty of Agriculture, Ahmadu Bello University and the Institute for Agricultural Research (IAR), Samaru, Zaria farm, situated at 11° 10ˈN, 07° 38ˈE and 685 m above sea level in the Northern Guinea Savanna zone of Nigeria.

3.2 Description of Groundnut Varieties

Groundnut varieties (SAMNUT 14, 18, 21, 22, 23 and 25) with varying degrees of resistance to late leaf spot were obtained from the breeder at the IAR with the following characteristics: SAMNUT 14 and 18 are early maturing, semi-erect and susceptible to leaf spots; SAMNUT 21, 22, 23 and 25 are early maturing, semi-erect and tolerant to leaf spots (Institute for Agricultural Research (IAR) descriptors, 2015)

3.3 Treatments and experimental designs used

3.3.1 Experiment 1

3.3.1.2 Determining effects of variety and fungicide application on late leaf spot of groundnut in the screenhouse

Groundnut leaves infected with late leaf spot were obtained from the field. The leaves were wetted and covered with polyethylene bags and kept under sunlight for 12 hours in order to increase the humidity. The conidia from sporulating spots were scrapped mixed with water and shaken thoroughly to obtain a homogenous suspension. Pots (50 cm diameter) were washed and filled with 6 kg heat – sterilized soil and watered. The seeds of five groundnuts varieties (SAMNUT - 18, 21, 22, 23, and 25) were obtained from the breeder at the IAR and treated with metalaxyl 20 % + imidacloprid 20 % (Allstar®, 40 DS, Jiangsu Kesheng Group Co. Ltd., China) at the rate of 10 g/4 kg seeds before sowing. Two seeds of each variety were sown per pot in forty (40) labelled plastic pots and watered regularly.

At 35 days after sowing, the seedlings were inoculated with *Phaeiosariopsis personata* inoculum suspension using hand held sprayer. This was done in the evening when temperature was relatively low. High relative humidity around the plants was maintained by covering the plants with polyethylene bags overnight before and after inoculation. At 60 DAS, the plants were subjected to sprayed and unsprayed treatments of fungicide with four replications that is ten (10) treatment combinations, a total of 40 pots. Funguforce® (Mancozeb + carbendazim) were applied at the rate of 2 kg ai/ha according to the manufacturer's recommendation to the plants that received the sprayed treatments.

The plants were observed daily for development of symptoms. The parameters recorded include:

1. Disease severity scores taken at 60, 80 and 90 DAS using a 1-9 scale described by Subrahmanyan *et al*. (1995) as presented in Table 2.

The disease severity was computed using the following formula as cited by Marley (2013):

$$\text{Disease severity} = \frac{\text{sum of all disease ratings}}{\text{Total no. of plants assessed X Maximum disease score}} \times 100$$

Disease severity scores were used to calculate the Area Under Disease Progress Curve (AUDPC) using the following formula adopted from Bharat *et al*. (2013):

$$\text{AUDPC} = \sum_{i=1}^{n-1} \frac{Y_i + Y_{i+1}}{2} \times (T_{i+1} - T_i)$$

Where:

Yi = Disease severity (percent) at i^{th} observation

Ti = Time (days) at i^{th} observation
n = Total number of observation

2. Percent defoliation: Total number of leaflets and fallen leaflets on the main stem were counted at 90 DAS. Percentage of defoliation was calculated using formula:

$$\text{Defoliation (\%)} = \frac{Number\ of\ detached\ leaflets}{\text{Total number of leaflets}} \text{ x } 100$$

Table 2: A 9 – point late leaf spot severity scale

Description	Score	Disease severity (%)
No disease	1	0
Lesions present largely on lower leaves; no defoliation	2	1 – 5
Lesions present largely on lower leaves; very few lesions on middle leaves; defoliation of some leaflets evident on lower leaves	3	6 – 10
Lesions are present on lower and middle leaves but severe on lower leaves; defoliation of some leaflets evident on lower leaves	4	11 – 20
Leaves are present on all lower and middle; 50 % defoliation of lower leaves	5	21 – 30
Lesions severe on lower and middle leaves; lesions present on top leaves but less severe; extensive defoliation of lower leaves; defoliation of some leaflets evident on middle leaves	6	31 – 40
Lesion present on all lower leaves but less severe on top leaves; defoliation of all lower and some middle leaves	7	41 – 60
Defoliation of all lower and middle leaves; lesions severe on top leaves and some defoliation of top leaves evident	8	61 – 80
Defoliation of almost all leaves leaving bear stems; some leaflets may be present with severe leaf spots	9	81 – 100

Subrahmanyam *et al*. (1995).

3.3.1.3 Determination of the effects of late leaf spot on yield and yield parameters of groundnut in the field

The experiment was established on the 23rd June, 2016 growing season at IAR farm. The field was ploughed, harrowed and ridged at 0.75 m spacing before setting out the plots. Two hundred and fifty gram (250 g) of the seeds of each of the groundnut varieties were treated with metalaxyl 20 % + imidacloprid 20 % (Allstar®, 40 DS Jiangsu Kesheng Group Co., Ltd., China) at the rate of 10g/4kg of seeds before sowing. The seeds were sown in plots of four ridges 3 m long with 20 cm intra-row spacing. There were two unplanted ridges between the plots and 2 m alleys between plots. The experimental field was 0.12 ha. Weeds were controlled using Butachlor 50 % EC (Buta-force®, Jubaili Agrotec Ltd., Nigeria) a pre-emergence herbicide at the rate of 0.24 L/ha. Supplementary hoe weeding was done on 18th July, 2016 and 2nd August, 2016. Natural infection in the field was relied upon as the source of inoculum during the growing season.

The experiment consisted of factorial combination of five varieties (SAMNUT 18, 21, 22, 23 and 25) and two fungicide spray regimes (sprayed and unsprayed) making a total of ten treatments. The treatments were laid out in a Randomized Complete Block Design (RCBD) and replicated three times.

At maturity, the plants were harvested using hoe and turned topside down on the ridges and allowed to dry for one week after which pods for each plot were picked, bagged and taken to the laboratory.

Data collected/calculated:

1. Disease severity scores were taken weekly using the scale described in Table 2 starting at 60 days after sowing (DAS) to one week before harvest.
2. The Area Under Disease Progress Curve (AUDPC) was computed using the disease severity scores.
3. Stand count at emergence was taken at seven days after sowing (DAS)

4. Stand count at harvest taken 3 days before harvest.
5. Lesions number (total number of lesions on five randomly selected leaves)
6. Lesion size (measuring the diameter of five randomly selected lesion and the average determined) at 90 days after sowing (DAS).
7. Number of pods per plant for five selected plants
8. Pod size,
9. Seed size,
10. 100 Seed weight,
11. Haulm and Pod weight
12. Shelling percentage (SP) was calculated as: seed weight/pod weight × 100 %.

3.3.2 Experiment 2

3.3.2.1 Determination of the effect of frequency of fungicide application on severity of late leaf spot in the screenhouse

In this experiment, 35 days old seedlings of SAMNUT – 14 were inoculated with *Phaeiosariopsis personata* inoculum suspension (prepared as described above) using hand held sprayer. At 60 DAS, the plants were subjected to five different frequencies (T_1, T_2, T_3, T_4 and T_5) of fungicidal application. The frequencies represented five (5) treatments and replicated four times making a total of 20 pots. The experiment was laid out in a Completely Randomized Design (CRD). The plants were observed daily for development of symptoms.

The parameters recorded include:- Disease severity scores at 60, 80 and 90 DAS using a 1-9 scale described by Subrahmanyan *et al*. (1995) as presented in Table 2.

The disease severity was computed using the following formula as cited by Marley (2013).

Disease severity scores were used to calculate the Area Under Disease Progress Curve

(AUDPC) using the formula adopted from Bharat *et al*. (2013) as described above.

Percent defoliation: Total number of leaflets and fallen leaflets on the main stem were counted at 90 DAS. Percentage of defoliation was calculated using formula as mentioned above.

3.3.2.2 Determination of the effect of frequency of fungicide application on severity of late leaf spot in the field

The experiment was established during 2016 rainy season at IAR farm, the field was ploughed, harrowed and ridged at 0.75 m spacing before setting out the experimental plots. Two hundred and fifty (250 g) of each seeds of the groundnut varieties were treated with metalaxyl 20 % + imidacloprid 20 % (Allstar®, 40 DS Jiangsu Kesheng Group Co., Ltd., China) at the rate of 10 g/4kg seeds before sowing. The groundnut seeds of SAMNUT 14 variety were sown in plots of four ridges 3 m long with 20 cm intra-row spacing. Two unplanted ridges between the plots and 2 m alleys between plots. The experimental field was 0.12 ha. Supplementary hoe weeding was done on 18th July, 2016 and 2nd August, 2016.

The variety, SAMNUT – 14 which is known to be susceptible to late leaf spot (IAR Released Variety Descriptors, 2015) was subjected to five different frequencies (T_1, T_2, T_3, T_4 and T_5) of fungicidal application. The frequencies represented five (5) treatments. The treatments were laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Stand count at emergence were recorded at fourteen (14) days after sowing and also at harvest.

Funguforce® was applied using a Knapsack sprayer at the rate of 2 kg ai/ha according to manufacturer's recommendation, starting at 60 days after sowing (DAS). Five randomly selected plants in each plot were tagged and the following were recorded: number of

pods per plant, pod size, seed size, 100 seed weight, haulm and pod weight and the shelling percentage (SP) was calculated.

The lesions numbers per leaf, lesion size were taken and the percent defoliation was calculated.

3.3.2.3 Determination of Crude Protein content of Groundnut Seeds

One gram of SAMNUT – 14 seeds was placed in a digestion flask, potassium sulphate 10 g, mercuric oxide 0.7 g and sulphuric acid 20 ml were added. Heat was applied to the flask gently at an inclined angle until frothing subsides and boiled until the solution clears, then continued for another half hour. One hundred (100 ml) of paraffin was added to reduce excessive frothing. On cooling, 90 ml distilled water and 25 ml sulphide solution were added. Pumic and sodium hydroxide (NaOH) 80 ml was added to prevent 'bumping' while tilting the flask so that two layers are formed. This was connected rapidly to the condenser unit, heated and distilled ammonia collected in 50 ml boric acid indicator solution and 50 ml of the distillate was collected. On completion of distillation, the receiver (wash condenser tip) was removed and titrated against standard acid solution.

The nitrogen and crude protein contents were calculated using the following formula:

$$\text{Nitrogen content of sample (\%)} = \frac{\text{volume of acid (ml)} \times \text{normality of standard acid}}{\text{weight of sample}} \times 0.014 \times 100$$

Crude protein content (%) = nitrogen content × 6.25.

Where

0.014 and 6.25 are constants.

3.3.2.4 Determination of Chlorophyll content in groundnut leaves:

Extraction of chlorophyll: twenty – five (25) fresh leaf samples of SAMNUT – 14 were collected randomly at 90 DAS from each plot to determine the chlorophyll content. From each sample, 1 g of the fresh leaves was taken and ground using laboratory mortar and pestle, 20 ml of 80 % acetone was added to the grounded leaves. It was then centrifuged at 10000 rpm for 5 minutes. Supernatant was collected, centrifuged till the residue became colourless. Absorbance of solution was read at 645 nm and 663 nm against the solvent (acetone) blank.

Calculation of chlorophyll content: the formula adopted from Jyosthna *et al*. (2004) was used to calculate total chlorophyll, chlorophyll 'a' and chlorophyll 'b' and results were expressed as 'mg' of chlorophyll / g of fresh leave weight (mg/g).

Total chlorophyll = (20.2 x OD at 645 nm) + (8.02 x OD at 663 nm) x df

Chlorophyll 'a' = (127 x OD at 663 nm) – (2.69 x OD at 645 nm) x df

Chlorophyll 'b' = (22.9 x OD at 645 nm) – (4.68 x OD at 663 nm) x df

Where:

OD = Optical Density

df = dilution factor.

3.3.2.5 Determination of cost – benefit analysis for using different application frequencies of fungicide to manage late leaf spot of groundnut.

