GENETIC VARIABILITY FOR RESISTANCE TO *CERCOSPORA* LEAF SPOTS IN GROUNDNUT

(*Arachis hypogaea* L.)

BY

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A thesis submitted to the Postgraduate School Ahmadu Bello University in partial fulfillment of the requirements for the Degree of Master of Science in Plant Breeding

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DECLARATION

I hereby declare that this thesis was written by me and is a record of my own research work. It has not been presented before in any previous application for a Higher Degree. References made to published and unpublished literature have been duly acknowledged.

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The above declaration is confirmed.

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CERTIFICATION

This thesis titled "Genetic Variability for Resistance to *Cercospora* leaf spots in Groundnut (*Arachis hypogaea* L.)" by HAMASSELBE ABOUBAKAR meets the regulations governing the award of the degree of master of science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my late father, Chief Elhaj BELAKA MANG-KOO ABOUBAKAR from whom I inherited faith, patience, courage, perseverance and willingness.

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ABSTRACT

Leaf spot diseases of groundnut caused by *Cercospora arachidicola,* Hori (early leaf spot) and *Cercosporidium personatum* (Berk and Curt) Deighton (late leaf spot) are serious causes of yield losses in West and Central Africa. Host plant resistance is the most economical, sustainable and environmentally friendly approach to manage leaf spot diseases. A field experiment was conducted in 2001 and 2002 at Samaru, Nigeria and Guiring, Cameroon to identify sources of resistance, estimate genetic variability for resistance to *Cercospora* leaf spots, yield and yield components as well as their relationship with *Cercospora* incidence. The Groundnut Germplasm Project (GGP) nine-point field scale was used to assess *Cercospora* severity. The genotypes were grouped into various classes of resistance to leaf spots using the method suggested by the West and Central African Council for Agricultural Research and Development (WECARD). Genotypic coefficients of variability, broad sense heritability, genetic gain and correlation coefficients between disease incidence and some agronomic traits were estimated by the variance components procedure. The genotypic coefficients of variability were low, while heritability estimates were high except for fodder yield. The estimates of genetic gain were low except for *Cercospora* severity at 75 days after sowing (DAS) and fodder yield. No strong inherent association was found between *Cercospora* incidence and all the agronomic traits studied except for *Cercospora* severity at harvest and fodder yield at Guiring. Resistance to early and late leaf spots was not stable among genotypes and across environmental conditions. The genotypes SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG 6902, SAMNUT 11, SAMNUT 22 were found to be resistant to early leaf spot at Samaru, while ICGV 91225 was resistant at Guiring. None of the genotypes tested was

resistant to late leaf spot in both locations. In breeding for resistance to leaf spot diseases, the genotypes that were resistant or performed better than the tolerant check SAMNUT 11 could be used as donor parents. Therefore, the potential parents that can be used for breeding for resistance to early leaf spot are SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG 6902, SAMNUT 11, SAMNUT 22 at Samaru and ICGV 91225 at Guiring. The promising sources for resistance to late leaf spot are 28-206, SAMNUT 10, ICGV 91225 at Samaru and ICG 6902, # 3-94, SAMNUT 22, SAMNUT 21, NC-GP 343, ICGV 91225, ICGMS 42, SAMNUT 10 at Guiring.

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CHAPTER ONE

1.0 INTRODUCTION

Groundnut (*Arachis hypogaea* L.) belongs to the genus *Arachis* and to the family *Leguminosae* or *Fabacaea* (Datta, 1988). Groundnut (*Arachis)* originated in south America where the genus *Arachis* is widely distributed (Ramanatha Rao and Murthy, 1994). Groudnut occupies an important place in agricultural systems and national economies of many countries (Ndiaga, 2001). In Nigeria, groundnut used to be a major export crop and ranked second after cotton in the amount of money received from export commodities (N. A. E. R. L. S., 1975). In Cameroon, groundnut is mainly a subsistence crop and ranked fourth after cotton, cassava and maize (Schilling, 1993).

According to Essomba *et al.* (1988), McDonald (1990), groundnut pod yields are low and averaged 900kg ha^{-1} and 400kg ha^{-1} in Nigeria and Cameroon, respectively. The major constraints to groundnut production in Nigeria and Cameroon include biotic, abiotic and socio-economic factors (Yayock, 1978; Fusillier and Dimanche, 1995; Dwivedi *et al.*, 2003). Among the biotic factors, foliar fungal diseases are the most important (Arokoyo *et al.,* 1977; Essomba *et al.,* 1988). According to McDonald and Fowler (1976) and Fontal *et al.,* (1996), the most destructive of these foliar diseases is the *Cercospora* leaf spot caused by *Cercospora arachidicola* , Hori (early leafspot) and *Cercosporidium personatum* (Berk and Curt) Deighton (late leafspot) which is widespread in Nigeria and Cameroon.

Groundnut yield losses due to *Cercospora* leaf spots were estimated at 40% and 50% of kernels in Nigeria and Cameroon, respectively (Fowler, 1971; Iroume and Fontem, 1992). These losses are significant and require effective control measures.

Carpospores leaf spots can be controlled through biological methods, cultural practices, chemical applications and cultivation of resistant varieties (Littler and Smith, 1980). Biological control through the use of mycoparasites has been suggested but not seriously pursued (McDonald *et al.*, 1985). Cultural practices are labor intensive and time consuming (Schilling, 1983). Chemical control not only increases the cost of production, but also leads to farmer's dependence on fungicides and causes health hasards (Samdur *et al.*, 1999). The control of *Cercospora* leaf spots by the use of resistant varieties has been described as a painless method, environmentally friendly and economical to farmers (Isleib *et al.*, 1994). While research is continuing in developing better and more economic methods of chemical control, interest should also be put into developing resistant varieties to *Cercospora* leaf spots. It is therefore worthwhile to develop resistant groundnut genotypes to *Carpospores* leaf spots in Nigeria and Cameroon. The objectives of this study were to:

i - Screen advanced groundnut genotypes for resistance to leaf spot diseases;

ii - Estimate genetic variability for resistance to leaf spots, yield and yield components and correlations among them;

iii - Determine the genetic gain possible from selection for resistance to *Cercospora* leaf spots as well as for yield and yield components.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Groundnut Plant

Groundnut requires warm tropical conditions with moderate rainfall, and a well-aerated soil with good drainage (Harkness, 1969). It is an erect or prostate, sparsely hairy annual legume, with a well developed tap-root system and lateral roots (Porter *et al.*, 1984). The main stem is always erect and flanked by two opposite erect or prostate cotyledonary laterals (Schilling *et al.*, 1996). Leaves are compound, tetrafoliate except in species belonging to the section Trifoliotae (Ramanatha Rao and Murthy, 1994). The inflorescence is carried on axillary branches and may consist of flower up to seven in a cluster (Harkness, 1969).

Groundnut is a self-pollinating and unusual plant that flowers above ground and pods are produced below the ground (Porter *et al.*, 1984). General classification is into two forms: Erect (bunched) types, and Prostate (Runner) types (Smartt, 1961).

Krapovickas and Gregory (1994) cited by Singh (2001), divided the genus *Arachis* into nine sections. Section *Arachis* contains cultivated groundnut. Gregory *et al.* (1973) cited by Schilling (1996) had earlier divided *A. Hypogaea* into two subspecies, *fastigiata* Waldran and *hypogaea* Krap. & Rig. and each subspecies into two botanical varieties, Virginia and hirsute with *hypogaea*, Valencia and Spanish from *fastigiata*.

2.2 *Cercospora* leaf spots: Taxonomy, Distribution and Symptoms

According to Loden and Hildebrand (1950), leaf spot disease has been known by a number of names among them are: "Leaf spot", "Black spot", "Tikka" disease, and "*Cercospora* leaf spot".

Early and late leaf spots are probably the most serious foliar diseases of groundnut on a woldwide scale (Jackson and Bell, 1969). The geographical distribution of the two diseases is similar, but the incidence of infection by either of the disease differs markedly (Hemingway, 1954). Both diseases occur in all the main groundnut growing areas of Nigeria and Cameroon (Fowler, 1971; Iroume and Fontem, 1992).

Based on their time of appearance, Woodruf (1933) designated the disease induced by *Cercospora. arachidicola* as "Early leaf spots" (Plate 1a) and that induced by *Cercosporidium. personatum* as "Late leaf spots" (Plate 1b). The perfect state of the early and late leaf spot pathogens (*Mycosphaerella arachis* Deighton and *Mycosphaerella berkeleyii* W. Jenkins, respectively) are rarely observed (Porter *et al.*, 1984). However, the imperfect states i.e., *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. and Curt.) Deighton are most commonly seen during the development of the disease in the field (Jackson and Bell, 1969).

Frezzi (1960) cited by Jackson and Bell (1969), reported that under natural conditions, the notations "early leafspot" (*C. arachidicola*) and "late leaf spot" (*C. personata*) are not necessarily pertinent in all groundnut areas where both pathogens occur, since both species may occur in the same lesion. Both diseases could be scored together in the field with respect to their time of onset (GGP, 2001).

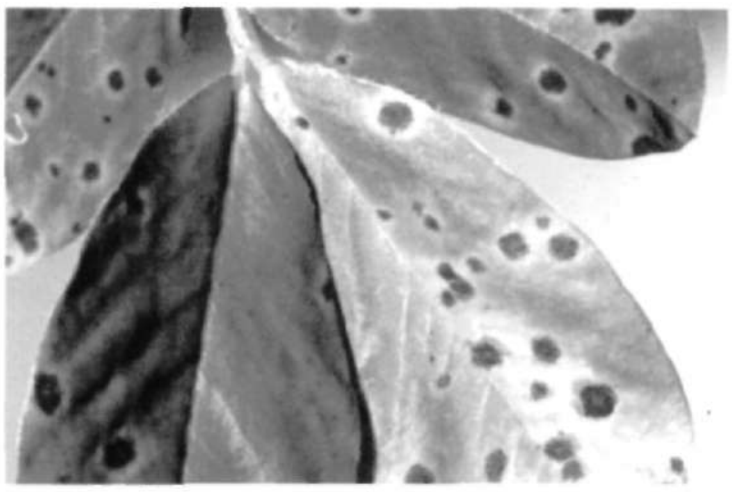
According to McDonald *et al.* (1985), Smith *et al.* (1992), the main distinguishing characteristics between early and late leaf spots are as follows:

1. The time of onset: Early leaf spots appear early in the cropping season, generally 1 to 2 months after planting, whereas late leaf spots is most prevalent during the later part of the growing season.
2. The colour of the lesions: Early leaf spot lesions are brown to dark-brown with sometimes yellow "halo" around each spot, whereas late leaf spot lesions are black and commonly show no yellow "halo".
3. The size and shape of the lesions: Early leaf spot lesions are bigger in size and irregular in shape, whereas late leaf spot lesions are smaller in size and concentric ring in shape.

2.3 Dissemination, Infection and Management of *Cercospora* leaf spots

There is a general consensus that *Cercospora* leaf spots are more serious in monoculture where groundnuts follow groundnuts (Jackson and Bell, 1969). Conidia produced on crop residue in the soil are the main source of initial inoculum (Subrahmanyam *et al.*, 1994a). However, ascospores, chlamydospores and mycelial fragments are potential sources of inoculum (Porter *et al.*, 1984). According to Higgins (1956) cited by Jackson and Bell (1969), inoculum from these possible sources is blown or splashed on leaves giving rise to primary infections. Subsequent sporulation provides conidia which are carried by the wind, rain, insects or machinery, thus leading to secondary infection cycles. Temperatures of 18-30°C, leaf wetness and total wetness period of greater than 160 hours favour infection and disease development (Butler *et al.*, 1994).

The most economical and effective method of leaf spot control would be to use an agronomically acceptable resistant variety (Jackson and Bell, 1969). Breeding lines with moderate resistance to early and/or late leaf spots and desirable agronomic



(a) : Early leaf spots *(Cercospora arachidicola)*

(b): Late leaf spots *(Cercosporidium personatum)*

Plate 1: Symptoms of *Cercospora* leaf spots in (a) Early leaf spots showing light brown spots surrounded with yellow halo and, (b) Late leaf spots displaying smaller and black spots.

traits have been developed elsewhere (Isleib *et al.*, 1994). Crop management practices that reduce initial inoculum, such as crop rotation, burial of groundnut crop residue, and planting when conditions are unfavourable for rapid disease development, provide practical control of early and late leafspots (Porter *et al.*, 1984). However, most of the control measures are uneconomical to small scale farmers (Samdur *et al.*, 1999).

In developed countries, fungicide control of leaf spots is effective and economical and has been widely adopted (Littrel and Smith, 1980; Subrahmanyam *et al.* 1984; McDonald *et al.*, 1985; Culbreath *et al.*, 1995).

However, after several years of extensive use of fungicides, tolerant strains of *C. personata* and *C. arachidicola* appeared (Smith *et al.*, 1978). In Cameroon, Esssomba *et al.* (1988) observed that maize-groundnut inrtercropping decreases the rate of the disease progression (percentage of leaf damage) by leaspots.

Leaf spot development is least with full NPK fertilisation and Gypsum as a calcium source (Chevaugeon, 1952). Recent studies have focused on developing disease-forecasting systems based on climatological data (Jacobi *et al.* 1995; Linvill and Drye 1995). According to Subrahmanyam *et al.* (1994a) partial resistance combined with judicious use of fungicides (such as Chlorothalomil and cultural practices such as early planting and crop rotation can be effective in reducing early leaf spot disease.

2.4 Host-Plant Resistance to *Cercospora* leaf spots

Resistance to leaf spot pathogens has been attributed to various morphological and anatomical characters of the host-plant (Taher *et al.*, 1997; Mayee and Suryawanshi, 1995) and different chemical constituents of leaves and seed (Alabi and Naqvi, 1977).

Sturgeon (1968) observed that the number of days between observed infection and date of leaflet fall increased with plant age. Gibbons (1966) observed that, defoliation caused by *Cercospora* hastened the maturity of the groundnut plant. Nwankiti (1976) indicated that field-grown groundnut appeared to become disease resistant if pod formation is prevented. However, Nevil and Evans (1980) showed that the prevention of pod formation did not affect pathogen development, although it increased the vegetative growth of the groundnut crop.

Plant growth habit has been reported to be unrelated to resistance (Chevaugeon, 1952), but Hemingway (1957) reported that resistance is related in some way to differences in the branching pattern of the host. Wild *Arachis* species were either highly resistant or immune to either one or both the species of *Cercospora* (Abdou *et al.*, 1974). According to Knauft and Gorbet (1990), both fungicide application and higher plant densities increased pod yield and biomass (haulm) suggesting that light interception was the limiting factor to yield at low plant population densities as result of the disease.