The cost and benefits of using different spray frequencies for the management of late leaf spot of groundnut during the 2016 cropping season was quantified. The cost of mancozeb + carbendazim was (₦1500:00) per kg. The labour cost based on the existing wage rate for unskilled labour which was one hundred Naira (₦100:00) per knapsack sprayer. Also the cost of water was twenty-five Naira (₦25:00) for twenty-five litters. The cost of fungicide, labour, water and number of spray per treatment represent the

total cost of fungicide management. At harvest, the pod yields were weighed and recorded. Groundnut (unshelled) at the prevailing market price cost ₦150 per kg. Total income was obtained by multiplying the groundnut yields per hectare by the selling price per kg. Net benefit per hectare for each treatment was derived by subtracting the total cost of plant protection from the total income (Shabozoi *et al*., 2011). Benefit over untreated control for each treatment was obtained by subtracting the income for the unsprayed from that of the sprayed plots. The cost: benefit ratio of each treatment was derived by subtracting the income of the untreated from the net income of each sprayed treatments and the products were divided by total cost of management for each treatment as described by Shabozoi *et al*. (2011).

$$\text{Cost: benefit ratio} = \frac{\text{net income treated} - \text{net income untreated}}{\text{cost of disease management}}$$

3.4 Data analysis

Data collected was subjected to analysis of variance (ANOVA) using SAS software version 9 (SAS, 2002). Means were separated using Least Significant Difference (LSD) where treatments were less than 8 and Student – Newman – Keuls (SNK) test where treatments were greater than 8 at 5 % level of significance.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of variety and fungicide spray on late leaf spot of groundnut in the screenhouse

Effect of variety and fungicide application on severity of late leaf spot and defoliation of groundnut is presented in Table 3. At 60 DAS, there was no significant difference ($P \geq 0.05$) in disease severity for the five varieties evaluated. Disease severity was significantly different ($P \leq 0.05$) on the varieties at 80 and 90 DAS. At 80 DAS, disease severity in SAMNUT 18, 25 and 23 were not different from each other but were significantly ($P \geq 0.05$) higher compared with SAMNUT 22 and 21. At 90 DAS, highest disease severity was obtained in SAMNUT 25 (30.09 %) which was statistically similar to SAMNUT 23 and 18. SAMNUT 21 and 22 had the least severity and were statistically similar.

SAMNUT 25 had the highest percent defoliation (33.44 %), which was significantly different from all other varieties. The least defoliation was obtained on SAMNUT 21 which was statistically similar to those of SAMNUT 18, 22 and 23.

At 60 DAS, there were no significant differences in disease severity in sprayed and unsprayed plots. Disease severity at 80 and 90 DAS and percent defoliation varied significantly with the unsprayed plants having higher values for all the parameters. At 90 DAS, disease severity and percent defoliation were reduced by 14.78 % and 56.66 % respectively on application of fungicide. The interaction of variety × fungicide was not significant at 60 DAS but highly significant at 80 and 90 DAS for disease severity and percent defoliation.

Table 3: Effect of variety and fungicide application on late leaf spot severity and percent defoliation of groundnut varieties in the screenhouse, 2016

Treatment	Disease severity (%) at			Defoliation (%)
	60 DAS	80 DAS	90 DAS	at 90 DAS
Variety				
SAMNUT 18	11.11	20.83[a]	26.55[ab]	22.86[b]
SAMNUT 21	11.11	17.13[b]	22.14[b]	19.83[b]
SAMNUT 22	11.11	16.67[b]	22.84[b]	22.94[b]
SAMNUT 23	11.11	20.37[a]	26.59[ab]	24.72[b]
SAMNUT 25	11.11	20.83[a]	30.09[a]	33.44[a]
SE±	0.00	0.46	1.63	1.54
Fungicide				
Sprayed	11.11	17.59[b]	23.29[b]	15.09[b]
Unsprayed	11.11	20.74[a]	27.33[a]	34.82[a]
SE±	0.00	0.29	1.03	0.97
Interaction				
Variety × fungicide	NS	**	**	**

Means with the same superscript in a column for a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.

[1]DAS = days after sowing

NS = Not significant

** = significant at 1 %

Table 4 shows the interaction effect of variety and fungicide application on late leaf spot disease severity and defoliation of groundnut in the screenhouse. At 80 DAS, disease severity in SAMNUT 18, 23 and 25 did not significantly differ from each other but were significantly high ($P \geq 0.05$) compared with SAMNUT 21 and 22 for both the unsprayed and sprayed treatments. At 90 DAS, highest severity was recorded in SAMNUT 25 unsprayed followed by SAMNUT 18 and 25 which were statistically similar. The least severity was observed in SAMNUT 21 which was similar to SAMNUT 22 but significantly lower ($P \geq 0.05$) compared with the other varieties. There was no significant difference among the sprayed treatment. Highest percent defoliation was observed in SAMNUT 25 unsprayed and this was significantly higher ($P \geq 0.05$) compared with the other varieties. SAMNUT 25 sprayed recorded the highest percent defoliation but did not differ significantly from SAMNUT 18. SAMNUT 21 sprayed recorded the lowest percent defoliation which did not differ significantly from those of SAMNUT 22 and 23.

Figure 1 shows the disease progression over time in the screen house. SAMNUT 25 recorded the highest Area Under Disease Progress Curve (434.22), followed by SAMNUT 18 and 23 which recorded 409.50 and 406.5 respectively. SAMNUT 22 had the least Area Under Disease Progress Curve (352.67) followed by SAMNUT 21 (354.29). Table 5 shows the correlation between disease severity and percent defoliation. Disease severity at 80 and 90 DAS correlated positively and highly significant $p \leq 0.01$ with percent defoliation.

Table 4: Interaction of variety and fungicide application on late leaf spot disease severity and defoliation of groundnut in the screenhouse, 2016

	Disease severity (%) at:					
	80 DAS		90 DAS		Defoliation (%) at 90 DAS	
Variety	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed
SAMNUT 18	22.22[a]	19.44[a]	29.96[ab]	23.15[a]	30.86[b]	16.43[ab]
SAMNUT 21	18.52[b]	15.74[b]	22.95[c]	21.34[a]	30.24[b]	9.43[b]
SAMNUT 22	18.52[b]	14.82[b]	24.62[bc]	21.05[a]	33.55[b]	12.33[b]
SAMNUT 23	22.22[a]	18.52[a]	28.34[ab]	24.83[a]	34.56[b]	14.88[b]
SAMNUT 25	22.22[a]	19.44[a]	34.06[a]	26.11[a]	44.89[a]	21.98[a]
SE±	0.65		2.30		2.18	

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.
DAS = Days after sowing

Table 5: Correlation between disease severity and percent defoliation of groundnut in the screenhouse

	DS 80 DAS	DS 90 DAS	Defoliation (%)
DS 80 DAS	1.00		
DS 90 DAS	0.67**	1.00	
Defoliation (%)	0.71**	0.67**	1.00

** = significant at 1 %,
DS = Disease severity
DAS = Days after sowing.

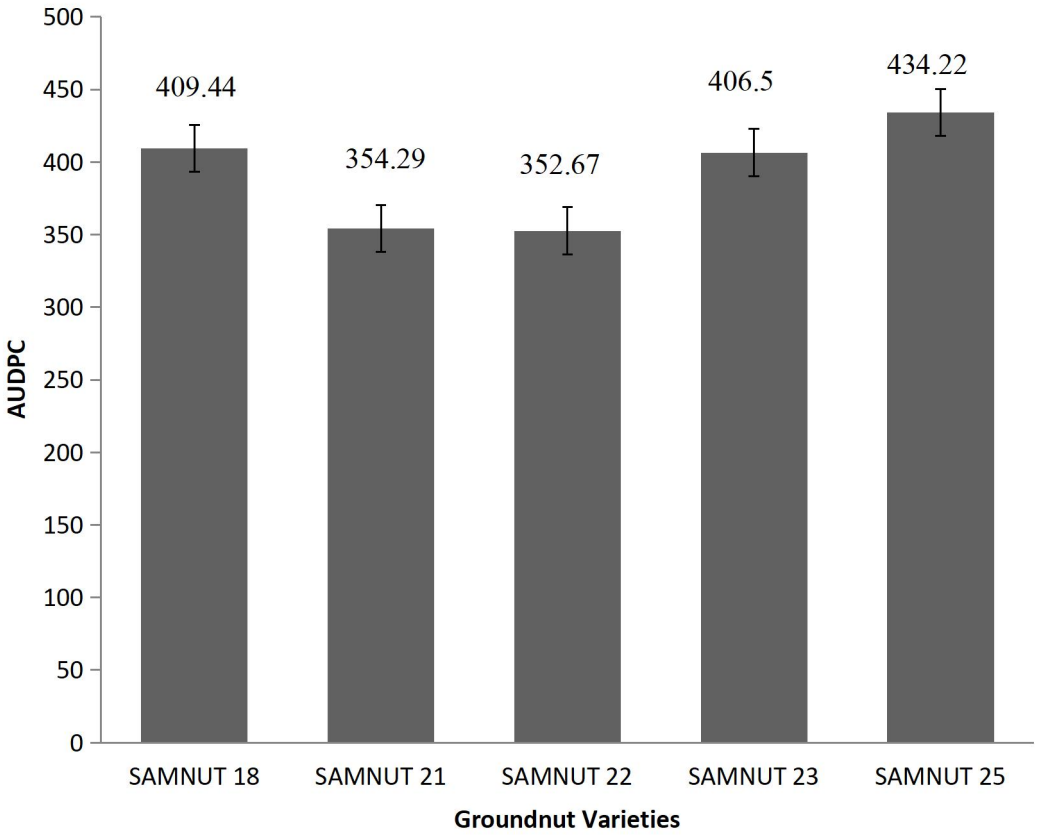

Figure 1: Cumulative Area under disease progress for five groundnut varieties in the screenhouse.

AUDPC = Area under disease progress curve.

The effect of spray frequency of mancozeb + carbendazim on severity of late leaf spot and defoliation is presented in Table 6. There was no significant difference in disease severity at 60 DAS for all the varieties. At 80 DAS, the significantly highest severity (22.22 %) was recorded for the unsprayed plot (T_5) followed by plants sprayed every three (T_3) and every four (T_4) weeks which were statistically similar. Plants sprayed biweekly (T_2) had lower severity (16.67 %) which was significantly higher than those plants sprayed weekly (T_1) which had the least severity (13.89 %). At 90 DAS, the highest severity (38.89 %) was also recorded for the unsprayed plants which were significantly higher than those sprayed at varying frequencies. The least severity was recorded in plants sprayed weekly (17.88 %) which did not differ from those sprayed biweekly. The highest percent defoliation (41.59 %) was recorded for the unsprayed plants which was statistically similar to plants sprayed every four weeks, plants sprayed every three weeks had percent defoliation (25.33 %) higher than those for plants sprayed biweekly, the least percent defoliation (2.10 %) was recorded on plants sprayed weekly.

The result in Figure 2 shows the area under disease progress curve (AUDPC) for plants subjected to different spray frequencies. The unsprayed plots (T_5) had the highest Area Under Disease Progress Curve (505.56), followed by plants sprayed every four weeks, every three weeks and biweekly, the least disease progression was observed in plants sprayed weekly (300.16).

Plates I to V show the different disease levels in plants subjected to the five different spraying frequencies in the screenhouse.

Table 6: Effect of spray frequency of mancozeb + carbendazim on severity of late leaf spot and percent defoliation of groundnut in the screenhouse

Frequency of fungicide application	Disease severity (%) at:			Defoliation (%)
	60 DAS	80 DAS	90 DAS	at 90 DAS
T_1	11.11	13.89^{d}	17.88^{d}	2.10^{d}
T_2	11.11	16.67^{c}	19.44^{cd}	8.30^{c}
T_3	11.11	19.44^{b}	22.22^{c}	25.33^{b}
T_4	11.11	20.37^{b}	24.89^{b}	36.66^{a}
T^5	11.11	22.22^{a}	38.89^{a}	41.59^{a}
SE±	0.00	0.42	1.36	1.77

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Least Significant Difference (SLD).