2.5 Mechanism and Components of Resistance to *Cercospora* Leaf spots

Several mechanisms have been proposed to explain the different degrees of susceptibility of groundnut to *Cercospora*. Hemingway (1957), cited by Abdou (1966), reported that the majority of infections originated through the upper epidermis and only through open stomata. No penetration was observed in stomata less than 13.4 µ in length and the majority of penetrated stomata were over 16.7 µ long. He did not find any significant difference in the number of stomata per mm^2 of leaf in three groundnut varieties with varying levels of resistance to the disease. However, there was greater frequency of larger stomata on the upper epidermis of the highly susceptible varieties than on moderate and susceptible ones. He concluded that probably the higher infection rates of the more susceptible varieties were as a result of greater frequency of stomata of penetrable size.

Abdou (1966) observed that the germ tubes on the leaves of susceptible varieties showed directional growth towards the stomata. This was thought to be due to some substance of host origin from open stomata which acted as an attractant to the growth of germ tubes. He also studied the post infection host-parasite relationship and reported that in highly *Cercospra* resistant *Arachis* species the spread of the fungus was restricted by the formation of an impermeable barrier, which resulted in the death of the fungus, thereby giving rise to hypersensitive flecks. The impermeable barrier was due to cell wall swelling and a deposition of apparently peptic substances on cell walls and in intercellular spaces.

Sporulation, lesion size, lesion number, and latent period are important components that contribute to low field scores of leafspot (Chiteka *et al.,* 1988; Anderson *et al.,* 1990). Resistant varieties have fewer lesions, longer incubation period and lower sporulation rates than susceptible cultivars (Nevil, 1981).

2.6 Screening for Resistance to *Cercospora* Leaf spots

Screening for resistance to leaf spots caused by *C. arachidicola* and *C.. personata* has been reported in recent years (Isleib *et al.,* 1994). Effective field and laboratory screening methods have been developed and systematic screening of groundnut germplasm for resistance to leaf spots has been intensively carried out in different parts of the world (Subrahmanyam *et al.,* 1994a).

Several sources of resistance to both early and late leaf spots have been reported (Hassan and Beute, 1997; Fostel *et al.,* 1981; Melouk *et al.,* 1984; Subrahmanyam *et al.,* 1984). At the International Crops Research Institute for the

Semi-Arid Tropics (ICRISAT) Center, field screening with infector rows is used to challenge host-plant in a worst-case situation (Subrahmanyam *et al.*, 1982a).

Genotypes and breeding populations to be screened are planted in nursery together with rows of highly susceptible cultivars arranged systematically through the nursery. The ratio of the test and infector rows varies from season to season and from location to location (Isleib *et al.*, 1994). Disease reaction on test plants is scored using a nine-point field scale for assessment of leafspot (Subrahmanyam *et al.* 1982a). Singh (2001) highlighted the Groundnut Germplasm Project nine-point field scale for assessment of leafspot as follows:

1 = No infected leaflet on the main stem of the groundnut plant

2 = 1 to 5% of infected leaflets and defoliation on the main stem

3 = 6 to 10% of infected leaflets and defoliation on the main stem

4 = 11 to 20% of infected leaflets and defoliation on the main stem

5 = 21 to 30% of infected leaflets and defoliation on the main stem

6 = 31 to 40% of infected leaflets and defoliation on the main stem

7 = 41 to 60% of infected leaflets and defoliation on the main stem

8 = 61 to 80% of infected leaflets and defoliation on the main stem

9 = 81 to 100% of infected leaflets and defoliation on the main stem

The West and Central African Council for Agricultural Research and Development (WECARD) (1991) classified groundnut genotypes into various classes of resistance to leafspot with the following average scores:

1 = Immune genotypes

2 – 3 = Resistant genotypes

4 – 5 = Medium resistant genotypes

6 – 7 = Medium susceptible genotypes

8 – 9 = susceptible genotypes.

For quick and large-scale measurement of leafspot disease in the field, defoliation data have been used as a single criterion to measure the disease incidence (Horsfall and Heuberger, 1994; Clark and Cork, 1958).

According to Haji and Beute (1977), percent defoliation of a groundnut plant is the ratio of leaflets lost to the total leaflets of the main stem.

Abdou (1966) combined the two different expressions of *Cercospora* leafspot of groundnut namely area infected and percentage defoliation, into a single number to measure the intensity of the disease. These subjective ratings offer little or no information on mechanism (s) of resistance, but have proved to be successful when employed in conjunction with overall agronomic assessment (Norden *et al.,* 1986).

2.7 Genetic coefficient of variability, Heritability and Genetic advance for Resistance to *Cercospora* Leaf spots

From quantitative genetic experiments, several researchers (Kornegay *et al.*, 1980; Anderson *et al.,* 1986, 1991; Wynne *et al.*, 1991) indicated that the genetic nature of resistance to early and late leaf spots of groundnut is quantitative and controlled predominantly by additive gene effects and independently inherited. Nevil (1982) observed that leafspot resistance was determined by recessive alleles at five loci.

Abdou *et al.* (1978) reported that crosses between resistant wild species and susceptible cultivars were susceptible, indicating that resistance was recessive. According to Wynne *et al.* (1985), resistance to early leafspot appeared to be inherited independently of resistance to late leaf spots, suggesting that a cultivar with resistance to both leaspots could be developed. From cytogenetic studies, the application of molecular tools including markers could lead to the development of probes for resistance gene detection in the near future (Moss, personal communication)

Anderson *et al.*, (1985; 1991) obtained broad-sense heritability estimates that ranged from moderate to high (0.4 to 0.8) and from low to high (0.12 to 0.88) for components of resistance to early and late leaf spots, respectively.

2.8 Genetic coefficient of variability, Heritability and Genetic advance for Plant height, Fodder, Pod and Seed yield

Genetic coefficient of variation indicates the amount of genetic variability existing in a character (Basu, 1969). Basu (1969) found moderate (43.5%) genetic coefficients of variation for plant height, high (70.3%) for number of days to flower, number of pods (76.5%%), fodder (79.1%) and seed (83.3%) weight per groundnut plant.

Heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance (Singh, 1990). Heritability along with genetic advance are useful in predicting the resultant effect from selecting best individuals for breeding programs (Johnson *et al.*, 1955). At the research center of Sirsa, Haryana, Basu (1969) found that number of pods per groundnut plant showed high genetic advance (69%) along with high heritability (73.5%). He has also reported that fodder weight per groundnut plant , plant height, fodder and seed yield had moderate heritability estimates, 41%, 46.7%, 44.8% and 42.7%, respectively and also showed high genetic gain values, 77,3%, 71%, 82.3% and 83.6%, respectively. He concluded that selections for these characters may be profitably made on phenotypic performance.

2.9 Correlation for Resistance to *Cercospora* Leaf spots

Correlation measures the degree of association, genetic or non-genetic between two or more characters (Echekwu, 1991). According to Anderson *et al.* (1990, 1991), moderate to high correlation (0.41 to 0.86) existed between early and late leaf spot disease components. Miller (1953) indicated that the amount of leaf shedding of groundnut was correlated with the amount of leaf spotting. Sturgeon (1968), Opona (1986) reported that leafspot infection was directly related to defoliation. Hemingway (1957) observed a positive correlation between the colour of foliage and resistance to leaf spots in groundnut and indicated that varieties with light-green foliage were more susceptible than those with dark foliage.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

Field experiments were conducted over two years (2001 and 2002) at two locations: the Institute for Agricultural Research (IAR) Farm, Samaru (11° 11'N, 73° 37'E, 686 m above sea level), Nigeria and the Institute of Agricultural Research for Development (IARD) Farm, Guiring (10° 35'N, 14° 18'E, 421 m above sea level), Cameroon.

3.2 Experimental Materials

Twenty groundnut genotypes comprising of seven plant introductions from ICRISAT/Niger, six Nigerian and seven Cameroonian improved varieties were used in the study. The check included were 55-437, and SAMNUT 11, susceptible and tolerant genotypes, respectively to both leafspots (Mauboussin *et al.*, 1970; Isleib *et al.*, 1994). The origin and characteristics of these genotypes are presented in Table 1.

3.3 Experimental Design and Field Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in two years and two locations. The agronomic practices for each location (IRAD, 1985; N. A. E. R. L. S., 1986) were separately applied in conducting the experiments.

Table 1. Origin and characteristics of genotypes used for the study

Genotype	Source	Origin	Characteristics
SAMNUT 21	Nigerian improved variety	ICRISAT/Mali	Medium maturing (120-130 days
SAMNUT 23	Nigerian improved variety	ICRISAT/Mali	Early maturing (100-110 days)
SAMNUT 10	Nigerian improved variety	IRHO/Senegal	Late maturing (135-150 days), Rosette resistant, Sensitive to drought, 49% oil content, 98% seed dormancy.
SAMNUT 11*	Nigerian improved variety	IRHO/Senegal	Late maturing (135-150 days), Rosette resistant, Tolerant to early and late leaf spots, sensitive to drought, 48% oil content, 98% seed dormancy.
SAMNUT 18	Nigerian improved variety	IAR/Nigeria	Early maturing (90-100 days), drought tolerant, Rosette susceptible, 53-55% oil content, 49% oil content, 30% seed dormancy, rosette and leafspot tolerant
SAMNUT 22	Nigerian improved variety	ICRISAT/Mali	Medium maturing (120-130 days)
CGS 269	Cameroonian improved variety	Cameroon	Early maturing (100-110 days)
CGS 1272	Cameroonian improved variety	Cameroon	Early maturing (100-110 days)
K3237-80	Cameroonian improved variety	Nigeria	Early maturing (90-100 days)
55-437*	Cameroonian improved variety	Argentina	Early maturing (90-100 days) Cercospora leafspot susceptible
JL 24	Cameroonian improved variety	Senegal	Early maturing (90-100 days), drought tolerant, 50% oil content.
ICGV 86003	Cameroonian improved variety	ICRISAT/Mali	Early maturing (90-100 days)
28-206	Cameroonian improved variety	Senegal	Medium maturing (120-130 days), Rosette resistant, 50% oil content, Complete seed dormancy.
ICG 6902	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
ICGV 91225	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
ICGV 92087	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
ICGV 92099	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
# 3-94	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
NC-GP 343	Plant Introduction	ICRISAT	Medium maturing (120-130 days)
ICGMS 42	Plant Introduction	ICRISAT	Medium maturing (120-130 days)

* Check genotypes

The experimental field was ploughed, harrowed to a fine tilth and ridged at 75 cm width at Samaru. Whereas, at Guiring sowing was done on flat. Plot size was a single row 10 m long, spaced 75 cm at Samaru and 60 cm at Guiring. Sowing was manually done on 02 July 2001 and 12 July 2002 at Samaru. At Guiring, the planting dates were 09 July 2001 and 02 July 2002.

Prior to sowing, groundnut seeds were dressed with Femasan D (Thiram and Lindane) at the rate of 3 g.a.i. kg $^{-1}$ of kernels at Samaru and with Marshall (Carbosulfan FMC 10%) at the rate of 40 grams 5 kg $^{-1}$ of kernels at Guiring. At Samaru, Single Super Phosphate (SSP) was applied as side dressing fertiliser at the rate of 300 kg ha $^{-1}$ at two weeks after sowing. Weeds were controlled with pre-emergence herbicides using a mixture of Gramoxone and Codal EC at the rate of 5 liters ha $^{-1}$ in addition to hand weeding. At Guiring, the compound fertiliser (NPK) 10-30-10 was used at the rate of 100 kg ha $^{-1}$ at two weeks after sowing. Weeds were controlled manually.

3.4 Data Collection

Data were collected on the following parameters:

- Plant Stand Count: this was measured as the number of plants per plot at 60 days after sowing (DAS).
- Plant Height (cm): as the height of the main axis from ground level to the tip of 10 randomly chosen plants per plot at 60 DAS.
- *Cercospora* severity: rating at 75 DAS and at harvest on the main axis of five previously labelled plants. The 9-point field scale of the Groundnut Germplasm Project (2001) was used to score disease severity. Groundnut genotypes were classified into various classes of resistance to *Cercospora* leaf spots using the

method suggested by the West and Central African Council for Agricultural Research and Development (WECARD) (1991).

- *Cercospora* Incidence: determined as the percent defoliation of the main axis of the 5 randomly selected plants in a plot, one week before harvest. It was computed thus:

  Percent Defoliation = [(leaflets lost) (total leaflets) $^{-1}$] x 100
- Pod Weight (g): measured as the weight of total pods per plot after two weeks of sun drying.
- Fodder Weight (g): as the weight of the total dried fodder per plot.
- Seeds Weight (g): was the weight of the total seeds per plot after hand shelling.

3.5 Statistical Analyses

Analysis of variance (ANOVA), means separation and correlation for all the traits observed were computed according to Snedecor and Cochran (1967), Duncan (1955), Mode and Robinson (1959) respectively, using Statistical Application for the Sciences (SAS, 1989) software program.

The statistical model for each location for the two years is as follows:

$$\mathbf{Y_{ijk} = \mu + Y_i + R_{ij} + G_k + (GY)_{ki} + \varepsilon_{ijk}}$$

Where,

Y_{ijk} = the effect of the k^{th} genotype in the j^{th} replication and in the i^{th} year.

μ = the overall mean

Y_i = the effect of the i^{th} year; i = 1, 2

R_{ij} = the effect of the j^{th} replication in the i^{th} year; j = 1, 2, 3

G_k = the effect of the k^{th} genotype; k = 1, 2, 3, . . . 20

$(GY)_{ki}$ = the interaction effect between the k^{th} genotype in the i^{th} year

ε_{ijk} = the pooled error

The phenotypic mean of a given genotype is the sum of the overall mean, the year effect, the replication effect, the genotype effect, the genotype x year interaction effect and the pooled error.

The statistical model for each year for the two locations is as follows:

$$\mathbf{Y_{ijk} = \mu + L_l + R_{lj} + G_k + (GL)_{kl} + \varepsilon_{ljk}}$$

Where,

Y_{ljk} = the effect of the k^{th} genotype in the j^{th} replication and in the l^{th} location.

μ = the overall mean

L_l = the effect of the l^{th} location; l = 1, 2

R_{ilj} = the effect of the j^{th} replication in the i^{th} year; j = 1, 2, 3

G_k = the effect of the k^{th} genotype; k = 1, 2, 3, . . . 20

$(GY)_{kl}$ = the interaction effect between the k^{th} genotype in the l^{th} location

ε_{ljk} = the pooled error

The phenotypic mean of a given genotype is the sum of the overall mean, the location effect, the replication effect, the genotype effect, the genotype x location interaction effect and the pooled error.

The statistical model for the combined analysis is as follows:

$$\mathbf{Y_{ijkl} = \mu + Y_i + L_l + R_{ijl} + G_k + (YL)_{lj} + (GY)_{kl} + (LG)_{jk} + (YLG)_{ijk} + \varepsilon_{ijkl}}$$

Where,

Y_{ijkl} = the observed mean for the k^{th} genotype in the i^{th} year, in the the l^{th} location and in the j^{th} replication

Y_i = the effect of the i^{th} year; i = 1, 2

L_l = the effect of the l^{th} location, l = 1,2

R_{ijl} = the effect of the j^{th} replication in the i^{th} year and in the the l^{th} location

G_k = the effect of the k^{th} genotype; k = 1, 2, 3, . . . 20

$(YL)_{il}$ = the interaction effect between the i^{th} year and the l^{th} location

$(GY)_{kl}$ = the interaction effect between the k^{th} genotype in the i^{th} year

$(LG)_{lk}$ = the interaction effect between the k^{th} genotype in the l^{th} location

$(YLG)_{ijk}$ = the interaction effect between the k^{th} genotype in the l^{th} location and in the i^{th} year

ε_{ijkl} = the composite error term

Table 2. Form of the general analysis of variance for one location for two years

Source of variation	df	MS	EMS
Years	y-1		
Replications in years	y(r-1)		
Genotypes	(g-1)	M_g	$\sigma^2_e + r\sigma^2_{gy} + ry\sigma^2_g$
Genotypes x years	(g-1)(y-1)	M_{gy}	$\sigma^2_e + r\sigma^2_{gy}$
Error	y(g-1)(r-1)	M_e	σ^2_e
Total	ygr-1		

Where,

y = number of years

r = number of replications

g = number of genotypes

df = degree of freedom

MS = observed mean squares

EMS = expected mean squares

σ^2_{gy} = genotype by year interaction variance

σ^2_g = total genetic variance among genotypes

σ^2_e = error variance

Table 3. Form of the general analysis of variance for one year and two locations

Source of variation	df	MS	EMS
Locations	l-1		
Replications in locations	l(r-1)		
Genotypes	(g-1)	M_g	$\sigma^2_e + r\sigma^2_{gl} + rl\sigma^2_g$
Genotypes x locations	(g-1)(l-1)	M_{gl}	$\sigma^2_e + r\sigma^2_{gl}$
Error	l(g-1)(r-1)	M_e	σ^2_e
Total	lgr-1		

Where,

l = number of locations

r = number of replications

g = number of genotypes

df = degree of freedom

MS = observed mean squares

EMS = expected mean squares

σ^2_{gl} = genotype x location interaction variance

σ^2_g = total genetic variance among genotypes

σ^2_e = error variance

Table 4. Form of general combined analysis of variance for two years and two locations

Source of variation	df	MS	EMS
Locations	l-1		
Years	y-1		
Replications in years x locations	yl(r-1)		
Location x years	(l-1)(y-1)		
Genotypes	(g-1)	M_g	$\sigma^2_e + r\sigma^2_{gly} + rl\sigma^2_{gy} + ry\sigma^2_{gl} + rly\sigma^2_g$
Genotypes x locations	(g-1)(l-1)	M_{gl}	$\sigma^2_e + r\sigma^2_{gly} + rl\sigma^2_{gy} + ry\sigma^2_{gl}$
Genotypes x years	(g-1)(y-1)	M_{gy}	$\sigma^2_e + r\sigma^2_{gly} + rl\sigma^2_{gy}$
Genotypes x locations **x years**	(g-1)(l-1)(y-	M_{gly}	$\sigma^2_e + r\sigma^2_{gly}$
Error	ly(r-1)(g-1)	M_e	σ^2_e
Total	lygr-1		

Where,

l = number of locations

y = number of years

r = number of replications

g = number of genotypes

MS = observed mean squares of the subscripted effect

EMS = expected mean squares

σ^2_{gy} = genotype x year interaction variance

σ^2_{gl} = genotype x location (environment) interaction variance

σ^2_{gly} = genotype x location x year interaction variance

σ^2_g = total genetic variance among genotypes

σ^2_e = error variance

The Genotypic coefficient of variability of a character was computed using the formular suggested by Hanson *et al.* (1956):

$$\text{GCV} \quad (\%) = \frac{\sqrt{\sigma_g^2}}{\overline{X}} \times 100$$

Where, the genetic coefficient of variability for a given character is the ratio of its genotypic standard deviation to its mean

Heritability in a broad sense on a phenotypic mean basis was computed using the formular suggested by Johnson *et al.* (1955):

$$h_b^2 = \frac{\sigma_g^2}{\frac{\sigma_e^2}{\text{rly}} + \frac{\sigma_{gly}^2}{\text{ly}} + \frac{\sigma_{gy}^2}{\text{y}} + \frac{\sigma_{gl}^2}{\text{l}} + \sigma_g^2}$$

Where, heritability in a broad sense for a given character is the ratio of its genotypic variance to its phenotypic variance.

The genetic advance was estimated by the method given by Burton and Devane (1963):

$$\Delta G = k.h^2_b.\sigma_{ph}$$

Where, the genetic advance for a given character is the product of the selection differential by its broad sense heritability and its phenotypic standard deviation among genotypes.

The values of k vary with the selection intensity (I). The selection intensity was calculated by the formular suggested by Singh (1990) as:

$$I\ (\%) = q/n \times 100$$

Where, q = number of selected plants

n = total number of plants or genotypes in the original population.

In this study q = 5 and n = 20, I = 5/20 = 0.25 or 25%

The expected genetic gain in percentage of mean was computed by the method given by Burton and Devane (1963) as:

$$\Delta G\ (\%) = \frac{\Delta G}{\bar{X}} \times 100$$

Where, the expected genetic gain for a given character is the ratio of its genetic advance to its mean.

The phenotypic, genotypic and environmental correlation coefficients were computed using the formular suggested by Mode and Robison (1959):

$$r_{pha.b} = \frac{\sigma_{ph_a ph_b}}{\sqrt{\sigma^2_{ph_a} . \sigma^2_{ph_b}}}$$

Where, the phenotypic correlation for a given pair of characters is the ratio of their phenotypic covariance to the square root of the product of their phenotypic variances

$$r g_{ab} = \frac{\sigma_{g_a g_b}}{\sqrt{\sigma^2_{g_a} . \sigma^2_{g_b}}}$$

where, the genotypic correlation for a given pair of characters is the ratio of their genotypic covariance to the square root of the product of their genotypic variances

$$r_{eab} = \frac{\sigma_{eab}}{\sqrt{\sigma^2_{ea} . \sigma^2_{eb}}}$$

Where, the environmental correlation for a given pair of characters is the ratio of their environmental covariance to the square root of the product of their environmental variances.

CHAPTER FOUR

4.0 RESULTS

4.1 Samaru 2001

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 at Samaru are presented in Table 5.

The results of the analysis of variance showed that differences among genotypes were significant ($p \leq 0.05$) for *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence, fodder and seed yield and highly significant ($p \leq 0.01$) for plant height (Appendix 1).

Mean plant density varied from 33,000 plants/ha for the genotype ICGV 91225 to 66,677 plants/ha for the genotype ICGV 92099. Plant height ranged from 15.9 cm for SAMNUT 21 to 33.3 cm with the genotype 55-437.

Cercospora leaf spot severity scores varied from 2.3 for ICG 6902 to 4.3 in JL24 at 75 DAS. At harvest, the genotypes 28-206 and SAMNUT 18 had the lowest and the highest disease scores, 3.0 and 4.9, respectively. *Cercospora* incidence ranged from 4.3% for the genotype 55-437 to 38% with SAMNUT 18.

Fodder yield varied from 1,782 kg/ha for ICGV 86003 to 4,760 kg/ha in the genotype SAMNUT 10. The genotypes ICGV 91225 and SAMNUT 23 showed the lowest and the highest levels of pod yield, 342 kg/ha and 1,614 kg/ha, respectively. Seed yield varied from 93 kg/ha for the genotype #3-94 to 690 kg/ha with the genotype CGS 269.

Table 5. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 at Samaru

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	47,677^{ab}	15.9^{h}	2.7^{cdef}	3.6^{bcd}	30.0^{abc}	2,960^{bcde}	573^{cde}	289^{abcd}
SAMNUT 23	48,333^{ab}	26.0^{bcde}	2.6^{def}	3.1^{cd}	17.0^{bcdef}	3,525^{abcd}	1,614^{a}	578^{ab}
SAMNUT 10	56,333^{ab}	18.5^{gh}	2.5^{ef}	3.5^{bcd}	20.0^{abcde}	4,760^{a}	716^{bcde}	333^{abcd}
SAMNUT 18	65,677^{a}	26.0^{bcde}	3.7^{abc}	4.9^{a}	38.0^{a}	1,996^{de}	1,089^{abcde}	489^{abcd}
SAMNUT 22	42,677^{ab}	21.2^{efg}	3.0^{bcdef}	3.6^{bcd}	26.3^{abcd}	4,324^{ab}	787^{bcde}	400^{abcd}
CGS 269	66,000^{a}	26.1^{bcde}	3.1^{bcdef}	3.5^{bcd}	23.3^{abcde}	2,933^{bcde}	1,084^{abcde}	690^{a}
CGS 1272	48,333^{ab}	26.7^{bcd}	3.4^{abcde}	3.9^{bcd}	32.3^{ab}	3,516^{abcd}	991^{abcde}	533^{abc}
K3237-80	54,333^{ab}	26.9^{bcd}	3.6^{abcd}	4.5^{ab}	37.7^{a}	3,453^{abcd}	1,240^{abcd}	489^{abcd}
JL 24	52,000^{ab}	32.0^{a}	4.3^{a}	4.1^{abc}	8.0^{de}	2,058^{de}	1,596^{a}	689^{a}
ICGV 86003	58,333^{ab}	29.9^{ab}	3.9^{ab}	4.4^{ab}	11.0^{cde}	1,782^{e}	1,418^{ab}	667^{a}
28-206	62,333^{a}	21.8^{defg}	2.6^{def}	3.0^{d}	18.7^{abcde}	3,382^{abcd}	422de	156^{cd}
ICG 6902	50,677^{ab}	26.8^{bcd}	2.3^{f}	3.8^{bcd}	12.3^{cde}	3,422^{abcd}	876^{abcde}	445^{abcd}
ICGV-91225	33,000^{b}	23.3^{cdef}	2.8^{cdef}	3.8^{bcd}	6.3^{e}	2,062^{de}	342^{e}	133^{cd}
ICGV-92087	63,677^{a}	28.8^{abc}	2.5^{ef}	3.8^{bcd}	18.7^{abcde}	3,938^{abc}	1,240^{abc}	467^{abcd}
ICGV 92099	66,677^{a}	24.3^{cdef}	3.0^{bcdef}	3.9^{bcd}	21.7^{abcde}	2,716^{cde}	800^{bcde}	382^{abcd}
#3-94	54,333^{ab}	18.9^{gh}	3.2^{bcdef}	4.4^{ab}	14.0^{bcde}	2,080^{de}	485de	93^{d}
NC.GP-343	55,677^{ab}	20.6^{fgh}	2.8^{cdef}	3.7^{bcd}	16.0^{bcde}	4,991^{abc}	618^{cde}	333^{abcd}
ICGMS 42	43,333^{ab}	20.9^{efg}	3.1^{bcdef}	3.6^{bcd}	21.3^{abcde}	3,044^{bcde}	422de	200^{bcd}
Checks								
SAMNUT 11	63,333^{a}	22.3^{defg}	2.8^{cdef}	3.5^{bcd}	32.3^{ab}	4,236^{abc}	982^{abcde}	533^{abc}
55-437	66,000^{a}	33.3^{a}	3.5^{abcde}	4.3^{ab}	4.3^{e}	2,769^{bcde}	1,111^{abcd}	445^{abcd}
CV (%)	29.4	32.3	29.5	21.2	83.9	47.9	72.2	74.4
SE±	8.0	1.6	0.3	0.3	5.9	467.7	219.5	122.5

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

The coefficient of variation (CV) ranged from 29.4% for plant height to 74.4% for seed yield (Table 5).

4.2 Guiring 2001

Mean plant density (stands/ha), plant height (cm), *Cercospora* leafspot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 at Guiring are presented in Table 6.

The results of the analysis of variance revealed significant ($p \leq 0.05$) differences among genotypes and highly significant ($p \leq 0.01$) differences for plant stand, plant height, *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence and seed yield (Appendix 2).

Plant density ranged from 52,667 stands/ha for ICGV 91225 to 94,333 stands/ha for the genotype 55-437. Plant height varied from 30.7cm with the genotype SAMNUT 21 to 54.1 cm for ICGV 86003.

Cercospora leaf spot severity scores ranged from 2.9 for SAMNUT 21 to 4.5 with the genotype JL24 at 75 DAS. While at harvest, the scores varied from 3.7 for SAMNUT 21 to 5.1 with the genotype JL24. The genotypes 55-437 and K3237-80 had the lowest and the highest *Cercospora* incidence, 10% and 55%, respectively.

Fodder yield varied from 3,222 kg/ha fot SAMNUT 22 to 6,111kg/ha for thegenotype ICGV 86003. Pod yield ranged from 900 kg/ha for SAMNUT 11 to 2,222 kg/ha with the genotype ICGV 86003. The genotypes ICGV 92099 and ICGV 86003 showed the lowest and the highest levels of seed yield, 611 kg/ha and 1,555 kg/ha, respectively.

The CV ranged from 17% for *Cercospora* leaf spot severity scores to 75.2% for *Cercospora* incidence (Table 6).