T_1 = Plants sprayed weekly, T_2 = Plants sprayed biweekly, T_3 = Plants sprayed every 3 weeks, T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

DAS = Days after sowing

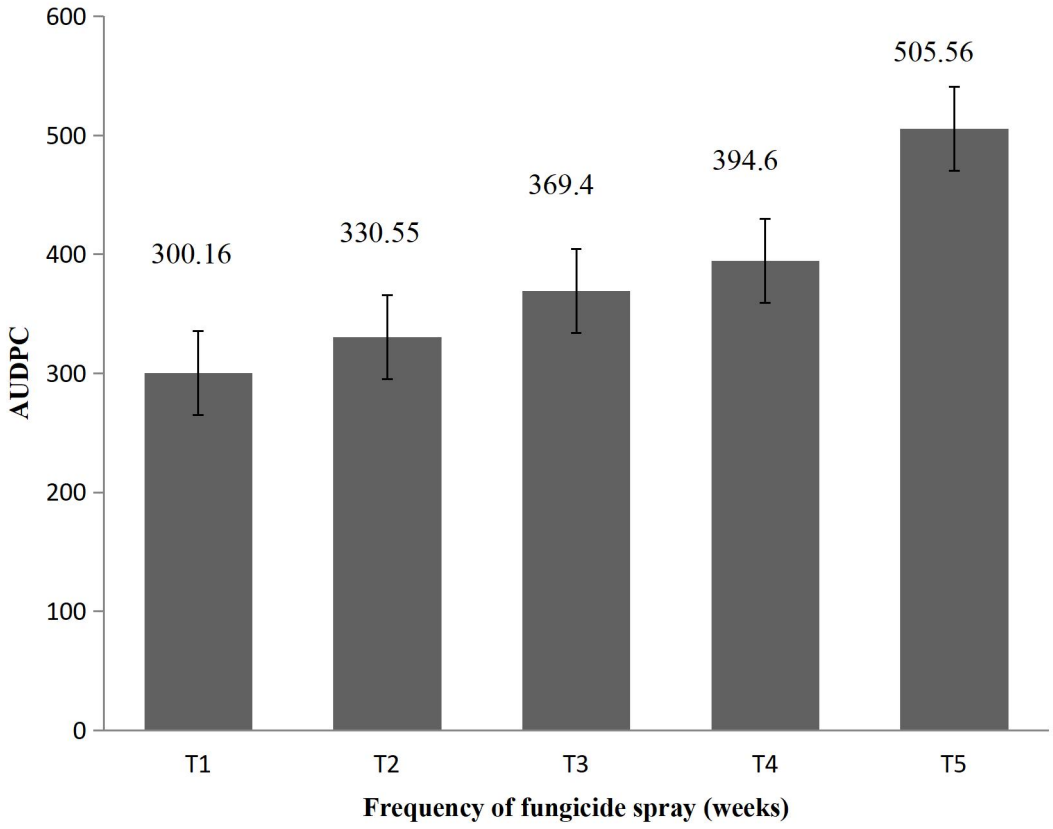

Figure 2: Cumulative Area under disease progress curve for varying fungicide spray frequency in the Screenhouse.

T_1 = Plants sprayed weekly; T_2 = Plants sprayed biweekly; T_3 = Plants sprayed every 3 weeks; T_4 = Plants sprayed every 4 week, T_5 = Unsprayed plants.

AUDPC = Area under disease progress curve.

Plate I: Plant sprayed weekly (T_1)

Plate II: Plant sprayed biweekly (T_2)

Plate III: Plant sprayed every three weeks (T_3)

Plate IV: Plant sprayed every four weeks (T_4)

Plate V: Unsprayed Plant (T_5)

4.1.2 Effects of variety and fungicide application on severity of late leaf spot, yield and yield parameters of groundnut under field condition

Table 7 shows the effect of variety and fungicide application on severity of late leaf spot, yield and some yield parameters of groundnut. Disease severity at 98 DAS was significantly higher ($P \geq 0.05$) in SAMNUT 25 compared with the other varieties. There was no significant difference in severity of late leaf spot on SAMNUT 18 and 23, but these were significantly higher ($P \geq 0.05$) compared with those of SAMNUT 21 and 22 which had the lowest severity. SAMNUT 25 had the highest stand count at emergence followed by SAMNUT 18, SAMNUT 22 and 23 which did not differ significantly and were higher than that of SAMNUT 21 which had the least number of stand count at emergence. SAMNUT 18 and 25 had the highest stand count at harvest which was statistically similar while SAMNUT 21, 22 and 23 had lower stand count at harvest and did not differ significantly from each other.

Stand count at emergence and at harvest did not significantly vary with spray and no spray of fungicide.

SAMNUT 21 and 22 had the highest pod yield followed by SAMNUT 25 which was statistically higher than that of SAMNUT 18 and 23 which did not vary significantly. SAMNUT 22 had significantly highest haulm yield followed by SAMNUT 21, 23 and 25 which did not statistically differ from each other. SAMNUT 18 had the lowest haulm

yield. Pod and haulm yields were significantly higher in sprayed plots than on unsprayed plots. The variety × fungicide interaction was not significant for both stand count at emergence and at harvest, but was significant for 98 DAS disease severity, pod and haulm yields (Table 7).

Table 7: Effect of variety and fungicide application on severity of late leaf spot, yield and some yield parameters of groundnut in the field in 2016

Treatment	Disease Severity % at 98 DAS	Stand count at emergence	Stand count at harvest	Pod yield (Kg/ha)	Haulm yield (Kg/ha)
Variety					
SAMNUT 18	66.49^{b}	47.00^{ab}	46.50^{a}	527.78^{c}	3314.80^{c}
SAMNUT 21	49.81^{c}	37.17^{c}	38.50^{b}	972.22^{a}	5222.20^{b}
SAMNUT 22	46.37^{c}	43.50^{b}	42.17^{b}	944.44^{a}	6490.70^{a}
SAMNUT 23	62.37^{b}	43.50^{b}	42.00^{b}	537.04^{c}	4842.60^{b}
SAMNUT 25	79.17^{a}	49.33^{a}	47.50^{a}	731.48^{b}	4370.40^{b}
SE±	2.44	1.45	1.25	53.23	260.57
Fungicide					
Sprayed	51.23^{b}	43.87	42.33	811.11^{a}	5325.90^{a}
Unsprayed	70.46^{a}	44.33	44.33	674.07^{b}	4370.40^{b}
SE±	1.55	0.91	0.79	33.66	164.80
Interaction					
Variety × fungicide	*	NS	NS	*	*

Means with the same superscript in a column of a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.
NS = Not significant

* = significant at 5 %

Table 8 shows the interaction of varieties and fungicide spray on disease severity and yield of groundnut. In the sprayed plots, SAMNUT 25 had the highest severity which was statistically higher than that of SAMNUT 18 followed by SAMNUT 23, the least severity were recorded on SAMNUT 21 and 22. SAMNUT 25 unsprayed had the highest severity; followed by SAMNUT 18 and 23 which were statistically similar; the least severity was observed in SAMNUT 21 and 22. Pod yield were highest for SAMNUT 21 and 22 sprayed which were statistically similar and the least was observed in SAMNUT 23 which did not differ significantly with that of SAMNUT 18 and 25. SAMNUT 21 and 22 unsprayed also recorded the highest pod yield, followed by SAMNUT 25 and 23; SAMNUT 18 recorded the lowest pod yield. Haulm yield varied significantly among the sprayed plots. SAMNUT 22 recorded the highest, followed by SAMNUT 21, 23 and 25 which were statistically similar; the lowest haulm yield was observed in SAMNUT 18. Among the unsprayed plots, SAMNUT 22 recorded the highest haulm yield and the least was recorded in SAMNUT 18.

Figure 3 shows the disease severity of late leaf spot in five groundnut varieties under field condition at Samaru during the 2016 cropping season. The severity of late leaf spot of groundnut varied among the varieties at varying assessment time. At 56 and 63 DAS, there were no significant differences among all the groundnut varieties with regards to severity of late leaf spot. At 70 and 77 DAS, SAMNUT 21 and 22 had similar trend and recorded lower disease severities. SAMNUT 25 had the highest severity compared with

the other varieties. At 98 DAS, the graphs show distinct differences among the varieties in terms of severities with SAMNUT 21 and 22 having the least followed SAMNUT 23 and 18, the highest disease severity was recorded in SAMNUT 25.

Table 8: Interaction between variety and fungicide application on disease severity of late leaf spot, pod and haulm yield of groundnut in the field, 2016

Variety	Disease severity % at 98 (DAS)		Pod yield (kg/ha)		Haulm yield (kg/ha)	
	Sprayed	Unsprayed	Sprayed	Unsprayed	Sprayed	Unsprayed
SAMNUT 18	57.3^{b}	75.7^{b}	611.11^{c}	444.44^{c}	3703.70^{c}	2925.92^{c}
SAMNUT 21	41.4^{c}	58.3^{c}	1074.08^{a}	870.37^{a}	5351.85^{b}	5092.59^{ab}
SAMNUT 22	39.5^{c}	53.3^{c}	1037.04^{a}	851.85^{a}	7425.93^{a}	5555.56^{a}
SAMNUT 23	48.5^{bc}	76.2^{b}	555.56^{b}	518.52^{b}	5259.26^{b}	4425.93^{b}
SAMNUT 25	69.4^{a}	88.9^{a}	777.78^{b}	685.19^{ab}	4888.87^{b}	3831.85^{bc}
SE±	3.46		75.27		368.50	

Means with the same superscript in a column are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.
DAS = Days after sowing

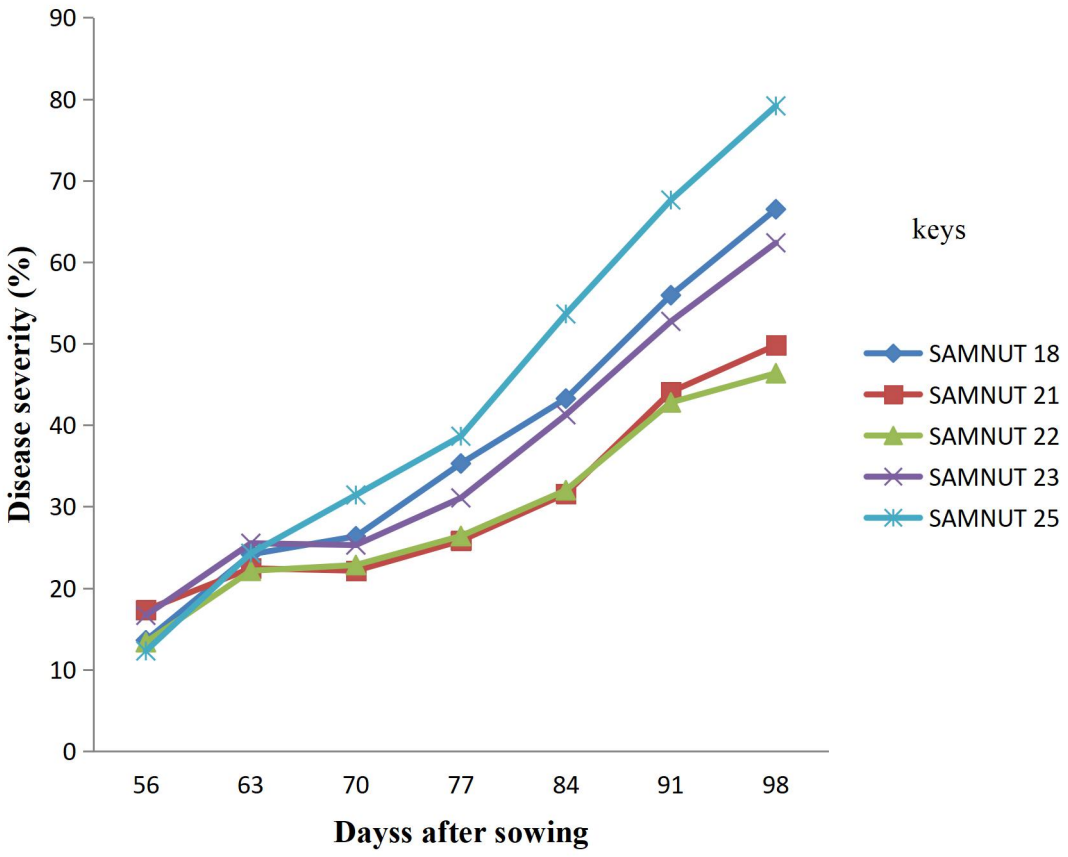

Figure 3: Disease severity of late leaf spot in five groundnut varieties under field condition at Samaru during the 2016 cropping season.