Table 6. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 at Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity 75 DAS	*Cercospora* severity Harvest	*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
SAMNUT 21	$64,667^{cde}$	30.7^{g}	2.9^{e}	3.7^{f}	13.3^{cdef}	$5,056^{abc}$	$1,278^{cdef}$	948^{defg}
SAMNUT 23	$74,667^{c}$	48.3^{abc}	3.2^{de}	4.0^{ef}	16.7^{cdef}	$4,306^{abc}$	$1,695^{abcd}$	989^{cdefg}
SAMNUT 10	$74,333^{c}$	34.9^{fg}	3.3^{cde}	4.1^{def}	19.7^{cd}	$3,417^{c}$	$1,250^{def}$	837^{efgh}
SAMNUT 18	$76,000^{bc}$	40.1^{cdef}	3.9^{abc}	4.7^{abcd}	31.6^{b}	$4,056^{bc}$	$1,611^{bcde}$	$1,028^{cde}$
SAMNUT 22	$65,667^{cd}$	33.5^{fg}	3.0^{e}	3.8^{ef}	10.7^{ef}	$3,222^{c}$	$1,056^{ef}$	731^{efgh}
CGS 269	$88,333^{a}$	49.0^{ab}	3.5^{bcde}	4.3^{bcdef}	15.3^{cdef}	$4,278^{abc}$	$1,833^{abc}$	$1,283^{abc}$
CGS 1272	$90,667^{a}$	46.0^{abcde}	3.8^{bcd}	4.7^{abcd}	11.7^{ef}	$4,889^{abc}$	$1,500^{cde}$	965^{defg}
K3237-80	$87,333^{ab}$	45.8^{abcde}	3.9^{abc}	4.9^{ab}	55.0^{a}	$4,389^{abc}$	$1,833^{abc}$	$1,227^{bcd}$
JL 24	$91,000^{a}$	54.0^{a}	4.5^{a}	5.1^{a}	18.0^{cde}	$4,667^{abc}$	$2,111^{ab}$	$1,476^{ab}$
ICGV 86003	$89,667^{a}$	54.1^{a}	4.1^{ab}	4.7^{abcd}	21.0^{c}	$4,056^{bc}$	$2,222^{a}$	$1,555^{a}$
28-206	$53,333^{ef}$	38.1^{efg}	3.0^{e}	3.8^{ef}	18.0^{cde}	$3,750^{bc}$	$1,194^{def}$	789^{efgh}
ICG 6902	$72,667^{c}$	37.0^{fg}	3.4^{cde}	4.2^{cdef}	16.7^{cdef}	$4,194^{abc}$	$1,617^{bcde}$	993^{cdefg}
ICGV-91225	$50,667^{f}$	46.2^{abcde}	3.2^{de}	4.0^{ef}	13.3^{cdef}	$5,111^{abc}$	$1,333^{cdef}$	765^{efgh}
ICGV-92087	$76,000^{bc}$	47.7^{abcd}	3.5^{bcde}	4.4^{bcde}	13.0^{def}	$4,833^{abc}$	$1,389^{cdef}$	878^{efgh}
ICGV 92099	$55,333^{def}$	41.1^{bcdef}	3.1^{e}	3.9^{ef}	15.3^{cdef}	$4,000^{bc}$	$1,167^{def}$	611^{h}
#3-94	$51,667^{f}$	38.4^{efg}	3.2^{de}	4.0^{ef}	16.3^{cdef}	$3,944^{bc}$	$1,833^{abc}$	704^{fgh}
NC.GP-343	$76,667^{bc}$	37.7^{efg}	3.4^{cde}	4.2^{cdef}	13.7^{cdef}	6111^{a}	$1,667^{abcd}$	987^{cdefg}
ICGMS 42	$54,000^{ef}$	39.8^{def}	3.1^{e}	3.9^{ef}	14.3^{cdef}	$5,111^{abc}$	$1,556^{bcde}$	$1,012^{cdef}$
Checks								
SAMNUT 11	$70,667^{c}$	38.8^{efg}	3.0^{e}	3.8^{ef}	15.7^{cdef}	$3,944^{bc}$	900^{f}	682^{gh}
55-437	$94,333^{a}$	53.8^{a}	4.1^{ab}	4.8^{abc}	10.0^{f}	$5,556^{ab}$	$1,556^{bcde}$	898^{efgh}
CV (%)	34.4	28.3	22.2	17.1	95.2	28.0	38.7	45.2
SE±	3.7	2.5	0.2	0.2	2.3	566.6	170.3	91.6

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

4.3 Samaru 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Samaru are presented in Table 7.

The results of the analysis of variance revealed that differences among genotypes were significant ($p \leq 0.05$) for *Cercospora* incidence, *Cercospora* severity at 75 DAS and at harvest; highly significant ($p \leq 0.01$) for plant height, fodder and pod yield (Appendix 3).

Plant stand varied from 69,333 plants/ha for SAMNUT 22 to 92,667 plants/ha for the genotype ICG 6902. Plant height ranged from 26.2 cm for the genotype NC-GP 343 to 43.8 cm for the genotype 55-437.

The genotypes #3-94 and ICGV 86003 had the lowest and the highest *Cercospora* severity scores, 3.3 and 5.5 at 75 DAS, respectively. At harvest, the scores varied from 4.2 for SAMNUT 10 to 7.5 for the genotype ICGV 86003. *Cercospora* incidence ranged from 41% for ICGV 91225 to 59% with the genotype K3237-80.

The genotypes ICGV 86003 and SAMNUT 10 showed the lowest and the highest levels of fodder yield, 2,634 kg/ha and 5,093 kg/ha, respectively. Pod yield varied from 480 kg/ha for the genotype 28-206 to 1,947 kg/ha for the genotype SAMNUT 23. Seed yield ranged from 190 kg/ha for the genotype 28-206 to 1,058 kg/ha for the genotype JL24.

Cercospora severity at 75 DAS and seed yield had the lowest and the highest CV, 0.3 and 79.5, respectively (Table 7).

Table 7. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Samaru

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	$70,667^{c}$	27.7^{f}	3.4^{f}	5.0^{ef}	54.3^{abcd}	$4,942^{a}$	827^{defg}	444^{de}
SAMNUT 23	$86,333^{abc}$	38.3^{bc}	4.6^{abcdef}	6.0^{abcde}	59.0^{ab}	$3,520^{abc}$	$1,947^{a}$	991^{ab}
SAMNUT 10	$75,333^{abc}$	26.0^{f}	3.5^{def}	4.2^{f}	44.3^{cd}	$5,093^{a}$	853^{defg}	404^{de}
SAMNUT 18	$85,667^{abc}$	38.3^{bc}	5.6^{a}	6.8^{abcd}	57.0^{abc}	$2,365^{c}$	$1,369^{bc}$	764^{bc}
SAMNUT 22	$69,333^{c}$	30.5^{def}	4.0^{bcdef}	5.2^{def}	48.3^{abcd}	$3,747^{abc}$	805^{defg}	385^{de}
CGS 269	$74,667^{bc}$	33.3^{cde}	4.4^{abcdef}	5.6^{bcdef}	53.0^{abcd}	$2,853^{bc}$	$1,351^{c}$	882^{ab}
CGS 1272	$86,333^{abc}$	33.6^{bcde}	4.8^{abcde}	5.8^{bcdef}	46.6^{abcd}	$3,298^{bc}$	$1,013^{cdef}$	554^{cd}
K3237-80	$80,667^{abc}$	36.6^{bc}	5.4^{ab}	7.0^{ab}	59.3^{a}	$3,049^{bc}$	$1,369^{bc}$	784^{bc}
JL 24	$83,000^{abc}$	38.7^{b}	5.3^{abc}	7.0^{abc}	45.0^{cd}	$2,809^{bc}$	$1,778^{ab}$	$1,053^{a}$
ICGV 86003	$75,333^{abc}$	37.9^{bc}	5.5^{a}	7.5^{a}	54.6^{abcd}	$2,364^{c}$	$1,218^{cd}$	$1,006^{ab}$
28-206	$70,000^{c}$	27.9^{f}	3.7^{def}	4.6^{ef}	51.0^{abcd}	$3,644^{abc}$	480^{g}	190^{e}
ICG 6902	$92,667^{a}$	34.8^{bcd}	4.4^{abcdef}	5.7^{bcdef}	42.6^{d}	$3,689^{abc}$	800^{defg}	478^{d}
ICGV-91225	$74,000^{bc}$	34.6^{bcd}	3.8^{cdef}	4.4^{ef}	41.0^{d}	$4,009^{abc}$	738^{efg}	360^{de}
ICGV-92087	$76,000^{abc}$	33.2^{cde}	5.2^{abc}	5.8^{abcdef}	48.3^{abcd}	$3,627^{abc}$	773^{defg}	399^{de}
ICGV 92099	$84,000^{abc}$	34.8^{bcd}	5.0^{abcd}	6.0^{abcdef}	45.3^{bcd}	$4,080^{ab}$	$1,101^{cde}$	583^{cd}
#3-94	$76,000^{abc}$	29.1^{ef}	3.3^{f}	5.2^{ef}	44.6^{cd}	$3,307^{bc}$	622^{fg}	338^{de}
NC.GP-343	$76,333^{abc}$	26.2^{f}	3.6^{def}	4.9^{ef}	42.3^{d}	$3,058^{bc}$	693^{fg}	354^{de}
ICGMS 42	$91,000^{ab}$	35.1^{bcd}	3.7^{def}	5.3^{cdef}	47.6^{abcd}	$4,169^{ab}$	747^{efg}	361^{de}
Checks								
SAMNUT 11	$73,333^{c}$	30.4^{def}	4.0^{bcdef}	4.9^{ef}	54.0^{abcd}	$4,293^{b}$	818^{defg}	409^{de}
55-437	$80,333^{abc}$	43.8^{a}	5.7^{a}	7.2^{ab}	42.6^{d}	$2,662^{bc}$	989^{defg}	486^{d}
CV (%)	15.1	24.5	0.3	29.3	20.5	37.5	66.0	79.5
SE±	5.1	1.5	0.4	0.5	4.0	481.6	136.4	78.0

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

4.4 Guiring 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Guiring are presented in Table 8.

The results of the analysis of variance showed significant ($p \leq 0.05$) differences among genotypes for plant height and seed yield and highly significant ($p \leq 0.01$) differences for plant height, *Cercospora* severity at harvest, *Cercospora* incidence, fodder and pod yield (Appendix 4).

Plant stand ranged from 81,000 plants/ha for ICGMS 42 to 97,667 plants/ha for the genotype JL24. Plant height varied from 30.7 cm for the genotype SAMNUT 21 to 53.8 cm for the genotype 55-437.

Cercospora severity scores ranged from 3.4 for ICGV 91225 to 5.4 with ICGMS 42 at 75 DAS. At harvest, the scores varied from 4.9 for ICGV 6902 to 7.9 for the genotypes JL24 and K3237-80. The genotypes ICG 6902 and SAMNUT 18 had the lowest and the highest *Cercospora* incidence, 40% and 62%, respectively.

Fodder yield varied from 3,000 kg/ha for SAMNUT 18 to 6,400 kg/ha in the genotype CGS 1272. Pod yield ranged from 1,394 kg/ha for SAMNUT 21 to 2,822 kg/ha for the genotype ICGV 86003. The genotypes ICG 6902 and ICGV 86003 showed the lowest and the highest levels of seed yield, 677 kg/ha and 1,690 kg/ha, respectively.

The CV varied from 8.9 for plant stand to 44.7 for seed yield (Table 8).

Table 8. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	83,333^{bcd}	30.7^{g}	4.6^{abcd}	5.8^{cdef}	45.3^{fgh}	4,028^{defg}	1,944^{bcdef}	841^{cde}
SAMNUT 23	91,333^{abcd}	48.3^{abc}	5.2^{ab}	7.8^{a}	55.3^{abcde}	4,583^{bcdef}	2,306^{bc}	899^{cde}
SAMNUT 10	93,667^{ab}	34.9^{fg}	4.2^{abcd}	6.0^{cde}	49.3^{efg}	4,600^{bcdef}	1,833^{cdef}	1,001^{cde}
SAMNUT 18	91,000^{abcd}	40.1^{cdef}	4.5^{abcd}	7.7^{a}	62.0^{a}	3,000^{g}	1,778^{cdef}	1,017^{cde}
SAMNUT 22	90,000^{abcd}	33.5^{fg}	4.2^{abcd}	5.7^{cdef}	48.0^{efg}	5,667^{abc}	1,667^{def}	825^{cde}
CGS 269	88,000^{abcd}	49.0^{ab}	3.9^{cd}	6.5^{bc}	54.7^{abcde}	4,556^{bcdef}	2,000^{bcde}	1,139^{cd}
CGS 1272	90,667^{abcd}	46.0^{abcde}	5.1^{abc}	6.6^{bc}	55.3^{abcde}	6,400^{a}	2,044^{bcd}	1,073^{cde}
K3237-80	89,333^{abcd}	45.8^{abcde}	4.3^{abcd}	7.9^{a}	57.7^{abcd}	3,294^{fg}	1,817^{cdef}	1,039^{cde}
JL 24	97,667^{a}	54.0^{a}	5.1^{abc}	7.9^{a}	61.0^{ab}	3,650^{efg}	2,461^{ab}	1,584^{ab}
ICGV 86003	87,333^{abcd}	54.1^{a}	4.0^{bcd}	7.5^{a}	59.3^{abc}	4,400^{cdef}	2,822^{a}	1,690^{a}
28-206	95,000^{a}	38.1^{efg}	4.4^{abcd}	6.5^{bc}	52.3^{cdef}	4,933^{bcde}	1,478^{ef}	891^{cde}
ICG 6902	82,333^{cd}	37.0^{fg}	4.3^{abcd}	4.9^{e}	40.3^{h}	5,956^{ab}	1,489^{def}	677^{e}
ICGV-91225	88,333^{abcd}	46.2^{abcde}	3.4^{d}	5.8^{cdef}	52.7^{cdef}	5,683^{abc}	1,650^{def}	814^{cde}
ICGV-92087	96,333^{a}	47.7^{abcd}	5.0^{abc}	7.0^{ab}	55.3^{abcde}	5,911^{ab}	1,533^{def}	912^{cde}
ICGV 92099	94,667^{a}	41.1^{bcdef}	4.8^{abc}	7.1^{ab}	59.7^{abc}	5,678^{abc}	1545^{def}	845^{cde}
#3-94	88,000^{abcd}	38.4^{efg}	4.7^{abc}	5.2^{ef}	49.7^{defg}	5,739^{abc}	1,594^{def}	802^{cde}
NC.GP-343	93,000^{abc}	37.7^{efg}	4.4^{abcd}	5.3^{def}	44.3^{gh}	5,867^{abc}	1,911^{cdef}	1076^{cde}
ICGMS 42	81,000^{d}	39.8^{def}	5.4^{a}	6.2^{bcd}	53.0^{bcdef}	4,650^{bcdef}	1,795^{cdef}	936^{cde}
Checks								
SAMNUT 11	87,667^{abcd}	38.8^{efg}	4.2^{abcd}	6.6^{bc}	54.0^{abcde}	4,606^{bcdef}	1,394^{f}	727de
55-437	95,333^{a}	53.8^{a}	4.4^{abcd}	7.6^{a}	58.3^{abc}	5,389^{abcd}	1,944^{bcdef}	1,235^{bc}
CV (%)	8.9	30.5	19.1	25.0	18.8	33.5	33.4	44.7
SE±	3.2	1.8	0.4	0.3	2.4	453.9	162.5	132.5

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

4.5 Samaru and Guiring 2001

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity and incidence, fodder, pod and seed yield (kg/ha) of the 20 groundnut genotypes tested in 2001 at Samaru and Guiring are presented in Table 9.

The results of the analysis of variance showed highly significant ($p \leq 0.01$) differences between locations for all characters studied except for *Cercospora* incidence. Diffferences among genotypes were significant ($p \leq 0.05$) for fodder and pod yield, highly significant ($p \leq 0.01$) for plant stand, plant height, *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence and seed yield. The interaction genotype x location was significant ($p \leq 0.05$) for plant stand, *Cercospora* severity at harvest, *Cercospora* incidence and fodder yield (Appendix 5).

Plant stand varied from 41,833 plants/ha for ICGV 91225 to 81,167 plants/ha for the genotype 55-437. Plant height ranged from 23.3 cm for the genotype SAMNUT 21 to 43.6 cm for the genotype 55-437.

Cercospora leaf spot severity scores varied from 2.8 for SAMNUT 21 and 28-206 to 4.4 for the genotype JL24. At harvest, the genotypes 28-206 and SAMNUT 18 showed the lowest and the highest disease scores, 3.4 and 4.8, respectively. *Cercospora* incidence ranged from 7.2% for 55-437 to 46.3% for the genotype K3237-80.

Fodder yield varied from 2,918.9 kg/ha for ICGV 86003 to 5.151.1 kg/ha for the genotype NC-GP 343. The genotypes 28-206 and JL24 had the lowest and the highest levels of pod yield, 808.3 kg/ha and 1853.3 kg/ha, respectively. Seed yield varied from 398.8 kg/ha for the genotype #3-94 to 1,110.7 kg/ha for the genotype ICGV 86003.