Table 9 shows the effect of variety and fungicide application on some yield parameters of groundnut in Samaru, Zaria during the 2016 cropping season. Pod size did not differ significantly in all the treatments. SAMNUT 21 recorded statistically the highest seed size followed by SAMNUT 22 which was statistically higher than that of SAMNUT 25 and 23. SAMNUT 18 had the lowest seed size which was not significantly different from SAMNUT 23. There was no significant difference in 100 seed weight across all the groundnut varieties except SAMNUT 18 which was the least. SAMNUT 25 had the highest shelling percentage and did not differ statistically with SAMNUT 18, 22 and 21; SAMNUT 23 had the least shelling percentage.

With respect to fungicide application, pod size, 100 seeds weight and shelling percentage did not differ significantly between the sprayed and unsprayed treatments. Seed size was significantly higher in fungicide sprayed and unsprayed. The variety × fungicide interaction were not significant in pod size, 100 seed weight and shelling percentage but was significant for seed size (Table 9).

The interaction of variety and fungicide on seed size is presented in Table 10. SAMNUT 21 had significantly the higher ($P \geq 0.05$) seed size in the sprayed plots, followed by SAMNUT 22. The least seed size was observed in SAMNUT 18 and this did not differ significantly from SAMNUT 23 and 25. SAMNUT 21 in the unsprayed plots recorded the highest seed size which was statistically similar to that of SAMNUT 22 while the least seed size was recorded in SAMNUT 18 which did not differ significantly with that of SAMNUT 23 and 25.

Table 9: Effect of variety and fungicide application on some yield parameters of groundnut in Samaru, Zaria during the 2016 cropping season

Treatment	Pod size (cm)	Seed size (cm)	100 seed weight (g)	Shelling percentage (%)
Variety				
SAMNUT 18	2.57[a]	1.16[d]	38.70[b]	74.60[a]
SAMNUT 21	2.85[a]	1.59[a]	46.39[a]	69.98[a]
SAMNUT 22	2.86[a]	1.47[b]	46.39[a]	71.72[a]
SAMNUT 23	2.81[a]	1.23[cd]	45.08[a]	59.75[b]
SAMNUT 25	2.78[a]	1.30[c]	49.31[a]	75.05[a]
SE±	0.09	0.04	1.69	2.30
Fungicide				
Sprayed	2.82[a]	1.39[a]	45.59[a]	70.97[a]
Unsprayed	2.73[a]	1.31[b]	44.61[a]	69.46[a]
SE±	0.06	0.02	1.07	1.46
Interaction				
Variety × fungicide	NS	*	NS	NS

Means with the same superscript in a column of a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test
NS = Not significant

* = significant 5 %

Table 10: Interaction of variety × fungicide application on seed size of groundnut at Samaru, 2016

Variety	Seed size (cm)	
	Sprayed	Unsprayed
SAMNUT 18	1.2[c]	1.1[b]
SAMNUT 21	1.7[a]	1.5[a]
SAMNUT 22	1.5[b]	1.4[a]
SAMNUT 23	1.3[c]	1.2[b]
SAMNUT 25	1.3[c]	1.2[b]
SE±		0.06

Means with the same superscript in a column of a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.

Table 11 shows the effect of variety and fungicide application on late leaf spot parameters and number of pods per plant. Number of lesions varied significantly in all the five groundnut varieties evaluated. SAMNUT 25 had the highest number of lesions followed by SAMNUT 23 which did not differ statistically with SAMNUT 18 but were significantly higher than that of SAMNUT 21. SAMNUT 22 recorded the least number of lesions. SAMNUT 18 and 25 recorded the largest lesion size and did not differ significantly followed by SAMNUT 21 and 23 which were statistically similar. SAMNUT 22 recorded the lowest lesion diameter of 1.43.

SAMNUT 25 had the highest percent defoliation (44.77 %) which was statistically similar to that of SAMNUT 18 and 23. SAMNUT 21 and 22 recorded the lowest percent defoliation and were statistically similar. Number of pods per plant did not differ significantly in all the five groundnut varieties evaluated.

Number of lesions, lesion size, percent defoliation and number of pods per plant varied significantly with fungicide treatment. The sprayed plants had the highest number of pods per plant and lesion diameter compared to the unsprayed plants. The unsprayed plants had the highest number of lesions and percent defoliation compared to the sprayed plants. The variety × fungicide interactions were significant for pod number per plant and were highly significant for number of lesion, lesion size and percent defoliation.

Table 11: Effect of variety and fungicide application on lesion number, lesion size, percent defoliation and number of pods per plant on groundnut grown in Samaru, Zaria during the 2016 cropping season

Treatment	Lesion number	Lesion size (cm)	Defoliation (%)	Pod number/ Plant
Variety				
SAMNUT 18	16.93^{bc}	2.93^{a}	45.19^{a}	25.50^{a}
SAMNUT 21	16.23^{c}	2.11^{b}	32.93^{b}	28.00^{a}
SAMNUT 22	11.23^{d}	1.43^{c}	35.35^{b}	25.17^{a}
SAMNUT 23	18.43^{b}	1.93^{b}	44.45^{a}	24.00^{a}
SAMNUT 25	32.97^{a}	2.77^{a}	44.77^{a}	28.83^{a}
SE±	0.54	0.10	1.50	1.85
Fungicide				
Sprayed	11.87^{b}	2.49^{a}	26.08^{b}	28.73^{a}
Unsprayed	26.45^{a}	1.97^{b}	54.99^{a}	23.87^{b}
SE±	0.34	0.06	0.95	1.17
Interaction				
Variety × fungicide	**	**	**	*

Means with the same superscript in a column of a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test
** = significant 1 %
* = significant 5 %

The interaction of variety and fungicide application on late leaf spot parameters and number of pod per plant is presented in Table 12. The highest lesion number was recorded in SAMNUT 25 sprayed whereas SAMNUT 21 had the least number of lesions. SAMNUT 25 unsprayed recorded the highest number of lesions while the least was observed in SAMNUT 22. Lesion size was highest in SAMNUT 25 sprayed which was statistically similar to that of SAMNUT 18, followed by SAMNUT 21 and 23 which did not also differ significantly. The least lesion size was recorded in SAMNUT 22 sprayed. SAMNUT 18 unsprayed recorded the highest lesion size, followed by SAMNUT 25, the least was observed in SAMNUT 22 which was statistically similar to that of SAMNUT 21 and 23. Percent defoliation among the sprayed plants was highest in SAMNUT 18, followed by SAMNUT 23 and 25, the least was observed in SAMNUT 21. SAMNUT 25 unsprayed recorded the highest percent defoliation which did not differ significantly with SAMNUT 18 and 23, SAMNUT 21 recorded the lowest and was statistically similar to that of SAMNUT 22. Pod number per plant did not vary significantly in both sprayed and unsprayed plots.

The cumulative Area Under Disease Progress Curve is presented in Figure 4. The calculated values of disease progression over time varied significantly among the groundnut varieties evaluated. SAMNUT 25 recorded the highest area under disease progress curve (2147.12) followed by SAMNUT 18, 23 and 21. The least area under disease progress curve was observed in SAMNUT 22 (1441.43).

Table 12: Interaction of variety and fungicide application on lesion number, lesion size, percent defoliation and number of pods per plant of groundnut at Samaru, Zaria

Variety	Lesion Number		Lesion size (cm)		Defoliation (%)		Pods number/ Plant	
	S	US	S	US	S	US	S	US
SAMNUT 18	13.3^{ab}	20.6^{d}	3.1^{a}	2.8^{a}	30.5^{a}	59.8^{a}	26.0	25.0
SAMNUT 21	7.3^{d}	25.2^{b}	2.5^{b}	1.7^{c}	20.0^{c}	45.8^{b}	31.3	24.7
SAMNUT 22	10.3^{c}	12.1^{e}	1.5^{c}	1.4^{c}	23.2^{b}	47.5^{b}	26.0	24.3
SAMNUT 23	12.9^{b}	23.9^{b}	2.3^{b}	1.5^{c}	28.8^{ab}	60.1^{a}	28.7	19.3
SAMNUT 25	15.5^{a}	50.4^{a}	3.4^{a}	2.2^{b}	27.8^{ab}	61.7^{a}	31.7	26.0
SE±	0.76		0.14		2.12		2.61	

Means with the same superscript in a column of a set are not significantly different at 5 % level of significance ($P \leq 0.05$) using Student – Newman – Keuls (SNK) Test.

S = Sprayed

US = Unsprayed

Table 13 shows the correlation between disease severities at various assessment periods, percent defoliation, pod and haulm yields recorded on the field. Disease severities correlated positively and highly significant across all the weeks evaluated. There was positively and highly significant correlation between percent defoliation and disease severities at 63, 70, 77, 84, 91 and 98 DAS. Percent defoliation correlated negatively and highly significant with pod yield (-0.55) and haulm yield (-0.57).

Lesion size and lesion number correlated positively and highly significant with disease severities across all the weeks evaluated. Lesion size and number also correlated positively and highly significant with percent defoliation but were negatively and highly correlated with pod and haulm yields. Pod and haulm yields also correlated negatively and highly significant with disease severities across all the weeks evaluated. Pod yield recorded positively and highly significant correlation (+0.70**) with haulm yield.

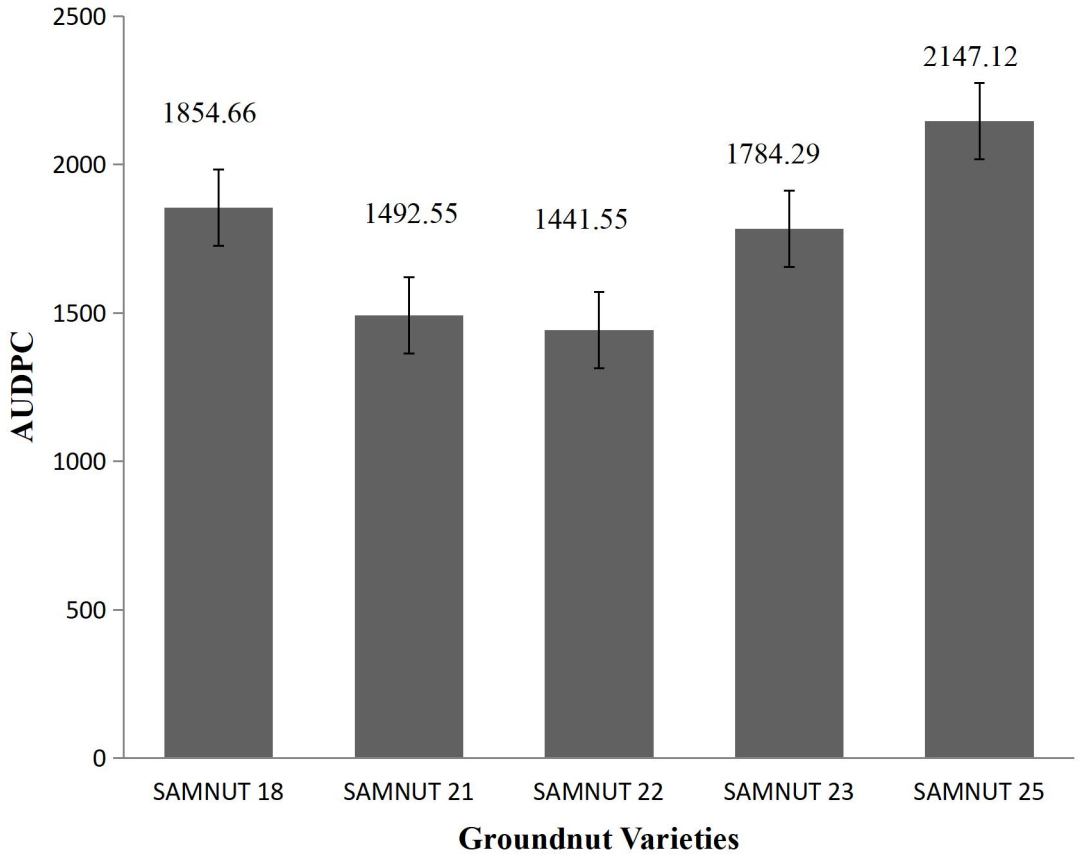

Figure 4: Cumulative area under disease progress curve for five groundnut varieties in the field.

AUDPC = Area under disease progress curve.