Table 9. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 at Samaru and Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	56,167 ^{efg}	23.3 ^{k}	2.8 ^{e}	3.6 ^{fg}	21.7 ^{cd}	4,007.8 ^{abcd}	925.5 ^{de}	618.7 ^{defgh}
SAMNUT 23	61,500 ^{cdefg}	37.2 ^{cde}	2.9 ^{e}	3.6 ^{fg}	16.8 ^{def}	3,915.0 ^{bcd}	1,654.0 ^{ab}	783.4 ^{cde}
SAMNUT 10	65,333 ^{bcdef}	26.8 ^{jk}	2.9 ^{e}	3.8 ^{defg}	19.0 ^{cde}	4,088.3 ^{abcd}	982.8 ^{de}	586.0 ^{efghi}
SAMNUT 18	70,833 ^{abcde}	33.1 ^{defgh}	3.8 ^{bc}	4.8 ^{a}	34.8 ^{b}	3,025.5 ^{cd}	1,350.0 ^{bcd}	758.2 ^{cde}
SAMNUT 22	54,167 ^{fgh}	27.4 ^{ijk}	3.0 ^{e}	3.7 ^{defg}	18.5 ^{cde}	3,773.3 ^{bcd}	921.1 ^{de}	565.3 ^{efghi}
CGS 269	77,167 ^{ab}	37.6 ^{cd}	3.3 ^{cde}	3.9 ^{defg}	19.3 ^{cde}	3,605.6 ^{bcd}	1,458.9 ^{abc}	986.1 ^{ab}
CGS 1272	69,500 ^{abcde}	36.4 ^{cdef}	3.6 ^{cde}	4.3 ^{bcd}	22.0 ^{cd}	4,202.2 ^{abc}	1,245.6 ^{bcde}	749.3 ^{cdef}
K3237-80	70,833 ^{abcde}	36.4 ^{cdef}	3.8 ^{bc}	4.7 ^{ab}	46.3 ^{a}	3,921.1 ^{bcd}	1,536.7 ^{abc}	857.7 ^{bcd}
JL 24	71,500 ^{abcd}	43.0 ^{a}	4.4 ^{a}	4.6 ^{abc}	13.0 ^{def}	3,362.2 ^{bcd}	1,853.3 ^{a}	1,082.4 ^{ab}
ICGV 86003	74,000 ^{abc}	42. 1 ^{ab}	4.1 ^{ab}	4.6 ^{abc}	16.0 ^{cdef}	2,918.9 ^{d}	1,820.0 ^{a}	1,110.7 ^{a}
28-206	57,833 ^{defg}	29.9 ^{ghi}	2.8 ^{e}	3.4 ^{g}	18.3 ^{cde}	3,566.1 ^{bcd}	808.3 ^{e}	472.4 ^{ghi}
ICG 6902	61,667 ^{cdefg}	31.9 ^{fghi}	2.9 ^{e}	4.0 ^{def}	14.5 ^{cdef}	3,808.3 ^{bcd}	1,246.1 ^{bcde}	718.8 ^{cdef}
ICGV-91225	41,833 ^{h}	34.8 ^{cdefg}	3.0 ^{e}	3.9 ^{defg}	9.8 ^{ef}	3,586.7 ^{bcd}	837.8 ^{e}	449.3 ^{hi}
ICGV-92087	69,833 ^{abcde}	38.2 ^{bc}	3.0 ^{e}	4.1 ^{cdef}	15.8 ^{cdef}	4,385.5 ^{ab}	1,314.5 ^{bcd}	672.2 ^{defgh}
ICGV 92099	61,000 ^{cdefg}	32.7 ^{efgh}	3.1 ^{de}	3.9 ^{defg}	18.5 ^{cde}	3,357.8 ^{bcd}	983.4 ^{de}	496.5 ^{fghi}
#3-94	53,000 ^{fgh}	28.7 ^{hij}	3.2 ^{de}	4.2 ^{bcde}	15.2 ^{cdef}	3,012.2 ^{cd}	1,158.9 ^{de}	398.6 ^{i}
NC GP-343	66,167 ^{abcdef}	29.2 ^{hij}	3.1 ^{de}	3.9 ^{defg}	14.8 ^{cdef}	5,151.1 ^{a}	1,142.2 ^{cde}	660.3 ^{defgh}
ICGMS 42	48,667 ^{gh}	30.4 ^{ghij}	3.1 ^{de}	3.8 ^{defg}	17.8 ^{cde}	4,077.8 ^{abcd}	988.9 ^{de}	606.0 ^{defghi}
Checks								
SAMNUT 11	67,000 ^{abcdef}	30.6 ^{ghij}	2.9 ^{e}	3.6 ^{efg}	24.0 ^{c}	4,090.0 ^{abcd}	941.1 ^{de}	607.9 ^{defghi}
55-437	80,167 ^{a}	43.6 ^{a}	3.8 ^{bc}	4.6 ^{abc}	7.2 ^{f}	4,162.2 ^{abcd}	1,333.3 ^{bcd}	671.4 ^{defgh}
CV (%)	37.6	40.8	34.5	24.7	472.9	148.3	63.1	69.7
SE±	6.2	2.1	4.3	0.2	4.4	519.5	196.4	108.2

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

The CV ranged from 24.7% for *Cercospora* severity at harvest to 472.9% for *Cercospora* incidence (Table 9).

4.6 Samaru and Guiring 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Samaru and Guiring are presented in Table 10.

The results of the analysis of variance showed significant ($p \leq 0.05$) differences among locations for plant height, highly significant ($p \leq 0.01$) differences for plant stand, *Cercospora* severity at harvest, fodder, pod and seed yield. Differences among genotypes were significant ($p \leq 0.05$) for *Cercospora* severity at 75 DAS and highly significant ($p \leq 0.01$) for plant height, *Cercospora* severity at harvest, fodder, pod and seed yield. The interaction between genotype and location was significant ($p \leq 0.05$) for plant stand, *Cercospora* severity at 75 DAS, *Cercospora* incidence, pod and seed yield, and highly significant ($p \leq 0.01$) for fodder yield (Appendix 6).

Mean plant stand ranged from 77,000 plants/ha for SAMNUT 21 to 90,333 plants/ha for the genotype JL24. Plant height varied from 26.5 cm for the genotype NC-GP 343 to 44.2 cm for the genotype 55-437.

Cercospora severity scores ranged form 2.3 for CGS 269 and #3-94 to 3.4 in the genotype ICGV 86003 at 75 DAS. At harvest, the genotypes ICGV 91225 and JL24 had the lowest and highest disease scores, 3.6 and 5.2, respectively. *Cercospora* incidence varied from 41.5% for ICG 6902 to 59.5% with the genotype SAMNUT 18.

Table 10. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2002 at Samaru and Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	77,000^{c}	26.8^{i}	2.6^{bcd}	4.0^{def}	49.8^{cde}	4,485.0^{ab}	1,385.5^{bcdef}	642.3^{def}
SAMNUT 23	88,833^{ab}	36.6^{bcd}	2.5^{bcd}	4.9^{abcd}	57.2^{abc}	4,051.2^{abc}	2,126.1^{a}	945.1^{bc}
SAMNUT 10	84,500^{abc}	26.4^{i}	2.3^{d}	3.9^{ef}	46.8^{def}	4,846.7^{a}	1,343.4^{bcdef}	702.3^{cdef}
SAMNUT 18	88,333^{ab}	36.8^{bcd}	2.8^{abc}	5.0^{abc}	59.5^{a}	2,682.2^{e}	1,573.4^{bcd}	990.4^{bcd}
SAMNUT 22	79,667^{bc}	29.8^{ghi}	2.4^{d}	4.1^{cdef}	48.2^{def}	4,706.7^{ab}	1,235.6^{defg}	604.6^{ef}
CGS 269	81,333^{abc}	31.9^{efgh}	2.3^{d}	4.2^{bcdef}	53.8^{abcd}	3,704.5^{bcd}	1,675.5^{b}	1,010.5^{b}
CGS 1272	88,500^{ab}	32.6^{efg}	2.7^{abcd}	4.9^{abcd}	51.0^{bcde}	4,848.9^{d}	1,528.9^{bcde}	813.6^{bcde}
K3237-80	85,000^{abc}	35.9^{cd}	2.7^{abcd}	4.9^{abcd}	58.5^{ab}	3,171.7^{de}	1,592.8^{bc}	911.2^{bc}
JL 24	90,333^{a}	40.1^{b}	2.4^{bcd}	5.2^{a}	53.0^{abcd}	3,229.5^{de}	2,119.4^{a}	1,318.3^{a}
ICGV 86003	81,333^{abc}	38.8^{bc}	3.1^{a}	4.7^{abcde}	57.0^{abc}	3,382.2^{cde}	2,020.0^{a}	1,347.6^{a}
28-206	82,500^{abc}	28.0^{hi}	2.4^{cd}	4.1^{cdef}	51.7^{bcd}	4,288.9^{abc}	978.9^{g}	540.4^{f}
ICG 6902	87,500^{ab}	30.1^{ghi}	2.6^{bcd}	4.3^{abcdef}	41.5^{f}	4,822.2^{a}	1,144.4^{fg}	577.5^{ef}
ICGV-91225	81,167^{abc}	34.2^{de}	2.5^{cd}	3.6^{f}	46.8^{def}	4,846.1^{a}	1,193.9^{efg}	586.6^{ef}
ICGV-92087	86,167^{abc}	34.4^{def}	2.5^{cd}	5.1^{ab}	51.8^{abcd}	4,768.9^{ab}	1,193.4^{fg}	655.8^{def}
ICGV 92099	89,333^{ab}	33.9^{def}	2.6^{bcd}	4.9^{abcd}	52.5^{abcd}	4,678.9^{a}	1,367.8^{bcdef}	714.0^{cdef}
#3-94	82,000^{abc}	28.2^{f}	2.3^{d}	4.0^{def}	47.2^{def}	4,522.8^{ab}	1,108.3^{fg}	569.5ef
NC.GP-343	84,663^{abc}	26.5^{i}	2.5^{bcd}	4.0^{def}	43.3^{ef}	4,462.2^{ab}	1,302.2^{cdefg}	715.1^{cdef}
ICGMS 42	86,000^{abc}	33.0^{defg}	2.6^{bcd}	4.6^{abcdef}	50.3^{de}	4,409.2^{ab}	1,270.6^{cdefg}	648.4^{def}
Checks								
SAMNUT 11	80,500^{abc}	29.6^{ghi}	2.3^{d}	4.1cdef	54.0^{abcd}	4,449.4^{ab}	1,106.1^{fg}	568.0^{ef}
55-437	87,833^{ab}	44.2^{a}	2.9^{ab}	5.0^{abc}	50.5^{cde}	4,025.6^{abcd}	1,421.1^{bcdef}	860.9^{bcd}
CV (%)	10.9	36.3	27.4	35.8	22.8	38.2	57.4	73.8
SE±	4.2	1.7	0.4	0.4	3.3	459.3	150.0	108.8

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

Fodder yield ranged from 2,682.2 kg/ha for SAMNUT 18 to 4,846.1 kg/ha for The genotype ICGV 91225. The genotypes 28-206 and SAMNUT 23 showed the lowest and the highest levels of pod yield, 978.9 gk/ha and 2,126.1 kg/ha, respectively. Seed yield ranged from 540.4 kg/ha for 28-206 to 1347.6 kg/ha with the genotype ICGV 86003.

The CV varied from 10.9% for plant stand to 73.8% for seed yield (Table 10).

4.7 Samaru 2001 and 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Samaru are presented in Table 11.

The results of the analysis of variance showed that differences between years were significant ($p \leq 0.05$) for fodder yield, highly significant ($p \leq 0.01$) for plant stand, plant height, *Cercospora* incidence, *Cercospora* severity at 75 DAS and at harvest. Differences among genotypes were highly significant ($p \leq 0.01$) for all characters studied except for plant stand. The interaction between genotype and year was significant ($p \leq 0.05$) for plant stand and plant height (Appendix 7).

Plant stand combined over years ranged from 53,500 plants/ha for ICGC 91225 to 75,667 plants/ha for SAMNUT 18. Plant height varied from 21.8 cm for SAMNUT 21 to 38.6 cm for the genotype 55-437.

Cercospora severity scores ranged from 3.0 for SAMNUT 10 to 4.8 with the genotypes JL24 and ICGV 86003 at 75 DAS. At harvest, the genotypes 28-206 and ICGV 86003 had the lowest and the highest disease scores, 3.8 and 6.0, respectively.

Table 11. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Samaru

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	59,167^{bcd}	21.8^{k}	3.1^{f}	4.3^{ef}	42.2^{abc}	3951^{abcd}	700^{fgh}	366^{defg}
SAMNUT 23	67,333^{abcd}	32.1^{bcd}	3.7^{def}	4.6^{def}	38.0^{abcd}	3523^{bcdef}	1780^{a}	785^{ab}
SAMNUT 10	65,833^{abcd}	22.3^{jk}	3.0^{f}	3.9^{ef}	32.2^{bcde}	4927^{a}	784^{fgh}	369^{defg}
SAMNUT 18	75,667^{a}	32.2^{bcd}	4.7^{abc}	5.9^{a}	47.5^{a}	2180^{gh}	1229^{cd}	627^{bc}
SAMNUT 22	56,000^{cd}	25.9^{ghij}	3.5^{ef}	4.4^{ef}	37.3^{abcd}	4036^{abc}	796^{efgh}	392^{cdef}
CGS 269	70,333^{abc}	29.7^{def}	3.8^{cdef}	4.6^{def}	38.2^{abcd}	2853^{defgh}	1218^{cde}	785^{ab}
CGS 1272	67,333^{abcd}	30.2^{cdef}	4.2^{abcde}	4.9^{bcdef}	39.5^{abcd}	3407^{bcdef}	1002^{cdef}	544^{cd}
K3237-80	67,500^{abcd}	31.8^{bcde}	4.5^{abcd}	5.8^{ab}	48.5^{a}	3251^{bcdefg}	1305^{bc}	636^{abc}
JL 24	67,500^{abcd}	35.4^{ab}	4.8^{a}	5.6^{abcd}	26.5^{de}	2433^{fgh}	1687^{ab}	871^{a}
ICGV 86003	66,833^{abcd}	33.9^{bc}	4.8^{a}	6.0^{a}	32.8^{bcde}	2064^{h}	1318^{bc}	836^{ab}
28-206	66,167^{abcd}	24.9^{hijk}	3.2^{ef}	3.8^{f}	34.8^{bcde}	3513^{bcdef}	451^{h}	173^{g}
ICG 6902	71,667^{abc}	30.8^{cde}	3.4^{ef}	4.7^{cdef}	27.5^{de}	3556^{bcdef}	838^{defgh}	461^{cdef}
ICGV-91225	53,500^{d}	29.0^{defg}	3.3^{ef}	4.1^{ef}	23.7^{e}	3036^{cdefgh}	540^{gh}	246^{efg}
ICGV-92087	69,833^{abc}	31.0^{cde}	3.9^{bcdef}	4.9^{bcdef}	33.5^{bcde}	3782^{bcde}	1007^{cdef}	433^{cdef}
ICGV 92099	75,333^{ab}	29.6^{defg}	4.0^{abcdef}	5.0^{abcde}	33.5^{bcde}	3398^{bcdef}	996^{cdef}	482^{cde}
#3-94	65,167^{abcd}	24.0^{ijk}	3.3^{ef}	4.8^{bcdef}	29.3^{cde}	2693^{efgh}	553^{gh}	215^{fg}
NC GP-343	66,000^{abcd}	23.4^{ijk}	3.2^{f}	4.3^{ef}	29.2^{cde}	3625^{bcde}	656^{fgh}	344^{defg}
ICGMS 42	67,167^{abcd}	28.1^{efgh}	3.4^{ef}	4.5^{ef}	34.5^{bcde}	3607^{bcde}	585^{fgh}	280^{efg}
Checks								
SAMNUT 11	68,333^{abcd}	26.4^{fghi}	3.4^{ef}	4.2^{ef}	43.2^{ab}	4264^{ab}	900^{cdefg}	471^{cde}
55-437	73,167^{ab}	38.6^{a}	4.6^{abc}	5.7^{abc}	23.5^{e}	2716^{efgh}	1005^{cdef}	465^{cde}
CV (%)	20.5	37.7	39.2	33.9	50.4	52.0	93.1	104.4
SE±	6.1	1.73	0.4	0.4	5.4	475.6	182.7	101.0

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

Cercospora incidence ranged from 23.5% for 55-437 to 48.5% for the genotype K3237-80.

Fodder yield varied from 2,064 kg/ha for ICGV 86003 to 4,927 kg/ha with the genotype SAMNUT 10. The genotypes 28-206 and SAMNUT 23 showed the lowest and the highest levels of pod yield, 451 kg/ha and 1,780 kg/ha, respectively. Seed yield ranged from 173 kg/ha for 28-206 to 871 kg/ha for the genotype JL24.

The CV varied from 20.5% for plant stand to 104.5% for seed yield (Table 11).

4.8 Guiring 2001 and 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leafspot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Guiring are presented in Table 12.

The results of the analysis of variance revealed significant ($p \leq 0.05$) differences between years for fodder yield, highly significant ($p \leq 0.01$) differences for plant stand, plant height, *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence and pod yield. Differences among genotypes were significant ($p \leq 0.05$) for *Cercospora* severity at 75 DAS and highly significant ($p \leq 0.01$) for *Cercospora* at harvest, *Cercospora* incidence, fodder, pod and seed yield. The interaction between genotype and year was significant ($p \leq 0.05$) for *Cercospora* severity at 75 DAS, *Cercospora* incidence and fodder yield, highly significant ($p \leq 0.01$) for plant stand, plant height and *Cercospora* severity at harvest (Appendix 8).

Plant stand ranged from 67,500 plants/ha for ICGMS 42 to 94,833 plants/ha with the genotype 55-437. Plant height varied from 28.3 cm for the genotype SAMNUT 21 to 42.9 cm for the genotype 55-437.

Table 12. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	74,000 ^{ef}	28.3^{h}	3.7^{bcd}	4.7^{ij}	29.3^{fgh}	4542^{bcdefg}	1611^{cdefg}	366^{defg}
SAMNUT 23	83,000 ^{bcd}	41.6^{b}	4.2^{abc}	5.9^{bcde}	36.0^{cde}	4444^{cdefg}	2000^{bc}	785^{ab}
SAMNUT 10	84,000 ^{bcd}	30.9^{gh}	3.8^{bcd}	5.1^{ghij}	34.5^{defg}	4008^{efg}	1542^{defg}	369^{defg}
SAMNUT 18	83,500 ^{bcd}	37.7^{bcde}	4.2^{abc}	6.2^{abc}	46.8^{b}	3528^{g}	1695^{cdefg}	627^{bc}
SAMNUT 22	77,833 ^{de}	31.3^{gh}	3.6^{cd}	4.7^{ij}	29.3^{fgh}	4444^{cdefg}	1362^{fgh}	392^{cdef}
CGS 269	88,167 ^{ab}	39.7^{bc}	3.7^{bcd}	5.4^{efgh}	35.0^{cde}	4417^{cdefg}	1917^{cd}	785^{ab}
CGS 1272	90,667 ^{ab}	38.2^{bcd}	4.4^{ab}	5.6^{def}	33.5^{efgh}	5644^{ab}	1772^{cde}	544^{cd}
K3237-80	88,333 ^{ab}	40.5^{b}	4.1^{abc}	6.4^{ab}	56.3^{a}	3842^{fg}	1825^{cde}	636^{abc}
JL 24	94,333 ^{a}	47.7^{a}	4.8^{a}	6.5^{a}	39.5^{cd}	4158^{efg}	2286^{ab}	871^{a}
ICGV 86003	88,500 ^{ab}	46.9^{a}	4.1^{abc}	6.1^{abcd}	40.2^{d}	4228^{defg}	2522^{a}	836^{ab}
28-206	74,167 ^{ef}	33.1^{efgh}	3.7^{bcd}	5.2^{fghi}	35.2^{cde}	4342^{cdefg}	1336^{gh}	173^{g}
ICG 6902	77,500 ^{de}	31.3^{gh}	3.8^{bcd}	4.5^{j}	28.5^{h}	5075^{abcde}	1553^{defg}	461^{cdef}
ICGV-91225	69,500 ^{f}	40.0^{bc}	3.3^{d}	4.9^{hij}	33.0^{efgh}	5397^{abcd}	1492^{efgh}	246^{efg}
ICGV-92087	86,167 ^{bc}	41.6^{b}	4.3^{abc}	5.7^{cdef}	34.2^{defg}	5372^{abcd}	1461^{efgh}	433^{cdef}
ICGV 92099	75,000 ^{ef}	36.9^{bcdef}	3.9^{bcd}	5.5^{efg}	37.5^{cde}	4839^{abcdef}	1356^{gh}	482^{cde}
#3-94	69,833\ ^{f}	32.9^{efgh}	3.9^{bcd}	4.6^{j}	33.0^{efgh}	4842^{abcdef}	1714^{cdefg}	215^{fg}
NC.GP-343	84,833 ^{bcd}	32.3^{fgh}	3.9^{bcd}	4.8^{ij}	29.0^{gh}	5989^{a}	1789^{cde}	344^{defg}
ICGMS 42	67,500 ^{f}	35.4^{cdefg}	4.3^{abc}	5.1^{ghij}	33.7^{efgh}	4881^{abcdef}	1675^{cdefg}	280^{efg}
Checks								
SAMNUT 11	79,167 ^{cde}	33.8^{defg}	3.6^{cd}	5.2^{fghi}	34.8^{cdef}	4275^{cdefg}	1147^{h}	471^{cde}
55-437	94,833 ^{a}	49.2^{a}	4.2^{abc}	6.2^{abc}	34.2^{defg}	5472^{abc}	1750^{cdef}	465^{cde}
CV (%)	24.6	38.9	20.8	28.5	44.5	34.4	47.2	60.7
SE±	3.5	2.2	0.3	0.2	2.3	498.8	166.4	113.8

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

The genotypes ICGV 91225 and JL24 had the lowest and the highest *Cercospora* severity scores, 3.3 and 4.8 at 75 DAS, respectively. At harvest, the scores ranged from 4.5 for ICG 6902 to 6.5 in the genotype JL24. *Cercospora* incidence varied from 28.5% for ICG 6902 to 56.3% in the genotype K3237-80.

Fodder yield ranged from 3,528 kg/ha for SAMNUT 18 to 5,989 kg/ha for the genotype NC-GP 343. The genotypes SAMNUT 11 and ICGV 86003 had the lowest and the highest levels of pod yield, 1,147 kg/ha and 2,522 kg/ha, respectively.Seed yield ranged from 173 kg/ha for the genotype 28-206 to 871 kg/ha for the genotype ICGV 86003.

The CV varied from 20.8% for *Cercospora* severity at 75 DAS to 60.7% for seed yield (Table 12).

4.9 Samaru and Guiring 2001 and 2002

Mean plant stand (plants/ha), plant height (cm), *Cercospora* leafspot severity and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Samaru and Guiring are presented in Table 13.

The results of the analysis of variance showed that differences between locations were significant ($p \leq 0.05$) for *Cercospora* severity at 75 DAS and highly significant ($p \leq 0.05$) for plant stand, plant height, *Cercospora* severity at harvest, fodder, pod and seed yield. Differences between years were significant ($p \leq 0.05$) for plant height, fodder and seed yield, highly significant ($p \leq 0.01$) for plant stand, *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence and pod yield. Differences among genotypes were highly significant ($p \leq 0.01$) for all characters studied (Appendix 9).

Table 13. Mean plant stand (plants/ha), plant height (cm), *Cercospora* leaf spot severity scores and incidence, fodder, pod and seed yield (kg/ha) for 20 groundnut genotypes tested in 2001 and 2002 at Samaru and Guiring

Genotypes	Plant stand (plants/ha)	Plant height (cm)	*Cercospora* severity		*Cercospora* incidence	Fodder yield (kg/ha)	Pod yield (kg/ha)	Seed yield (kg/ha)
			75 DAS	Harvest				
SAMNUT 21	66,583^{ef}	25.1^{j}	3.4^{ef}	4.5^{d}	35.8^{bcd}	4,246.4^{abcd}	1,155.5^{defg}	630.5^{efgh}
SAMNUT 23	75,167^{bcde}	36.9^{c}	3.9^{bcde}	5.2^{bc}	[illegible]	3,983.3^{abcde}	1,890.1^{a}	864.3^{bc}
SAMNUT 10	74,917^{bcde}	26.6^{ij}	3.4^{ef}	4.5^{d}	46	4,467.5^{abc}	1,163.1^{defg}	644.1^{efgh}
SAMNUT 18	79,583^{ab}	34.9^{cd}	4.4^{ab}	6.1^{a}	47.2^{a}	2,853.9^{g}	1,461.7^{bc}	824.3^{cd}
SAMNUT 22	66,917^{def}	28.6^{ghi}	3.5^{def}	4.5^{d}	33.3^{bcde}	4,240.0^{abcd}	1,078.3^{efg}	584.9^{fgh}
CGS 269	79,250^{ab}	34.7^{cde}	3.9^{cdef}	4.9^{bcd}	[illegible]	3,655.0^{cdef}	1,567.2^{b}	998.3^{b}
CGS 1272	79,000^{ab}	34.2^{cde}	4.3^{abc}	5.2^{bc}	45	4,525.5^{ab}	1,387.2^{bcd}	781.5^{cde}
K3237-80	77,917^{abc}	36.1^{cd}	4.3^{abc}	6.1^{a}	52.4^{a}	3,546.4^{defg}	1,564.7^{b}	884.5^{bc}
JL 24	80,917^{ab}	41.5^{ab}	4.8^{a}	6.0^{a}	33.0^{bcde}	3,295.8^{efg}	1,986.4^{a}	1,200.3^{a}
ICGV 86003	77,667^{abc}	40.4^{b}	4.4^{ab}	6.1^{a}	36.5^{bc}	3,150.6^{fg}	1,920.0^{a}	1,229.1^{a}
28-206	70,167^{cde}	29.0^{ghi}	3.4^{ef}	4.5^{d}	35.0^{bcde}	3,927.5^{abcdef}	893.6^{g}	506.4^{gh}
ICG 6902	74,588^{bcde}	31.0^{fgh}	3.6^{def}	4.6^{cd}	28.0^{e}	4,315.3^{abcd}	1,195.3^{cdefg}	648.1^{efgh}
ICGV 91225	61,500^{f}	34.5^{cde}	3.3^{f}	4.5^{d}	28.3^{e}	4,216.4^{abcd}	1,015.8^{fg}	517.9^{gh}
ICGV-92087	78,000^{abc}	36.3^{cd}	4.1^{bcd}	5.3^{b}	33.8^{bcde}	4,577.2^{ab}	1,233.9^{cdef}	664.0^{efgh}
ICGV 92099	75,167^{bcde}	33.3^{def}	3.9^{cde}	5.2^{bc}	35.5^{bcd}	4,118.3^{abcde}	1,175.6^{cdefg}	605.2^{efgh}
#3-94	67,500^{def}	28.4^{hi}	3.6^{def}	4.7^{bcd}	33.2^{cde}	3,767.5^{abcdef}	1,133.6^{defg}	484.0^{h}
NC.GP-343	75,417^{abcd}	27.9^{hi}	3.5^{def}	4.5^{d}	29.1^{de}	4,806.7^{a}	1,222.2^{cdef}	687.7^{defg}
ICGMS 42	67,3333^{def}	31.7^{efg}	3.8^{bcdef}	4.8^{bcd}	34.1^{bcde}	4,243.6^{abcd}	1,129.7^{defg}	627.2^{efgh}
Checks								
SAMNUT 11	73,750^{de}	30.1^{gh}	3.5^{def}	4.7^{bcd}	39.0^{b}	4,269.7^{abcd}	1,023.6^{fg}	587.9^{fgh}
55-437	84,000^{a}	43.8^{a}	4.4^{ab}	5.9^{a}	28.8^{de}	4,093.9^{abcde}	1,377.2^{bcde}	766.1^{cdef}
CV (%)	27.1	53.0	38.9	41.4	58.4	189.2	81.8	433.2
SE±	5.3	2.0	0.4	0.4	4.3	509.7	183.7	183.7

Means followed by the same letter (s) within a treatment group are not significantly different at 0.05 level of probability using Duncan Multiple Range Test (DMRT).

The interaction between year and location was significant ($p < 0.05$) for plant stand, *Cercospora* severity at harvest, *Cercospora* incidence, highly significant ($p \leq 0.01$) for plant height. The genotype x year interaction was significant ($p \leq 0.05$) for *Cercospora* incidence and highly significant ($p \leq 0.01$) for plant stand, plant height and *Cercospora* severity at harvest. The interaction between genotype and location was significant ($p \leq 0.05$) for plant stand, plant height, *Cercospora* incidence, pod and seed yield, highly significant ($p \leq 0.01$) for fodder yield. The genotype x year x location interaction was significant for plant stand, *Cercospora* severity at 75 DAS and fodder yield (Appendix 9).

Plant stand varied from 61,500 plants/ha for ICGV 91225 to 84,000 plants/ha for the genotype 55-437. Plant height ranged from 25.1 cm for the genotype SAMNUT 21 to 43.8 cm with the genotype 55-437. The genotypes ICGV 91225 and JL24 had the lowest and the highest *Cercospora* severity scores, 3.3 and 4.8 at 75 DAS, respectively. At harvest, the scores varied from 4.5 for SAMNUT 21, SAMNUT 10, SAMNUT 22, 28-206, ICGV 91225 and NC-GP 343 to 6.1 for the genotype K3237-80. *Cercospora* incidence ranged from 28.0% for ICG 6902 to 52.4% for the genotype K3237-80.