Table 13: Correlation between disease severity, percent defoliation, lesion size, lesion number, pod and haulm yields under natural condition

	DS63D	DS70D	DS77D	DS84D	DS91D	DS98D	PD	LS	LN	PY	HY
DS63D	1.00										
DS70D	0.36*	1.00									
DS77D	0.59**	0.86**	1.00								
DS84D	0.53**	0.88**	0.94**	1.00							
DS91D	0.45**	0.85**	0.88**	0.96**	1.00						
DS98D	0.51**	0.76**	0.82**	0.89**	0.90**	1.00					
PD	0.56**	0.61**	0.61**	0.68**	0.69**	0.77**	1.00				
LS	0.52*	0.74*	0.78*	0.81*	0.84**	0.87**	0.92**	1.00			
LN	0.47*	0.54*	0.62*	0.65**	0.71**	0.78**	0.82**	-0.88**	1.00		
PY	-0.40*	-0.39*	-0.40**	-0.43**	-0.38*	-0.53**	-0.55**	-0.58**	-0.61**	1.00	
HY	-0.37*	-0.46**	-0.51**	-0.51**	-0.52**	-0.64**	-0.57**	-0.61**	-0.72**	0.70**	1.00

DS = Disease severity, PD = Percent defoliation, PY = Pod yield/ha and HY = Haulm yield/ha, LS = Lesion size, LN = Lesion number
* = significant at 5 %

** = significant at 1 %

D = Days after sowing.

4.2 Effect of fungicide application frequency on late leaf spot severity

Table 14 shows effect of fungicide application frequency on stand count and yields of SAMNUT 14, 2016. The unsprayed plants (T_5) had the highest stand count at emergence (48.67) which was statistically similar to plants sprayed biweekly (48. 33) and every four weeks (46.00); plants sprayed every three weeks recorded the least, but did not significantly differ from weekly and four weeks spray intervals.

Plants sprayed biweekly recorded the highest stand count at harvest (47.33), followed by unsprayed plants which recorded 46.67 and did not differ significantly with the other treatments sprayed weekly and every four weeks. Plants sprayed every three weeks had the lowest stand count (40.67) at harvest.

The highest pod yield was obtained on plants sprayed weekly which were statistically similar to plants sprayed biweekly and was significantly higher than those sprayed every three and four weeks. Unsprayed plants and plants sprayed every four weeks recorded the lowest yield and were statistically similar. The haulm yields did not differ significantly across all the treatments but plants sprayed weekly (5759.30 kg/ha) recorded the highest haulm yield.

Table 15 shows the effect of fungicide frequency on agronomic traits of groundnut. Plants sprayed weekly produced largest pod size which did not statistically differ from those plants sprayed biweekly but were significantly larger than those sprayed every three and four weeks. Unsprayed plants produced least pod size though it did not differ statistically from those sprayed every four weeks.

Table 14: Effect of fungicide application frequency on stand count and yields of SAMNUT 14 at Samaru, 2016

Frequency of fungicide application	Stand count at emergence	Stand count at harvest	Pod yield (kg/ha)	Haulm yield (kg/ha)
T_1	46.67^{ab}	46.33^{abc}	888.90^{a}	5759.30^{a}
T_2	48.33^{a}	47.33^{a}	851.90^{ab}	5611.10^{a}
T_3	44.00^{b}	40.67^{c}	574.10^{bc}	5055.60^{a}
T_4	46.00^{ab}	41.00^{bc}	463.00^{c}	4481.50^{a}
T_5	48.67^{a}	46.67^{ab}	444.40^{c}	4237.00^{a}
SE±	1.24	1.81	86.96	527.63

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

T_1 =Plants sprayed weekly, T_2 =Plants sprayed biweekly, T_3 = Plants sprayed every 3 weeks, T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

The seed size, 100 seed weight and shelling percentage varied significantly among the spray frequencies (Table 15). Plants sprayed weekly and biweekly had the largest seed size and were significantly higher than seed size of plants sprayed every three and four weeks. The unsprayed plants had the least seed size. Plants sprayed weekly recorded the highest seed weight, followed by plants sprayed biweekly; plants sprayed every three weeks recorded low seed weight which did not differ significantly from those sprayed every four weeks, unsprayed plants (T_5) recorded the least seed weight. Shelling percentage follows similar trend with seed size.

Table 16 shows the effect of fungicide application frequency on pod and seed size, seed weight and shelling percentage of groundnut. Disease severity at 98 DAS was highest in unsprayed plants; followed by plants sprayed every three and four weeks which were statistically similar and recorded 68.99 % and 75.99 % respectively. Plants sprayed biweekly recorded 56.41 % which was higher than those sprayed weekly that recorded the least severity of 33.33 %. The unsprayed plants had the highest lesion number which was not significantly different from those sprayed every four weeks, but significantly higher ($p \geq 0.05$) than plants sprayed every three, two and one weeks respectively, which were significantly different from each other (Table 16). The biggest lesion size was recorded in plants sprayed weekly (7.63) which was statistically higher than those sprayed biweekly, every three and four weeks which were all statistically similar. Unsprayed plants had the lowest lesion size. Percent defoliation differed significantly across all the spray frequencies. Plants sprayed weekly had lowest percent defoliation, followed by those sprayed biweekly, every three and four weeks. The highest percent defoliation was observed in unsprayed plants. Plants sprayed weekly produced the highest pod number which was statistically

similar to those sprayed biweekly followed by plants sprayed every three and four weeks, the least pod number was recorded for unsprayed plants. (Table 16). Plates VI to X show the different disease levels of plants subjected to the five different spray frequencies in the field.

Table 15: Effect of fungicide application frequency on pod and seed size, seed weight and shelling percentage of groundnut

Frequency of fungicide application	Pod size (cm)	Seed size (cm)	100 seed Weight (g)	Shelling percentage (%)
T_1	2.58[a]	1.29[a]	42.07[a]	77.62[a]
T_2	2.45[ab]	1.26[a]	39.36[b]	77.13[a]
T_3	2.39[b]	1.14[b]	38.76[bc]	76.81[b]
T_4	2.31[bc]	1.10[bc]	36.90[bc]	76.16[bc]
T_5	2.18[c]	0.99[c]	39.47[c]	75.48[c]
SE±	0.05	0.04	0.76	0.28

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

T_1 = Plants sprayed weekly, T_2 = Plants sprayed biweekly, T_3 = Plants sprayed every 3 weeks, T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants

Table 16: Effect of fungicide application frequency on late leaf spot severity, lesion number, lesion size, percent defoliation and pod number per plant at Samaru, 2016

Frequency of fungicide application	Disease severity (%) at 98 DAS	Lesion (no./plant)	Lesion size (cm)	Defoliation (%)	Pod (no./plant)
T_1	33.33^{d}	1.60^{d}	7.63^{a}	6.96^{e}	33.33^{a}
T_2	56.41^{c}	10.60^{c}	3.51^{b}	14.78^{d}	30.33^{ab}
T_3	68.99^{b}	17.60^{b}	3.18^{b}	31.64^{c}	26.67^{bc}
T_4	75.99^{b}	34.60^{a}	2.91^{b}	41.81^{b}	25.00^{bc}
T_5	87.04^{a}	37.00^{a}	1.97^{c}	49.26^{a}	21.33^{c}
SE±	2.65	0.79	0.23	2.10	1.99

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

T_1 = Plants sprayed weekly; T_2 = Plants sprayed biweekly; T_3 = Plants sprayed every 3 weeks; T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

DAS = Days after sowing.

Plate VI: Plot sprayed weekly (T_1)

Plate VII: Plot sprayed biweekly (T_2)

Plate VIII: Plot sprayed every three weeks (T_3)

Plate IX: Plot sprayed every four weeks (T_4)

Plate X: Unsprayed plants (T_5)

Plate VI – X: Show the effect of different spray frequency on the infected plants.

The effect of frequency of fungicide application on severity of late leaf spot on groundnut is presented in Figure 5. At 56 and 70 DAS, there were no significant differences among all the treatments. At 63 DAS, unsprayed plants recorded the highest disease severity and did not differ significantly from plants sprayed every four weeks (15.19 %) while plants sprayed biweekly and every three weeks had low severity scores of 13.11 % and 13.89 % respectively. Plants sprayed weekly had the least disease severity (12.64 %) but was statistically similar to those sprayed every two weeks. At 77 DAS, unsprayed plants, plants sprayed every three and four weeks recorded the highest disease severity which did not differ significantly, while plants sprayed weekly had the lowest severity (24.67 %) and did not differ statistically with plants sprayed biweekly (27.54 %). A similar trend was observed at 84 DAS. At 91 DAS, unsprayed plants recorded the highest severity (76.49 %) which did not differ statistically from plants sprayed every four weeks (73.04 %), followed by plants sprayed every three weeks (54.03 %) and plants sprayed biweekly (38.32 %). The lowest disease severity (29.43 %) was recorded for plants sprayed weekly. At 98 DAS, plants sprayed every three and four weeks were statistically similar. All other treatment significantly varied from each other. The highest severity was recorded in unsprayed plants (87.04 %) which was significantly higher than those sprayed every four weeks (75.99 %) and those sprayed every three weeks (68.99 %) which did not differ significantly, followed by plants sprayed biweekly (56.41 %). Plants sprayed weekly had significantly the least disease severity (33.33 %).

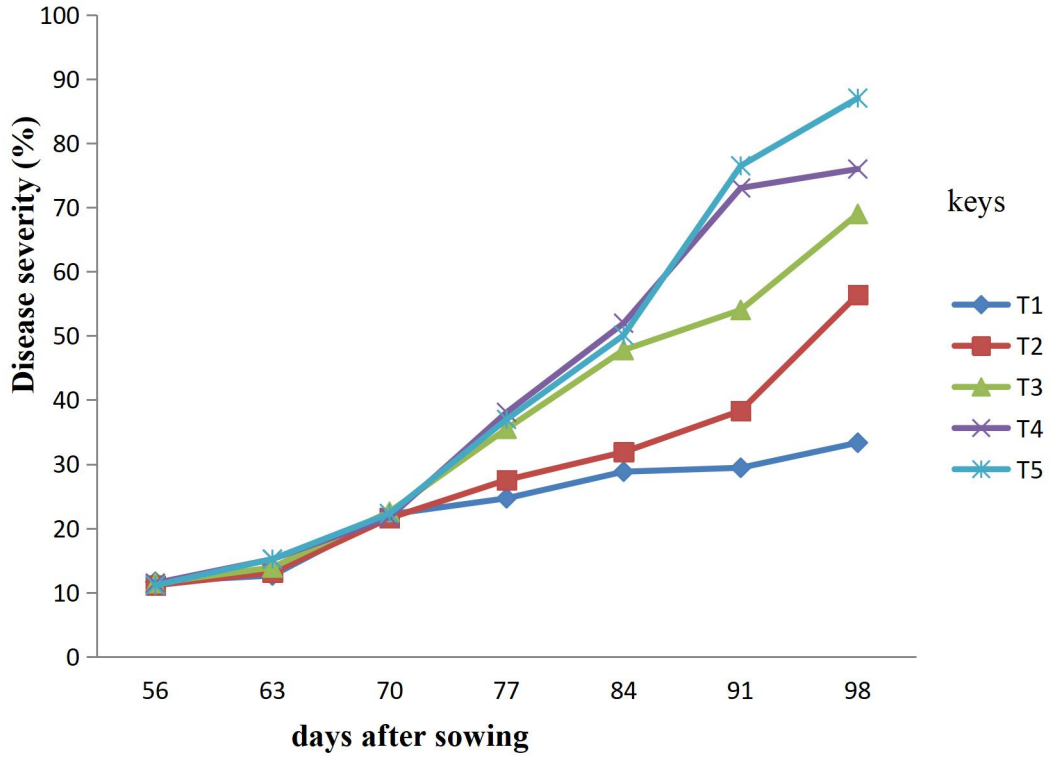

Figure 5: Effect of frequency of fungicide application on severity of late leaf spot on groundnut at Samaru, 2016.