Fodder yield varied from 2,853.9 kg/ha for SAMNUT 18 to 4,806.7 kg/ha for the genotype NC-GP 343. The genotypes 28-206 and JL24 showed the lowest and the highest levels of pod yield, 893.6 kg/ha and 986.4 kg/ha, respectively. Seed yield varied from 484.0 kg/ha for the genotype #3-94 to 1,229.1 kg/ha for the genotype ICGV 86003.

The CV ranged from 27.1% for plant stand to 432.2 % for seed yield (Table 13).

These results showed in general that late and medium maturing genotypes as well as dwarf genotypes and those genotypes which had low plant densities, had the lowest *Cercospora* severity scores. In addition, these results revealed that plant stand, These results showed in general that late and medium maturing genotypes as well as dwarf genotypes and those genotypes which had low plant densities, had the lowest *Cercospora* severity scores. In addition, these results revealed that plant stand, plant height, fodder, pod and seed yield were higher at Guiring than at Samaru. The coefficients of variation were generally high for most of the characters studied.

4.10 Classification of Groundnut Genotypes for Resistance to *Cercospora* leaf spots

The classification of 20 groundnut genotypes tested in 2001 and 2002 at Samaru and Guiring, into various classes of resistance to *Cercospora* lesf spot diseases is presented in Tables 14 and 15.

At Samaru, the genotypes SAMNUT (3.0), SAMNUT 21 (3.1), 28-206 (3.2), NC-GP 343 (3.2), #3-94 (3.3), ICGV 91225 (3.3), ICGMS 42 (3.4), ICG 6902 (3.4), SAMNUT 11 (3.4) and SAMNUT 22 (3.5) were found to be resistant to *Cercospora* leaf spot diseases at 75 DAS. No genotype was resistant to *Cercospora* leaf spots at harvest. However, the genotypes 28-206 (3.8), SAMNUT 10 (3.9), ICGV 91225 (4.1) performed better than the tolerant check genotype SAMNUT 11 (Table 14).

At Guiring, ICGV 91225 was found to be resistant to *Cercospora* leaf spot diseases at 75 DAS. No genotype was resistant at harvest. The genotypes which performed better than the tolerant check SAMNUT 11 were ICG 6902 (4.5), #3-94 (4.0), SAMNUT 22 (4.7), SAMNUT 21 (4.7), NC-GP 343 (4.8), ICGV 91225 (4.9), ICGMS 42 (5.1) at harvest (Table 15).

Table 14. Classification of 20 groundnut genotypes tested in 2001 and 2002 at Samaru into various classes of resistance to *Cercospora* leaf spot diseaseS.

Class of resistance (scores)	Periods of disease rating: 75 DAS	Harvest
Immune (1)	-	-
Resistant (2-3)	SAMNUT 10 (3.0)	-
	SAMNUT 21(3.1)	
	28-206 (3.2)	
	NC-GP 343 (3.2)	
	# 3-94 (3.3)	
	ICGV 91225(3.3)	
	ICGMS 42 (3.4)	
	ICG 6902 (3.4)	
	SAMNUT 11 (3.4)*	
	SAMNUT 22 (3.5)	
Medium resistant (4-5)	SAMNUT 23 (3.7)	28-206 (3.8)
	CGS 269 (3.8)	SAMNUT 10 (3.9)
	ICGV 92087 (3.9)	ICGV 91225 (4.1)
	ICGV 92099 (4.0)	SAMNUT 11 (4.2)*
	CGS 1272 (4.2)	SAMNUT 21 (4.3)
	K3237-80 (4.5)	NC-GP 343 (4.3)
	55-437 (4.6)*	SAMNUT 22 (4.4)
	SAMNUT 18 (4.7)	ICGMS 42 (4.5)
	JL 24 (4.8)	CGS 269 (4.6)
	ICGV 86003 (4.8)	SAMNUT 23 (4.6)
		ICG 6902 (4.7)
		# 3-94 (4.8)
		ICGV 92087 (4.9)
		CGS 1272 (4.9)
		ICGV 92099 (5.0)
Medium susceptible (6-7)	-	JL 24 (5.6)
		55-437 (5.7)*
		K3237-80 (5.8)
		SAMNUT 18 (5.9)
		ICGV 86003 (6.0)
Susceptible (8-9)	-	-

*The checks

Table 15. Classification of 20 groundnut genotypes tested in 2001 and 2002 at Guiring into various classes of resistance to *Cercospora* lesf spot diseases.

Class of resistance (scores)	Periods of disease rating: 75 DAS	harvest
Immune (1)	-	-
Resistant (2-3)	ICGV 91225 (3.3)	-
Medium resistant (4-5)	SAMNUT 11 (3.6)*	ICG 6902 (4.5)
	SAMNUT 22 (3.6)	# 3-94 (4.6)
	SAMNUT 21 (3.7)	SAMNUT 22 (4.7)
	CGS 269 (3.7)	SAMNUT 21(4.7)
	28-206 (3.7)	NC-GP 343 (4.8)
	ICG 6902 (3.8)	ICGV 91225 (4.9)
	SAMNUT 10 (3.8)	ICGMS 42 (5.1)
	# 3-94 (3.9)	SAMNUT 10 (5.1)
	ICGV 92099 (3.9)	SAMNUT 11 (5.2)*
	NC-GP 343 (3.9)	28-206 (5.2)
	K3237-80 (4.1)	CGS 269 (5.4)
	ICGV 86003 (4.1)	ICGV 92099 (5.5)
	55-437 (4.2)*	
	SAMNUT 18 (4.2)	
	SAMNUT 23 (4.2)	
	ICGMS 42 (4.3)	
	ICGV 92087 (4.3)	
	CGS 1272 (4.4)	
	JL 24 (4.8)	
Medium susceptible (6-7)	-	CGS 1272 (5.6)
		ICGV 92087 (5.7)
		SAMNUT 23 (5.9)
		ICGV 86003 (6.1)
		55-437 (6.2)*
		SAMNUT 18 (6.2)
		K3237-80 (6.4)
		JL 24 (6.5)
Susceptible (8-9)	-	-

* The checks

4.11 Genetic Coefficient of Variability, Heritability and Genetic Advance

The estimates of genotipic coefficients of variability (G.C.V.), broad sense heritability (h^2_b %), genetic advance (ΔG) and expected genetic gain ($\Delta G\%$) for the characters studied in 2001 and 2002 at Samaru and Guiring are presented in Table 16. Genotypic coefficients of variability were low and ranged from 9.5% for *Cercospora* leafspot at 75 DAS to 26.4% for seed yield.

Heritability estimates were generally high except for fodder yield, and varied from 97.1% for *Cercospora* severity at harvest to 14% for fodder yield.

Genetic gain estimates were high for plant height (62.8%), *Cercospora* severity at harvest (51.5%), *Cercospora* incidence (51%), pod yield (77.8%) and seed yield (97.6%), moderate for *Cercospora* severity at 75 DAS (36.5%) and low for fodder yield (8.2%) (Table 16).

Table 16. Estimates of genetic coefficients of variability (G.C.V.), broad sense heritability ((h^2_b %), genetic advance (ΔG) and expected genetic gain (ΔG%) for seven characters studied in 2001 and 2002 at Samaru and Guiring

Characters	G.C.V. (%)	h^2_b %	ΔG	ΔG (%)
Plant height	14.7	92.6	20.9	62.8
C. severity at 75 DAS	9.5	73.7	1.4	36.5
C. severity at harvest	11.2	97.1	2.6	51.5
C. incidence	13.94	68.2	17.96	51.0
Fodder yield	5.3	14.7	328.6	8.2
Pod yield	20.8	75.2	1046.6	77.8
Seed yield	26.4	84.6	792.8	97.6

4.12 Correlation

The estimates of phenotypic, genotypic and environmental correlations between *Cercospora* incidence and some agronomic traits are presented in Tables 16 and 17.

Phenotypic correlation coefficients were generally low to high and significant in both locations, except for pod yield (0.17) at Samaru (Table 17), fodder yield (0.09) and seed yield (0.18) at Guiring (Table 18).

Genotypic correlation coefficients were low and varied from – 0,16 for plant height to 0.24 for seed yield at Samaru (Table 17). At Guiring, *Cercospora* severity at harvest and fodder yield were positive (0.75) and highly significant ($p \leq 0.01$) but negatively (-0.61) and significantly ($p \leq 0.05$) correlated with *Cercospora* incidence (Table 18).

Environmental correlation coefficients were low and ranged from 0.02 for seed yield to 0.31 for *Cercospora* severity at harvest at Samaru (Table 17). At Guiring, environmental correlation coefficients were moderate (0.44) and highly significant ($p \leq 0.01$) with *Cercospora* severity at harvest, high (0.58) and significant ($p \leq 0.05$) with *Cercospora* severity at 75 DAS. There was a low negative (- 0.19) correlation with fodder yield (Table 18).

Table 17. Phenotypic (p), Genotypic (g) and Environmental (e) correlation coefficients between yield, yield components and *Cercospora* leaf spot incidence obtained from 20 groundnut genotypes from the two years combined at Samaru

		Plant height	*Cercospora* scores at 75 DAS	*Cercospora* scores at harvest	*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
Plant stand	(p)	0.609**	0.514**	0.614**	0.602**	0.181*	0.269*	0.340**
	(g)	0.476*	0.480*	0.496*	0.135	0.278	0.386	0.374
	(e)	0.147	0.091	0.185*	0.142	0.278*	0.237*	0.189*
Plant height	(p)		0.726**	0.681**	0.500**	- 0.019	0.499**	0.580**
	(g)		0.861**	0.788**	- 0.157	- 0.651*	0.680*	0.650*
	(e)		0.105	- 0.156	0.046	0.519**	0.356**	0.383**
Cercospora severity at 75 DAS	(p)			0.801**	0.570**	- 0.226*	0.348**	0.474**
	(g)			0.931**	0.119	- 0.712*	0.709*	0.727*
	(e)			0.427**	0.161	- 0.167	0.057	0.068*
Cercospora severity at harvest	(p)				0.646**	- 0.201*	0.304*	0.455**
	(g)				0.109	- 0.751**	0.611*	0.624*
	(e)				0.307*	- 0.147	0.050	0.107
Cercospora incidence	(p)					0.214*	0.173	0.313*
	(g)					0.138	0.234	0.238
	(e)					0.084	0.079	0.021
Fodder yield	(p)						0.000	- 0.014
	(g)						- 0.391	- 0.462*
	(e)						0.437**	0.416**
Pod yield	(p)							0.843**
	(g)							0.944**
	(e)							0.725**

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table 18. Phenotypic (p), Genotypic (g) and Environmental (e) correlation coefficients between yield, yield components and *Cercospora* leaf spot incidence obtained from 20 groundnut genotypes from the two years combined at Guiring

		Plant height	*Cercospora* scores at 75 DAS	*Cercospora* scores at harvest	*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
Plant stand	(p)	- 0.034	0.553**	0.652**	0.606**	0.252*	0.4290**	0.384**
	(g)	0.648*	0.559*	0.732*	0.349	- 0.052	0.543*	0.673*
	(e)	0.295*	0.055	0.039	- 0.006	0.252*	0.160	0.169
Plant height	(p)		- 0.186*	- 0.250*	- 0.461**	- 0.062	0.173	0.404**
	(g)		0.564*	0.833**	0.434	0.005	0.629*	0.674*
	(e)		- 0.012	- 0.081	- 0.065	0.157	0.322*	0.307*
Cercospora severity at 75 DAS	(p)			0.712**	0.641**	0.165	0.463**	0.254*
	(g)			0.687*	0.356	- 0.016	0.560*	0.545*
	(e)			0.529**	0.579*	- 0.077	0.093	0.160
Cercospora severity at harvest	(p)				0.875**	0.052	0.508**	0.309**
	(g)				0.749**	- 0.352	0.554*	0.659*
	(e)				0.438**	- 0.057	0.009	0.102
Cercospora incidence	(p)					0.085	0.414**	0.178
	(g)					- 0.613*	0.312	0.397
	(e)					- 0.188*	- 0.116	-0.126
Fodder yield	(p)						0.109	0.025
	(g)						- 0.140	- 0.235
	(e)						0.127	- 0.066
Pod yield	(p)							0.729**
	(g)							0.910**
	(e)							0.567**

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively.

CHAPTER FIVE

5.0 DISCUSSION

The results of this study revealed that resistance to early and late leaf spots was not stable among genotypes and across environmental conditions in both locations. This were probably due to the differences in the reaction of the genotypes to the to leaf spot diseases and the variation of weather parameters such as rainfall, temperature, sunshine, evaporation and relative humidity between years (Appendices 10, 11). Waliyar *et al.* (1994) reported similar observations that resistance to early leafspot varied with diverse climatic conditions. On the contrary, Singh *et al* (1997) observed that late leaf spot resistance was generally stable among genotypes.

None of the genotypes tested was immune to leafspot in both locations. This result corroborated the findings of Abdou *et al.* (1978) who reported that all known varieties of cultivated groundnut are susceptible in varying degrees to the two leaf spot diseases.

The genotypes SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG 6902, SAMNUT 11, SAMNUT 22 at Samaru and ICGV 91225 at Guiring, were found to be resistant to early leaf spots, due to their low disease severity scores at 75 DAS. It is likely that resistant genotypes have smaller stomata diameters and thicker palisade tissue that prevent *Cercospora* pathogen penetration (Jackson and Bell, 1969). Similar results have been reported by Wells et *al.* (1994).

None of the genotypes tested was resistant to late leaf spots, due probably to higher disease presure at havest as indicated by *Cercospora* severity scores.

Percent defoliation did not always correspond to the disease scores of the genotypes as indicated by the disease incidence of the susceptible genotype 55-437 (28.8%) and the resistant one SAMNUT 10 (33.3%), suggesting that leaf shedding would be more of a physiological process than a pathogenic effect. Sturgeon (1968) had also reported that the highest disease ratings were not associated with the greatest defoliation, indicating that some resistance might be produced in the host-pathogen association, which initiates formation of abscission layer.

Cercospora leaf spot diseases were more severe at high plant densities than at low densities. The plausible explanation is that at high plant densities, there is less air circulation and light penetration, giving rise to a cooler and wetter microclimate, which is favorable for *Cercospora* leaf spot pathogen colonization and infection (Wells *et al.*, 1994). Yayock (1978, 1981) also observed that the higher the groundnut plant density, the more severe the leaf spot diseases.

Shorter genotypes were generally more resistant to leaf spots than their taller counterparts. The later genotypes would be more exposed to the conidia produced from secondary infections and blown on leaves. McDonald *et al.* (1997) observed that air-borne conidia are the source of most infections due to leaf spots. Fowler (1971) found that erect varieties were more susceptible to leaf spot diseases than the spreading cultivars.

Higher fodder, lower pod and seed yielding genotypes were found to be more resistant to leaf spots than lower fodder, higher pod and seed yielding ones. The good pod and seed yields of the later genotypes could be as a result of the equilibrium between physiological and reproductive functions due to defoliation (McDonald *et* al., 1997). It is likely that defoliation would increase the amount of energy used for pod formation and filling (Opona, 1986). Pixley et *al.* (1990) reported that a moderate defoliation during the last 75 days of the plant development or a severe defoliation prior to harvest is desirable, as this tends to conserve energy for pod filling.

late maturing genotypes (McDonald *et* al., 1997). Similar results have been reported by Haji and Beute (1977).

Genotypic coefficients of variability were low for all the charaters studied, indicating a small amount of genetic variation for these traits. On the contrary, Basu (1969) reported high genetic coefficient of variation for number of pods (29.32) and fodder weight (30.02) per plant.

Heritability estimates were generally high for all traits except for fodder yield, suggesting that mass selection could be effective to exploit any additive gene effect. Basu (1969) reported high heritability values for number of pods per plant (56%) and 100 pod weight (49%), moderate for fodder (43.19%) and low for pod weight per plant (30%).

Genetic gain estimates were high for most of the characters studied, indicating that these characters had high level of additive gene effect and selection based on phenotypic performance could be effective for these traits which exhibit high genetic gain along with high heritability. Similarly, Basu (1969) reported high genetic gain (55%) coupled with high heritability (56%) for number of pods per plant.

In both locations, phenotypic correlation was in many cases significant and higher than genotypic and environmental correlations, indicating a low inherent association between these characters.This could probably be due to the lack of pleiotropic gene action and/or linkage between genes governing these characters (Singh, 1990).

At Guiring, *Cercospora* severity at harvest and fodder yield had positive and negative significant genotypic correlation with *Cercospora* incidence, respectively, indicating a strong inherent association between these traits. The selection for one character will result in a progress for all positively correlated but in a regress to all negatively correlated characters (Singh, 1990). Thus, at Guiring, *Cercospora* incidence could be improved through selection for high fodder yield and low *Cercospora* severity at harvest. However, fodder yield had low genetic gain and heritability estimates that might make selection for this character inefficient.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

The results of this study indicated that resistance to early and late leaf spots was not stable among genotypes and across environmental conditions. None of the groundnut genotypes tested was immune to *Cercospora* leaf spots in both locations. However, the genotypes SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG 6902, SAMNUT 11, SAMNUT 22 were found to be resistant to early leaf spot at Samaru, while ICGV 91225 was resistant at Guiring.

Higher fodder yielding, late and medium maturing genotypes, lower pod and seed yielding and shorter genotypes had higher levels of resistance to leaf spots than others. Leaf spot diseases were severe at high groundnut plant densities.

All the characters studied showed low levels of genetic variation and high additive gene effect as a result of high genetic advance except for *Cercospora* severity at 75 DAS and fodder yield, indicating that selection based on phenotypic performance could be effective for most of these characters.

No strong inherent association was found between *Cercospora* leaf spot incidence with other characters except for *Cercospora* leaf spot severity at harvest and fodder yield at Guiring. Thus, for improving *Cercospora* incidence at Guiring, selection could be carried out on these two traits.

Based on the findings from this study, it is recommended that the genotypes which were resistant or performed better than the tolerant check SAMNUT 11 could be used as donor parents in the groundnut breeding programme for resistance to *Cercospora* lesf spots. The potential sources of resistance to early leaf spot are SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG

6902, SAMNUT 11, SAMNUT 22 at Samaru and ICGV 91225 at Guiring. The promising donor parents for late leaf spot resistance breeding are 28-206, SAMNUT 10, ICGV 91225 at Samaru and ICG 6902, # 3-94, SAMNUT 22, SAMNUT 21, NC-GP 343, ICGV 91225, ICGMS 42, SAMNUT 10 at Guiring.

Since under natural conditions, *Cercospora* leaf spot diseases may vary with environmental conditions, further investigations would be required to confirm these findings under artificial inoculation techniques.

SUMMARY

Twenty groundnut genotypes collected from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)/Niger, the Institute for Agricultural Research (IAR), Samaru, Nigeria and the Institute of Agricultural Research for Development (IRAD), Guiring, Cameroon were evaluated in a randomized complete block design with three replications at Samaru and Guiring in two years (2001 and 2002). Plot size was a single row 10 m long, spaced 75 cm at Samaru and 60 cm at Guiring. Groundnut seeds were sown on ridge at Samaru and on flat at Guiring. Data were collected on eight quantitative traits, namely, plant stand, plant height, *Cercospora* severity at 75 DAS and at harvest, *Cercospora* incidence, fodder, pod and seed yield. Analysis of variance, mean separation, genetic coefficients of variability, broad sense heritability, genetic advance and correlation coefficients were computed for all the characters studied. *Cercospora* severity was scored using the nine-point scale of the Groundnut Germplasm Project (GGP). Groundnut genotypes were grouped into various classes of resitance to *Cercospora* leaf spots using the method suggested by the West and Central African Council for Agricultural Research and Development (WECARD).

The results showed that no genotype was immune to both leaf spots at Samaru and Guiring. The genotypes SAMNUT 10, SAMNUT 21, 28-206, NC-GP 343, #3-94, ICGV 91225, ICGMS 42, ICG 6902, SAMNUT 11, SAMNUT 22 were found to be resistant to early leaf spots at Samaru, while ICGV 91225 was the only resistant genotype at Guiring. No genotype was resistant to late leaf spots in both locations.

All the characters studied had low genetic coefficient of variability, high heritability estimates and genetic gain except for *Cercospora* severity at 75 DAS and fodder yield.

No strong inherent association was found between *Cercospora* incidence and other traits except for *Cercospora* severity at harvest and fodder yield at Guiring. Thus, selection could be carried out on these two traits to reduce *Cercospora* incidence at Guiring. At Samaru, selection for *Cercospora* incidence could be effective based on phenotypic performance for most of the traits as a result of high heritability and genetic gain estimates.

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APPENDICES

Appendix 1. Mean squares from the analysis of variance for seven traits in groundnut grown in Samaru in 2001

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Replication	2	259.0	6.98	1.20*	0.66	257.01	114722.44	406013.22	111874.92
Genotype	19	260.1	62.70**	0.84*	0.68*	295.01*	2289468.88*	441724.27*	96314.77*
Error	38	192.1	7.36	0.28	0.26	99.10	654747.08	144196.72	44938.97
Total	59								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 2. Mean squares from the analysis of variance for seven traits in groundnut grown in Guiring in 2001

Source of variation	df	Plant stand	Plant height	*Cercospora* incidence		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Replication	2	8830881.76*	95.68*	0.36	0.2	6.01	8830881.766*	244157.69	69318.44
Genotype	19	1550216.18**	146.50**	0.6**	0.53**	292.45**	1550216.18	350861.54*	1916335.80**
Error	38	951039.41	19.41	0.11	0.1	15.45	961039.41	86834.05	25106.13
Total	59								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 3. Mean squares from the analysis of variance for seven traits in groundnut grown in Samaru in 2002

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Replication	2	117.7	1.42	1.15	2.97*	270.11*	1113718.35	47941.08	22302.66
Genotype	19	142.1	67.48**	1.99*	2.82*	101.52*	1746636.74*	446638.37**	199155.51**
Error	38	78.8	7.03	0.58	0.80	48.95	694087.22	55708.19	18234.39
Total	59								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 4. Mean squares from the analysis of variance for seven traits in groundnut grown in Guiring in 2002

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Replication	2	125.5*	49.96*	4.58*	2.08*	68.81*	103911.70	416212.53*	14764.23
Genotype	19	64.3*	86.39**	0.73	2.72**	101.27**	27273144.65**	383179.48**	200668.22*
Error	38	30.4	10.22	0.44	0.25	17.53	5688878.71	78995.94	52594.41
Total	59								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 5. Mean squares from the combined analysis of variance over locations (Samaru and Guiring) for seven traits in groundnut in 2001

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Location	1	9666.1**	9955.40**	3.85**	4.10**	187.50	49697505.21**	11154522.61**	9103236.93**
Replication (location)	4	207.1	51.33*	0.78*	0.43	131.51	4472802.10*	325085.46*	90596.68*
Genotype	19	577.3**	188.66**	1.28**	1.01**	434.89**	1673527.05*	597215.38*	233290.48**
Genotype x location	19	312.4*	20.59	0.15	0.19*	153.18*	2166158.01*	195370.44	54660.09
Pooled Error	76	116.6	13.36	0.19	0.18	57.27	807893.2	115515.39	35022.55
Total	119								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 6. Mean squares from the combined analysis of variance over locations (Samaru and Guiring) for seven traits in groundnut in 2002.

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Location	1	3729.7**	60.06*	0.01	22.36**	559.00**	58846349.13**	20958520.83**	5808528.01**
Replication (location)	4	121.6	25.69*	2.86*	2.53**	169.46*	608815.03	233076.81*	18528.44
Genotype	19	84.9	142.63**	1.51*	4.87**	137.19**	2622975.26**	676957.63**	332060.04**
Genotype x location	19	121.4*	11.23	1.21*	0.67	65.60*	1850976.13**	154860.23*	67763.69*
Pooled Error	76	54.6	8.62	0.51	0.52	33.224	631483.00	67352.06	35414.40
Total	119								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 7. Mean squares from the combined analysis of variance over years (2001 and 2002) for seven traits in groundnut grown in Samaru

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Year	1	16973.7**	2140.2**	52.0**	94.4**	24133.5**	5014268.8*	293544.9	81266.1
Replication (year)	4	221.7	4.4	1.0	2.1*	246.2*	520407.8	235479.4	118171.7*
Genotype	19	188.5	120.2**	2.2**	2.6**	307.3**	3023519.8**	811772.4**	213363.2**
Genotype x year	19	234.7*	19.7*	0.7	0.9	55.3	970033.8	74362.4	23799.7
Pooled Error	76	134.6	8.8	0.49	0.60	88.9	678511.6	100203.5	30623.9
Total	119								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively

Appendix 8. Mean squares from the combined analysis of variance over years (2001 and 2002) for seven traits in groundnut grown in Guiring

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Year	1	3376.1**	8996.0**	33.0**	165.2**	37630.2**	7057574.5*	3077410.4**	32947.8
Replication (year)	4	72.8*	140.3*	2.5**	1.1*	37.4	4467396.7**	331185.1*	42036.3
Genotype	19	213.6**	402.7**	0.7*	2.4**	251.5**	2509690.4**	635755.7**	357727.9**
Genotype x year	19	19.2**	291.2**	0.6*	0.9**	142.2*	1767840.4*	98285.3	34576.2
Pooled Error	76	14.8	35.7	0.28	0.18	16.5	764959.1	82914.9	38850.3
Total	119								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively.

Appendix 9. Mean squares from the combined analysis of variance over locations (Samaru and Guiring) and years (2001 and 2002) for seven traits in groundnut

Source of variation	df	Plant stand	Plant height	*Cercospora* severity		*Cercospora* incidence	Fodder yield	Pod yield	Seed yield
				75 DAS	Harvest				
Location	1	12702.2**	4234.44**	2.18*	22.81**	49.50	108350728.4**	31346462.68**	14727498.88**
Year	1	25750.8**	61.39*	84.11**	255.93**	61043.02**	11006153.6*	2789620.97**	510210.23*
Replication (year x loc.)	4	2944.1*	46.25*	1.92*	1.78*	154.59*	2091925.7*	104661.80	16075.17
Genotype	19	406.6**	310.83**	2.28**	4.48**	423.87**	3037188.6***	1182932.24**	536248.98**
Year x location	1	693.6*	5454.95**	0.86	3.66*	720.67*	193125.9	581334.28	136594.26
Genotype x year	19	255.7**	19.11**	0.61	1.54**	120.61*	1259313.7	90792.17	33388.62
Genotype x location	19	1844.7*	22.97*	0.62	0.55	134.89*	2496021.6**	264595.89*	82673.43*
Genotype x year x loc.	19	249.1*	19.82	0.72*	0.29	76.85	1521112.6*	81855.58	35750.94
Pooled Error	156	84.3	12.27	0.41	0.41	54.67	777893.3	101057.79	36717.63
Total	239								

*, ** Significantly different at 0.05 and 0.01 level of probability, respectively.

Appendix 10. weather data

Location: Samaru

	2001							2002						
*Param	Temperature (°C)			*Evap. Piche (mm)	Sun Shine (hrs)	Rainfall (mm)	*RH	Temperature (°C)			*Evap Piche (mm)	Sun Shine (hrs)	Rainfall (mm)	*RH
Month	Maxi	Mini	Aver.					Maxi	Mini	Aver.				
June	31.8	22.8	27.3	193.9	219.9	177.7	81.2	33.1	23.2	28.1	163.1	247.6	133.1	85.7
July	30.4	22.0	26.2	108.9	183.7	388.4	87.2	31.1	22.1	26.6	107.7	189.0	229.0	90.1
August	29.7	22.1	25.6	68.2	124.9	330.7	88.9	29.8	22.3	26.0	66.4	171.1	201.4	90.6
Sept	31.1	22.0	26.5	69.8	180.4	256.3	86.7	31.1	222.3	26.7	73.7	210.7	193.9	88.7
October	31.6	20.0	25.8	195.0	211.8	0.0	63.0	31.6	21.2	26.4	128.1	192.0	125.2	86.6
Total	154.6	108.9	131.3	635.8	915.7	1152.8	408	156.7	111.1	132.7	537	1010.4	882.6	441.7
average	30.9	21.8	26.3	127.2	183.1	230.5	81.6	31.3	22.2	26.5	107.4	202.1	176.5	88.3

*Param. = parameter; *RH = Relative Humidity; Evap. = evaporation

Appendix 11. weather data

Location: Guiring

	2001							2002						
*Param	Temperature (°C)			*Evap.	Sun	Rainfall	*RH	Temperature (°C)			*Evap	Sun	Rainfall	*RH
Month				Piche	Shine	(mm)					Piche	Shine	(mm)	
	Maxi	Mini	Aver.	(mm)	(hrs)			Maxi	Mini	Aver.	(mm)	(mm)		
June	35.8	24.4	28.9	121.8	173.0	147.0	55.8	35.2	24.4	29.8	95.8	177.3	78.1	66.2
July	32.4	28.8	26.2	65.2	155.8	267.8	77.1	32.9	23.4	28.2	60.0	168.2	146.3	73.6
August	30.8	22.2	25.6	43.9	134.3	296.0	91.1	31.7	22.4	27.0	46.4	138.3	199.9	77.6
Sept	32.2	22.3	26.6	63.2	160.7	213.5	91.4	33.4	22.5	27.9	55.8	172.4	123.6	74.4
October	35.0	22.1	27.8	130.1	183.7	6.0	63.7	35.4	22.6	29.0	126.0	255.8	13.8	58.0
Total	166	119.8	135.1	424.2	807.5	930.3	379.1	168.6	115.3	141.9	384.0	912.0	561.7	349.8
average	33.2	23.9	27.0	84.8	161.5	186.0	75.8	33.7	23.1	28.4	76.8	182.4	112.3	69.9

*Param. = parameter; *RH = Relative Humidity; *Evap. = evaporatio