T_1 =Plants sprayed weekly, T_2 =Plants sprayed biweekly, T_3 = Plants sprayed every 3 weeks, T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

Figure 6 shows the calculated values of Area Under Disease Progress Curve over time, under field condition. Unsprayed plants recorded the highest area under disease progress curve of (2011.88) followed by plants sprayed every four weeks (1966.58) and those sprayed every three weeks (1779.66) which was higher compared to the plants sprayed biweekly. The least estimate of Area Under Disease Progress Curve was observed in plants sprayed weekly.

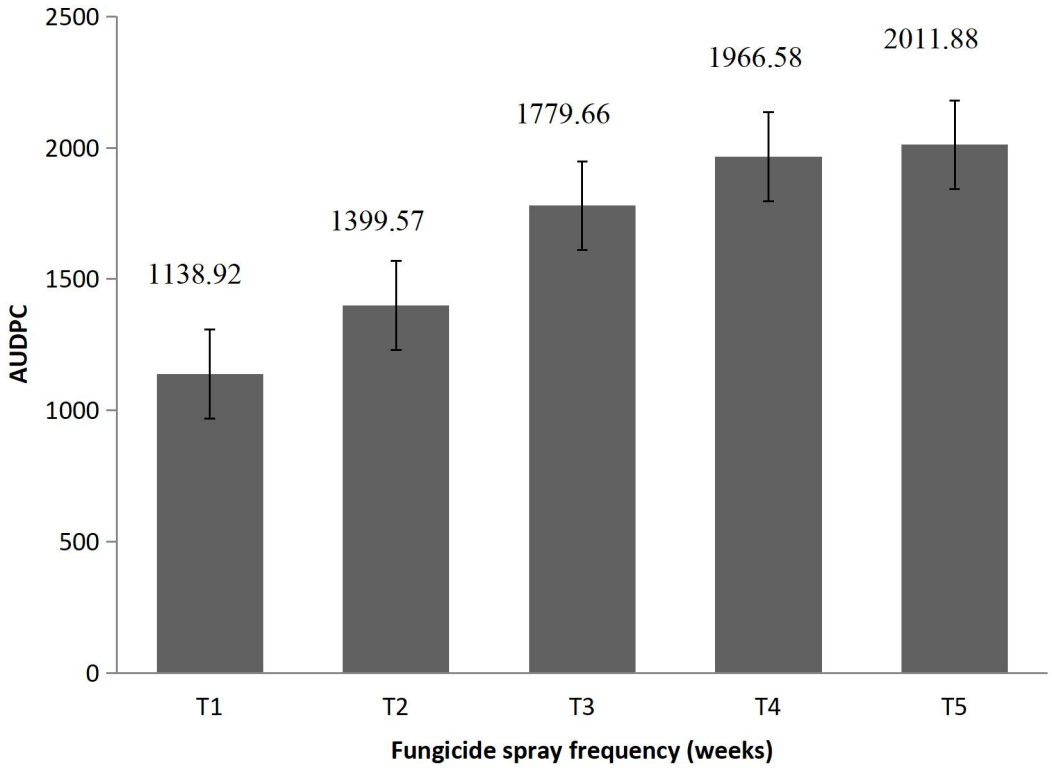

Figure 6: Cumulative area under disease progress curve for varying fungicide spray frequency in the field.

AUDPC = Area under disease progress curve.

T_1 = Plants sprayed weekly; T_2 = Plants sprayed biweekly; T_3 = Plants sprayed every 3 weeks; T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

4.2.1 Effects of Fungicide Application Frequency on Crude Protein and Chlorophyll Contents.

Table 17 shows the effect of frequency of fungicide application on crude protein and chlorophyll contents of groundnut seed and leaf. Crude protein and chlorophyll contents increased significantly with an increase in the spray frequency across all the treatments. The highest crude protein content (33.18 %) was recorded for plants sprayed weekly, followed by those sprayed biweekly, every three weeks and every four weeks with percent crude protein content of 29.92, 28.05 and 24.69 respectively. Unsprayed plants had the lowest crude protein content of 23.41 %.

The total chlorophyll content was higher in plants sprayed weekly with 1.40 mg/g. Plants sprayed biweekly (1.00 mg/g) and every three weeks (1.00 mg/g) which did not differ significantly but were statistically higher than those plants sprayed every four weeks (0.70 mg/g). The lowest chlorophyll content was observed in the unsprayed plants (0.300 mg/g). The results for chlorophyll 'a' and chlorophyll 'b' content followed the same trend.

The correlation between disease severities at 56, 63, 70, 77, 84, 91 and 98 DAS, percent defoliation, pod and haulm yields, crude protein content and chlorophyll content is shown in Table 18. Disease severity at 56 DAS, was not significantly correlated with all the other parameters evaluated. Disease severity at 77, 84, 91 and 98 DAS correlated positively and highly significant with percent defoliation. Disease severity at all assessment periods were negatively and highly significant for pod and haulm yields, crude protein content, chlorophyll 'a', 'b' and total chlorophyll content. Lesion size and lesion number correlated positively and highly significant with disease severities across all the assessment periods. On the other hand, lesion size and lesion number also correlated positively and highly

significant with percent defoliation but were negatively and highly correlated with yields, crude protein content, chlorophyll a, b and total chlorophyll. Crude protein content, chlorophyll ‘a’, ‘b’ and total chlorophyll on the other hand correlated positively and highly significant with pod and haulm yields.

Table 17: Effect of fungicide application frequency on crude protein and chlorophyll contents of groundnut seed and leaf at Samaru, 2016

Frequency of fungicide application	Crude protein Content (%)	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)	'Total' Chlorophyll (mg/g)
T_1	33.18	0.90	0.50	1.40
T_2	29.92	0.60	0.40	1.00
T_3	28.05	0.60	0.40	1.00
T_4	24.69	0.40	0.20	0.70
T_5	23.41	0.20	0.10	0.30
SE±	0.00	0.86	1.36	1.22

T_1 = Plants sprayed weekly, T_2 = Plants sprayed biweekly, T_3 = Plants sprayed every 3 weeks, T_4 = Plants sprayed every 4 weeks, T_5 = Unsprayed plants.

Table 18: Correlation between disease severity, percent defoliation, lesion size, lesion number, pod and haulm yields, crude protein content and chlorophyll content

	DS 56	DS63	DS70	DS77	DS84	DS91	DS98	PD	LS	LN	PY	HY	CPC	CHLa	CHLb	CHLt
DS56	1.00															
DS63	0.07	1.00														
DS70	0.45	-0.11	1.00													
DS77	0.09	0.50	0.22	1.00												
DS84	0.02	0.58*	0.26	0.91**	1.00											
DS91	0.15	0.62*	0.13	0.87**	0.91**	1.00										
DS98	0.23	0.53*	0.09	0.87**	0.86**	0.94**	1.00									
PD	0.17	0.59*	0.59*	0.87**	0.85**	0.947**	0.93**	1.00								
LS	0.24	0.48*	0.57*	0.62**	0.67**	0.77**	0.83**	0.89**	1.00							
LN	0.09	0.32*	0.51*	0.59**	0.66**	0.72**	0.79**	0.83**	-0.85**	1.00						
PY	-0.21	-0.73**	-0.73*	-0.68**	-0.85**	-0.82**	-0.72**	-0.76**	-0.79**	-0.83**	1.00					
HY	-0.12	-0.68**	-0.68*	-0.46	-0.48	-0.61*	-0.54*	-0.54*	-0.64**	-0.75**	0.58*	1.00				
CPC	0.28	-0.02*	-0.59*	-0.71**	-0.69**	-0.88**	-0.89**	-0.86**	-0.93**	-0.97**	0.66**	0.51**	1.00			
CHLa	0.28	-0.61*	-0.01*	-0.76**	-0.76**	-0.91**	-0.94**	-0.92*	-0.96**	-0.99**	0.70**	0.51**	0.97**	1.00		
CHLb	0.22	-0.63*	-0.01*	-0.75**	-0.75**	-0.93**	-0.88**	-0.92**	-0.98**	-0.98**	0.71**	0.54**	0.96**	0.97**	1.00	
CHLt	0.28	-0.60*	-0.01	-0.74**	-0.73**	-0.90**	-0.92**	-0.91**	-0.99**	-0.99**	0.69**	0.49**	0.96**	0.99**	0.98**	1.00

DS = Disease severity (DAS), PD = Percent defoliation, LS = Lesion size, LN = Lesion number, PY = Pod yield/ha, HY = Haulm yield/ha, CPC = Crude protein content, CHL = Chlorophyll content.

* = significant at 5 %, ** = significant at 1 %, WAS = Weeks after sowing.

4.2.2 Cost – benefit analysis for using different application frequencies to manage late leaf spot on SAMNUT 14.

Table 19 shows the cost and benefit analysis of using different application frequencies for managing late leaf spot on SAMNUT 14. All the sprayed frequencies (T_1 – T_4) had superior financial costs and benefits compared to the untreated (T_5). Groundnut yields in all the treatments resulted in revenue that exceeded the cost of the plant protection even in the unsprayed plots. The cost of plant protection for plants sprayed weekly (₦1,515.5.00) was higher than all the treatments and the least (₦433.00) was observed in plants sprayed every four weeks. The highest net profit (₦131,819.5.00) was obtained from plants sprayed weekly while the lowest net profit (₦66,660.00) was obtained from untreated plot. The highest benefit over the untreated was obtained from the plants sprayed weekly (₦65,159.5.00) while the lowest was obtained from plants sprayed every four weeks (₦2,357.00). The difference between the highest benefit over untreated (E) and the lowest was (₦62,802.5.00). The highest cost: benefit ratio (1:69.6) was obtained from plants sprayed biweekly followed by plants sprayed weekly (1:42.9), plants sprayed every three weeks recorded a cost: benefit of 1:28.9 and the lowest was observed in plants sprayed every four weeks (1:5.4). However, the highest return on investment of ₦160.39 was obtained from plants sprayed every four weeks followed by plants sprayed biweekly ₦147.56. Plants sprayed every three weeks and those sprayed weekly recorded ₦132.59 and ₦87.99 as return on investment respectively.

Table 19: Cost and Benefit analysis of using of different application frequencies for managing late leaf spot on SAMNUT 14

Variables	T_1	T_2	T_3	T_4	T_5 (Untreated)
Spray regimes (times)	7	4	3	2	0
(A) Total yield (kg/ha)	888.9	851.9	574.1	463.0	444.4
(B) Total income (₦/ha)	133,335	127,785	86,115	69,450	66,660
(C) Protection cost (₦/ha)	1,515.5	866	649.5	433.0	0.00
(D) Net Benefit (₦/ha) (B - C)	131,819.5	126,919	85,465.5	69,017	66,660
(E) Benefit over untreated (₦/ha)	65,159.5	60,259	18,805.5	2,357	-
(F) Cost : Benefit ratio (E/C)	1:42.9	1:69.6	1:28.9	1:5.4	-
ROI (B/C)	87.99	147.56	132.59	160.39	-

ROI = Return on Investment.

T_1 = Plants sprayed weekly, T_2 = Plants sprayed biweekly, T_3 = Plants sprayed every three weeks, T_4 = Plants sprayed every four weeks, T_5 = Unsprayed plants.

CHAPTER FIVE

5.0 DISCUSSION

The results of the present study showed that the five groundnut varieties evaluated produced varying levels of leaf spot lesions when inoculated artificially with *Phaeiosariopsis personata* suspension in the screenhouse with none of the varieties found to be immune. Higher severities, percent defoliation and area under disease progress curve were recorded on the field than in the screenhouse. These differences are probably attributed to the fact that in the screenhouse the soil was sterilized and infection was only due to the fungus inoculated and the absence of environmental conditions that favours the development of the disease such as leaf wetness for about 7 days, high temperature and high relative humidity. This agrees with the report of Yakubu (2016) that higher incidence and severity of cowpea stem rot disease were recorded on the field than in the Screenhouse which was attributed to none sterilization of the field soil and favourable environmental factors in the field. These findings agrees with the reports of previous workers (McDonald, 1978; Salako 1985) who investigated the application of a range of fungicide for control of early and late leaf spots of groundnut in the screenhouse and reported increase yield of sprayed plots over unsprayed.

The results of the sprayed and unsprayed study show the effectiveness of mancozeb + carbendazim in the management of late leaf spot of groundnut in the field which resulted in increased pod and haulm yields over the unsprayed plots by lowering the disease severity across all the five groundnut varieties studied. This finding agrees with Johnson *et al.* (1998) who reported that spraying of fungicide mixture (mancozeb 0.2 % + carbendazim 0.1 %) effectively controlled the late leaf spot of groundnut, led to significant increase in pod and haulm yields and reduced the spread of the disease in Virginia. Smith and Littrell (1980)

reported that using fungicides mixture reduced resistance development by cercospora leaf spot fungus and gave effective control of the disease in groundnuts. This work agrees with Trivellas (1988) who reported that control of late leaf spot in groundnut plots treated with non-consecutive application of full rate mixtures of chlorothalonil and benomyl applications was in most cases better than plots treated with full rates of chlorothalonil alone. Singh and Singh (1977) evaluated five fungicides against early and late leaf spots and reported carbendazim as most effective in controlling the diseases and gave the highest yield. Chandra *et al.* (1998) reported a significant increase in yield and reduced disease index when carbendazim + mancozeb were applied at 30 to 80 DAS at 10 days interval. Vyas *et al.* (1986) recommended the application of carbendazim (0.075 %) and mancozeb (0.15 %) in the middle of August for early and late leaf spot of groundnut when the crop is most susceptible to these diseases. This study also agrees with Pande *et al.* (1998) who reported that fungicide application on different groundnut varieties with different levels of resistance improved yield and biomass production about twice when compared with non – treated plots of same varieties. Salako (1985) investigated the application of a range of fungicides for cercospora leaf spot disease control in groundnuts and reported a yield increase of 132 – 286 % over unsprayed control plots depending on the fungicide used.

The increase in frequency of mancozeb + carbendazim spray particularly at weekly and biweekly interval resulted in a significant increase in pod and haulm yields compared to those sprayed at longer intervals. This result agrees with the findings of Naab *et al.* (2005) who reported that application of foliar sprays of fungicide in Ghana was effective in controlling early and late leaf spots and improved groundnut biomass and pod yield by 39 % and 75 % respectively. In Nigeria, Salako (1985) reported a yield increase of 132 – 286 % in protected plots over unsprayed control plots depending on the fungicide used. In a

similar study, Subrahmanyam *et al.,* (1984) observed significant increase in pod yield in all sprayed cultivars than in unsprayed plots. Ndedu (1986) also reported that, irrespective of the time spraying commenced, spraying at weekly and biweekly intervals resulted in a significantly lowered disease severity for early, late leaf spot and rust than spraying at three weeks interval. Similar results were also obtained for pod and haulm yields.

The results also revealed significant decrease in disease score, fewer lesions but larger lesion size on leaflet with increase in the frequency of fungicide spray. The fewer lesion numbers recorded on the groundnut treated with mancozeb + carbendazim shows that the fungicide is efficient in inhibiting the spread of the fungus. This agrees with the findings of Ambang *et al.* (2011) who reported that after two or more sprays of METPS and benomyl, there was a significant reduction in the evolution of lesion size. Also, they reported that increase in the number of spray resulted in increase efficiency of photosanitary products. Studies by Bovey *et al.* (1994), Talukder *et al.* (2002) and Subrahmanyam *et al*. (2008) reported similar results. The findings agrees with Ndedu (1986) who reported that higher application frequency of fungicide formulations resulted in lower disease scores and fewer lesions on the leaflets.

The severity of late leaf spot and Area Under Disease Progress Curve (AUDPC) also varied among the five groundnut varieties and in all the spray frequencies evaluated which increases with an increase in severity. This result agrees with Izge *et al*. (2007) who in a study found a lot of variability existing among the groundnut varieties evaluated in all characters, probably due to their inherent level of resistance to the pathogens. Iwo *et al*. (1998) earlier reported various levels of susceptibility to cercospora leaf spot by sesame genotypes. Fontem and Aighewi (1990) reported that, fungicide sprays significantly

reduced epidemic rates and areas under disease progress curves of late blight of potato in the West Province of Cameroon.

The results also showed significant reduction in percent defoliation with increase in the spray frequency. Increased in spray frequency reduces the susceptibility of groundnut to late leaf spot thereby lowering the percent defoliation. This might be due to the failure of the fungus to successfully invade the host tissue, resulting in low infection frequency. This low percentage of leaf damage resulted in low percent defoliation. This finding agrees with Hossain *et al*. (2007) who reported that moderately resistant groundnut genotypes to leaf spots and rust had lower percentage defoliation. However, previous reports have shown that more than one fungicide spray is needed in a season for effective control of cercospora leaf spot (Hagan *et al.,* 2003).

This result also shows increase in pod and haulm yields and slight increase in seed weight with increasing spray frequency. This conforms to the earlier report by Hagan *et at.* (2003) who reported increased in haulm yields following the application of fungicides. They also reported that seed weight was found to be slightly higher on sprayed plots than on unprotected ones.

The present study showed clearly that severe late leaf spot infection caused significant reduction in crude protein and chlorophyll contents in all the five spray frequencies evaluated. This might be due to the interference of the fungus with the photosynthetic activity causing higher number of lesions thereby reducing the net leaf area available for photosynthesis and resulting in reduced chlorophyll contents required for normal synthesis of the various nutrients needed by the plants and consequent reduction in pod yield of the crop. On the other hand the fungus might have also utilized the protein synthesized by the plants for their growth and development thereby reducing the amount left in the infected

leaves. The reduction in protein and chlorophyll contents in the plants due to destruction of leaves by the disease have been reported earlier (Allen, 2003; Alabi *et al*. 1993; Gupta, 1987). Crude protein, chlorophyll 'a', chlorophyll 'b' and 'total' chlorophyll increase with an increase in the spray frequency of fungicide. This confirmed earlier report by Lalithakumari *et al*. (1984) that the effect of systemic fungicide on the physiological response of groundnut plants against early and late leaf spots reduced the disease incidence and increased the protein, total nitrogen and phenols and decreased total sugar contents. Jyosthna *et al.* (2004) also reported decrease in total chlorophyll, chlorophyll 'a' and chlorophyll 'b' due to late leaf spot infection which was severe in susceptible cultivars than the resistant ones. Bera *et al*. (1999) reported higher chlorophyll contents in resistant cultivars having less leaf spot infection which is low in susceptible groundnut cultivars having higher number of leaf spot lesions.

The cost: benefit analysis of using different spray frequencies of fungicide shows that plants sprayed weekly gave higher yield which resulted in higher income than all other treatments but had higher cost for plant protection. However, plants sprayed biweekly gave higher cost benefit ratio of 1:69.6 than all the other treatments. The result agrees with FAOSTAT (2004) who reported that the highest usable yields of tomato with greater financial benefits obtained in chlorothalonil or mancozeb at 7 and 14 days interval was primarily due to suppression of *Alternaria sp*. and other fruit rot. This result is also in line with Niederhauser (1993) who noticed that best control of leaf blight disease of tomato caused by *Alternaria solani* was achieved by three foliar sprays of mancozeb at 15 day interval and gave the highest economic benefit.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The effect of variety and fungicide application on late leaf spot and some physiological parameters on groundnut varieties was assessed in the screenhouse and field trials at Samaru, Northwest Nigeria in 2016 rainy season. The first experiment was designed to compare the effects of sprayed and unsprayed treatments of mancozeb + carbendazim against late leaf spot on five groundnut varieties (SAMNUT 18, 21, 22, 23 and 25) and the second experiment was carried out to evaluate the effects of fungicide application frequencies (T_1, T_2, T_3, T_4 and T_5) of mancozeb + carbendazim on SAMNUT 14, a susceptible variety to late leaf spot. Mancozeb + carbendazim was found to be effective in managing the late leaf spot of groundnuts both in the screenhouse and on the field.

Disease severity, percent defoliation and AUDPC significantly varied among the varieties with SAMNUT 25 recording the highest values while SAMNUT 21 and 22 recorded the least. Disease severities and percent defoliation were highly and negatively correlated with pod and haulm yields. Disease severity, percent defoliation and AUDPC varied significantly with frequency of fungicide application. Sprayed plants recorded lowest disease. Biweekly sprayed plants recorded significant yield and lower disease severity at all the assessment periods; and percent defoliation and was found to be more economical in terms of cost benefit analysis.

The result also indicated increase in crude protein content, chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll with increasing frequency of spray. Weekly sprayed plants recorded the highest values in both the parameters. Disease severities and percent defoliation were negatively and highly correlated with yields, crude protein content and chlorophyll content.

6.2 Conclusions

The following conclusions can be made from this study:

Use of varieties that are resistant or tolerant and timely application of fungicide are essential for optimum yield in that they play important roles in lowering disease severity and the level of late leaf spot infection.

SAMNUT 21 and 22 were found to be moderately resistant in both screenhouse and field compared to the other varieties of groundnut evaluated; they could therefore be use alongside other integrated pest management (IPM) options for late leaf spot particularly in areas where the disease is causing severe yield loss.

Biweekly application of the fungicide was found to be effective in reducing disease with minimum value of disease severity (56.41 %) and increase in yield by (45.65 %), crude protein by (29.45 %) and total chlorophyll by (78.57 %) over unsprayed; and was most economical with cost: benefit ratio of (1:69.6).

6.3 Recommendations

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

1. Farmers should be advised to use fungicide formulations such as mancozeb + carbendazim which have contact and systemic actions against the late leaf spot disease.
2. Farmers should also be advised to sow SAMNUT 21 and 22 which were found to be moderately resistant compared to the other varieties of groundnut used in the study with higher pod and haulm yields. These varieties should be used alongside fungicide application at biweekly interval.

3. Further research should be conducted on frequency and rates of fungicides on different varieties to come up with a specific recommendation for each variety in order to reduce indiscriminate fungicide usage.

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APPENDIX

APPENDIX 1: Groundnut Production Table

Table 1: Top ten producers of groundnut in the world

Ranking	Country	Annual production (MT)
1.	China	13,336,860
2.	India	7,156,448
3.	Nigeria	2,755,649
4.	USA	1,837,519
5.	Sudan	1,399,500
6.	Indonesia	1,274,271
7.	Myanmar	841,925
8.	Senegal	694,147
9.	Argentina	463,227
10.	Vietnam	414,968

Source: (FAO, 2015).

APPENDIX 2: ANOVA Tables

2.1 ANOVA Tables for Screenhouse Trial

2.1.1 Disease severity at 60 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Variety	4	0.000	0.000	.	.
Fspray	1	0.000	0.000	.	.
Variety*F spray	4	0.000	0.000	.	.
Error	20	0.000	0.000		
Corrected Total	29	0.000			

2.1.2 Disease severity at 80 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Variety	4	104.252	26.063	20.32	<.0001
Fspray	1	74.292	74.292	57.93	<.0001
Variety*F spray	4	1.536	0.384	0.30	0.8748
Error	20	25.650	1.282		
Corrected Total	29	205.731			

2.1.3 Disease severity at 90 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Variety	4	249.531	62.382	3.93	0.0164
Fspray	1	165.064	165.064	10.39	0.0043
Variety*F spray	4	40.859	10.214	0.64	0.6383
Error	20	317.849	15.892		
Corrected Total	29	773.304			

2.1.4 Percent defoliation

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Variety	4	621.049	155.262	10.90	<.0001
Fspray	1	2917.574	2917.574	204.83	<.0001
Variety*F spray	4	69.562	17.390	1.22	0.3333
Error	20	284.871	14.243		
Corrected Total	29	3893.056			

2.1.5 Disease severity at 60 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Treatment	4	0.000	0.000	.	.
Error	10	0.000	0.000	.	.
Corrected Total	14	0.000			

2.1.6 Disease severity at 80 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Treatment	4	128.417	32.104	62.31	<.0001
Error	10	5.152	0.515		
Corrected Total	14	133.570			

2.1.7 Disease severity at 90 DAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Treatment	4	845.235	211.308	38.37	<.0001
Error	10	55.068	5.506		
Corrected Total	14	900.303			

2.1.8 Percent defoliation

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Treatment	4	3571.614	892.903	94.76	<.0001
Error	10	94.231	9.423		
Corrected Total	14	3665.845			

2.2 ANOVA Tables for Field Trial

2.2.1 Stand count at emergence

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	20.87	10.43	1.13	0.3455
Variety	4	323.33	80.83	8.74	0.0004
Fspray	1	30.00	30.00	3.24	0.0885
Variety*F spray	4	70.00	17.50	1.89	0.1556
Error	18	166.47	9.25		
Corrected Total	29	610.67			

2.2.2 Stand count at harvest

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	20.87	10.43	1.13	0.3455
Variety	4	323.33	80.83	8.74	0.0004
Fspray	1	30.00	30.00	3.24	0.0885
Variety*F spray	4	70.00	17.50	1.89	0.1556
Error	18	166.47	9.25		
Corrected Total	29	610.67			

2.2.3 Disease severity at 8 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	124.75	62.37	5.83	0.0111
Variety	4	116.95	29.24	2.73	0.0613
Fspray	1	0.21	0.21	0.02	0.8905
Variety*F spray	4	19.68	4.92	0.46	0.7639
Error	18	192.44	10.69		
Corrected Total	29	454.02			

2.2.4 Disease severity at 9 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	32.22	16.11	0.68	0.5196
Variety	4	47.23	11.81	0.50	0.7377
Fspray	1	204.94	204.94	8.64	0.0088
Variety*F spray	4	23.16	5.79	0.24	0.9095
Error	18	427.03	23.72		
Corrected Total	29	734.58			

2.2.5 Disease severity at 10 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	65.15	32.57	1.45	0.2616
Variety	4	325.49	81.37	3.61	0.0249
Fspray	1	254.57	254.57	11.30	0.0035
Variety*F spray	4	71.96	17.99	0.80	0.5416
Error	18	405.43	22.52		
Corrected Total	29	1122.59			

2.2.6 Disease severity at 11 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	26.03	13.01	0.27	0.7646
Variety	4	743.37	185.84	3.89	0.0190
Fspray	1	550.58	550.58	11.53	0.0032
Variety*F spray	4	183.99	45.99	0.96	0.4515
Error	18	859.65	47.76		
Corrected Total	29	2363.62			

2.2.7 Disease severity at 12 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	35.08	17.54	0.33	0.7210
Variety	4	1937.39	484.35	9.20	0.0003
Fspray	1	1241.38	1241.38	23.58	0.0001
Variety*F spray	4	466.79	116.69	2.22	0.1.80
Error	18	947.69	52.65		
Corrected Total	29	4628.34			

2.2.8 Disease severity at 13 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	128.95	64.48	0.93	0.4142
Variety	4	2432.29	608.07	8.73	0.0004
Fspray	1	1805.59	1805.59	25.93	<.0001
Variety*F spray	4	415.83	103.96	1.49	0.2460
Error	18	1253.45	69.64		
Corrected Total	29	6036.12			

2.2.9 Disease severity at 14 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	12.74	6.37	0.18	0.8386
Variety	4	4208.29	1052.07	29.36	<.0001
Fspray	1	2772.68	2772.68	77.36	<.0001
Variety*F spray	4	161.69	40.42	1.13	0.3746
Error	18	645.10	35.84		
Corrected Total	29	7800.50			

2.2.10 Percent defoliation

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	31.98	15.99	1.18	0.3296
Variety	4	836.90	209.23	15.46	<.0001
Fspray	1	6273.90	6273.90	463.56	<.0001
Variety*F spray	4	92.59	23.15	1.71	0.1916
Error	18	243.62	13.53		
Corrected Total	29	7478.99			

2.2.11 Number of lesions

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.536	0.268	0.15	0.8594
Variety	4	1605.045	401.261	228.78	<.0001
Fspray	1	1595.781	1595.781	909.83	<.0001
Variety*F spray	4	977.178	244.295	139.28	<.0001
Error	18	31.571	1.754		
Corrected Total	29	4210.112			

2.2.12 Lesion size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.229	0.114	2.07	0.1548
Variety	4	9.212	2.303	41.78	<.0001
Fspray	1	2.059	2.059	37.36	<.0001
Variety*F spray	4	2.205	0.551	10.00	0.0002
Error	18	0.992	0.055		
Corrected Total	29	14.697			

2.2.13 Number of pod

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	155.400	77.700	3.79	0.0422
Variety	4	99.133	24.783	1.21	0.3408
Fspray	1	177.633	177.633	8.67	0.0087
Variety*F spray	4	73.533	18.383	0.90	0.4857
Error	18	368.600	20.477		
Corrected Total	29	874.300			

2.2.14 Seed size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.009	0.004	0.57	0.5769
Variety	4	0.764	0.191	22.54	<.0001
Fspray	1	0.048	0.048	5.66	0.0286
Variety*F spray	4	0.050	0.012	1.47	0.02515
Error	18	0.152	0.008		
Corrected Total	29	1.024			

2.2.15 Pod size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.089	0.044	0.98	0.3936
Variety	4	0.321	0.080	1.76	0.1805
Fspray	1	0.067	0.067	1.47	0.2405
Variety*F spray	4	0.022	0.005	0.12	0.9723
Error	18	0.821	0.045		
Corrected Total	29	1.322			

2.2.16 100 seed weight

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	11.625	5.812	0.34	0.7169
Variety	4	367.306	91.826	5.36	0.0051
Fspray	1	7.261	7.261	0.42	0.5234
Variety*F spray	4	12.273	3.068	0.18	0.9463
Error	18	308.638	17.146		
Corrected Total	29	707.106			

2.2.17 Shelling percentage

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	63.191	31.595	0.99	0.3896
Variety	4	927.201	231.800	7.29	0.0011
Fspray	1	17.130	17.130	0.54	0.4724
Variety*F spray	4	79.941	19.985	0.63	0.6484
Error	18	572.345	31.796		
Corrected Total	29	1659.810			

2.2.18 Pod yield per plot

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.221	0.011	0.80	0.4626
Variety	4	0.884	0.221	16.06	<.0001
Fspray	1	0.114	0.114	8.29	0.0100
Variety*F spray	4	0.023	0.005	0.43	0.7832
Error	18	0.247	0.013		
Corrected Total	29	1.292			

2.2.19 Haulm yield per plot

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.408	0.204	0.62	0.5494
Variety	4	26.328	6.582	19.95	<.0001
Fspray	1	2.547	5.547	16.81	0.0007
Variety*F spray	4	1.670	0.417	1.27	0.3198
Error	18	5.939	0.329		
Corrected Total	29	39.894			

2.2.20 Pod yield per hectare

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	27366.263	13683.132	0.80	0.4626
Variety	4	1091975.321	272993.830	16.06	<.0001
Fspray	1	140844.28	140844.230	8.29	0.0100
Variety*F spray	4	29425.132	7356.283	0.43	0.7832
Error	18	305972.996	16998.500		
Corrected Total	29	1595583.943			

2.2.21 Haulm yield per hectare

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	504534.81	252267.40	0.62	0.5494
Variety	4	32504777.60	8126194.52	19.95	<.0001
Fspray	1	6848154.52	6848154.52	16.81	0.0007
Variety*F spray	4	2062334.06	515583.52	1.27	0.3198
Error	18	7332943.67	407385.76		
Corrected Total	29	49252744.66			

2.3 ANOVA Tables for Frequency of Spray in the Field

2.3.1 Stand count at emergence

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	4.933	2.466	0.53	0.6066
Treatment	4	42.933	10.733	2.32	0.1450
Error	8	37.066	4.633		
Corrected Total	14	84.933			

2.3.2 Stand count at harvest

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	12.400	6.200	0.63	0.5553
Treatment	4	128.933	32.233	3.29	0.0710
Error	8	78.266	9.783		
Corrected Total	14	219.600			

2.3.3 Disease severity at 8 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.044	0.022	0.06	0.9450
Treatment	4	0.683	0.170	0.43	0.7809
Error	8	3.146	0.393		
Corrected Total	14	3.874			

2.3.4 Disease severity at 9 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	19.496	9.748	49.25	<.0001
Treatment	4	16.547	4.136	20.90	0.0003
Error	8	1.583	0.197		
Corrected Total	14	37.627			

2.3.5 Disease severity at 10 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	2.789	1.394	0.94	0.4299
Treatment	4	2.029	0.507	0.34	0.8425
Error	8	11.871	1.483		
Corrected Total	14	16.690			

2.3.6 Disease severity at 11 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	21.970	10.985	1.52	0.2751
Treatment	4	437.400	109.350	15.16	0.0008
Error	8	57.698	7.212		
Corrected Total	14	517.069			

2.3.7 Disease severity at 12 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	11.631	5.815	0.28	0.7663
Treatment	4	1422.999	355.749	16.84	0.0006
Error	8	169.041	21.130		
Corrected Total	14	1603.672			

2.3.8 Disease severity at 13 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	16.165	8.082	0.39	0.6887
Treatment	4	5152.696	1288.174	62.31	<.0001
Error	8	165.393	20.674		
Corrected Total	14	5334.255			

2.3.9 Disease severity at 14 WAS

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	65.608	32.804	1.56	0.2676
Treatment	4	5091.456	1272.864	60.60	<.0001
Error	8	168.045	21.005		
Corrected Total	14	5325.110			

2.3.10 Percent defoliation

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	12.900	6.450	0.49	0.6321
Treatment	4	3809.770	952.442	71.76	<.0001
Error	8	106.178	13.272		
Corrected Total	14	3928.848			

2.3.11 Number of lesions

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	9.232	4.616	2.49	0.1446
Treatment	4	2803.344	700.836	377.61	<.0001
Error	8	14.848	1.856		
Corrected Total	14	2827.424			

2.3.12 Lesion size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.059	0.029	0.20	0.8266
Treatment	4	57.672	14.418	93.90	<.0001
Error	8	1.228	0.153		
Corrected Total	14	58.961			

2.3.13 Number of pods

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	73.733	36.866	3.11	0.1004
Treatment	4	260.666	65.166	5.49	0.0200
Error	8	94.933	11.866		
Corrected Total	14	429.333			

2.3.14 Seed size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.016	0.008	2.35	0.1574
Treatment	4	0.171	0.042	12.33	0.0017
Error	8	0.027	0.003		
Corrected Total	14	0.215			

2.3.15 Pod size

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.040	0.020	3.23	0.0938
Treatment	4	0.269	0.067	10.79	0.0026
Error	8	0.050	0.006		
Corrected Total	14	0.360			

2.3.16 100 seed weight

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	8.772	4.386	2.52	0.1421
Treatment	4	59.987	14.996	8.60	0.0054
Error	8	13.952	1.744		
Corrected Total	14	82.712			

2.3.17 shelling percentage

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.310	0.155	0.68	0.5347
Treatment	4	8.435	2.108	9.22	0.0043
Error	8	1.830	0.228		
Corrected Total	14	10.576			

2.3.18 Pod yield per plot

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.043	0.021	1.17	0.3583
Treatment	4	0.439	0.109	5.97	0.0158
Error	8	0.147	0.018		
Corrected Total	14	0.629			

2.3.19 Haulm yield per plot

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	2.407	1.203	1.78	0.2295
Treatment	4	4.373	1.093	1.62	0.2608
Error	8	5.411	0.676		
Corrected Total	14	12.192			

2.3.20 Pod yield per hectare

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	53088.913	26544.456	1.17	0.3583
Treatment	4	541976.024	135494.006	5.97	0.015
Error	8	181483.85	22685.398		
Corrected Total	14	776548.123			

2.3.21 Haulm yield per hectare

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	2972217.180	1486108.590	1.78	0.2295
Treatment	4	5399448.351	1346862.088	1.62	0.2608
Error	8	6681354.94	835169.37		
Corrected Total	14	15053020.47			

2.3.22 Crude protein content

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.000	0.000	INFTY	<.0001
Treatment	4	187.299	46.824	INFTY	<.0001
Error	8	0.000	0.000		
Corrected Total	14	187.299			

2.3.23 Chlorophyll 'a'

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.000	0.000	0.00	1.0000
Treatment	4	0.816	0.204	9.19E14	<.0001
Error	8	0.000	0.000		
Corrected Total	14	0.816			

2.3.24 Chlorophyll 'b'

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.000	0.000	0.00	1.0001
Treatment	4	0.324	0.081	1.46E15	<.0001
Error	8	0.000	0.000		
Corrected Total	14	0.324			

2.3.25 Total chlorophyll

Source	DF	Sum of Squares	Mean Square	F value	Pr >F
Rep	2	0.000	0.000	0.00	1.0001
Treatment	4	2.004	0.501	1.13E15	<.0001
Error	8	0.000	0.000		
Corrected Total	14	2.004			