VARIABILITY IN GENOTYPIC RESPONSE TO END-OF-SEASON DROUGHT IN GROUNDNUT (*Arachis hypogaea*. L.)

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A thesis submitted to the Postgraduate School Ahmadu Bello University, in partial fulfillment of the Requirements for the degree of Masters of Science in Genetics and Crop Breeding

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March, 1998

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 References made to published and unpublished literature have been duly acknowledged.

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CERTIFICATION

This thesis entitled "Variability in Genotypic Response to End-of-Season Drought in Groundnut (Arachis hypogaea L.)" by Adamu Usman, Izge 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 of literary presentation.

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DEDICATION

To my late sister Hauwa Adamu Dizgo and to all the drought affected areas of the World.

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ABSTRACT

Field and screenhouse experiments were conducted during the cropping seasons of 1995 and 1996 at the Institute for Agricultural Research (IAR) Samaru, Zaria (11°11'N, 70°38'E). The treatments consisted of 16 groundnut genotypes : JL-24, 55-437. 48-115B, RRB, ICG 221, ICG 4601, ICG 4790, ICGV 86745, ICGV 86708, ICGV 86702. ICG 4747, ICGV-SM 85045, ICGV 88023, ICGV 86124. ICGV 90127 and FLEUR 11. The field experiments were laid out in a randomized complete block design with 3 replications. There were 2 planting dates in the field experiments; normal planting (May to October) and late planting (August to December). The aim of late planting was to expose the groundnut genotypes to end-of-season drought. In the screen house, treatments were laid out in a completely randomized design with two replications. Plants were grown under adequate moisture and controlled moisture from 50% flowering. This was done to investigate the response of the different genotypes to end-of-season drought. Results indicated significant differences ($P > 0.05$) among the parameters measured in control and end-of-season drought experiments. Yield parameters among the genotypes were significantly different ($P > 0.05$), except for oil and protein content. Reduction of up to 39, 33 and 28% in pod yield, haulm yield and number of pods per plant, respectively were recorded as a result of end-of-season drought. Genotypes ICG 4747, ICGV 86745, ICGV 86124, FLEUR 11 and ICGV-SM 85045

recorded the highest pod yield under drought condition in the field. Results from the screen house did not follow similar trend to that of the field. Genotypes responded differently to end-of-season drought, probably, as a result of variations in water use ratio (due to variation in the shoot dry matter recorded) or as a result of early maturity in some genotypes. However, large variations in response of genotypes to end-of-season drought could be due to the ability of genotypes to withstand drought as a result of physiological, morphological and anatomical adaptations and or early maturity. High yield obtained by most genotypes could be as a result of their yield potential. In breeding groundnut for end-of-season drought, a balance must be struck between yield potential, adaptations, duration or earliness of the crop.

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CHAPTER 1

INTRODUCTION

Groundnut, Arachis hypogaea L. belongs to the family Leguminosae (Fabaceae). It originated in South America and was probably domesticated in the Granchaco area, including the valleys of Paraguay and Parana Rivers (Purseglove, 1977). The crop was brought to the East and West coasts of Africa by Spanish and Portuguese explorers (Hammons, 1973). Groundnut is a widely grown crop, predominantly in seasonally arid areas. It is an important crop in arid and semi-arid tropics and produces the highest percentage of world crop (FAO, 1982; Cummins, 1986). In Nigeria, the total land area under groundnut cultivation has been approximated to 1.2 million hectares with an estimated total output of nearly one million metric tons of kernel annually (Harkness et al., 1975).

Morphological variations exist between groundnut genotypes. Plant types range from prostrate runners to upright bunch types. Individual leaf area may vary from 8 to 10 fold, while the time to maturity may vary from 80 -180 days. The size and the nature of the root system also vary substantially.

Groundnut is mostly grown under stressed conditions due to low water availability and temperature extremes which limit production. Drought and temperature affect most crops, and groundnut is no exception (Ketring, 1985). Drought is a negative departure from normal rainfall caused by either reduced amount of rains, longer dry spells between rains, a

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shift in time of rainfall establishment and cessation or a shortened length of the rainy period which result in poor agricultural production (Adebayo and Muhammed. 1985: Yayock. 1988). Agriculturally significant droughts usually occur when normal expected rain fails and this failure is largely random (Ketring. 1986). Lack of rain may cause drought at any stage of crop growth and development. Lack of rain may vary the evapotranspirational demand relative to water shortage and even the duration of drought experienced by the crop.

Drought has reduced groundnut production in Nigeria. The annual production of shelled groundnut in Nigeria (outside drought years) is about one million tons and over 90 percent is consumed locally in one form or the other (Harkness et al.. 1975). Groundnut is normally grown in Northern Nigeria. concentrated in the upper one half of the region (in the Sudan. Northern Guinea and parts of Southern Guinea Savanna) with Kano being the centre of marketing activity. (MOA 1966). However. the production of groundnut has been on the decline since 1967. when a total of one million metric tons of kernels were purchased by the marketing board (Yayock. 1984). Yayock (1984) also reported that the drought in 1972 and 1973. as well as the epidemic of rosette virus diseases in 1975 caused great losses in production. thus making Nigeria an importer of groundnut and groundnut products instead of the number two position it had hitherto occupied (after India) as an exporter of this commodity. Such natural disaster as drought and

diseases epidemic have discouraged farmers from growing groundnut. In sites north of Kano, (Harkness and Yayock, 1979) at one time considered to be major groundnut producing areas, very poor yields have been recorded since 1969/70. season due to drought. There is strong evidence that in the Sudan savanna zone the weather has been getting drier over the past 25 years and groundnut is no longer well suited there as before. The drought of 1972 and especially 1973 seriously affected the groundnut production. In the South of drought stricken areas in 1972, bumper crops were recorded which were reflected in good Northern state marketing board purchases in that season. Groundnut yield trials at Samaru and Kano reached the highest yields ever, in 1972. Harkness and Yayock (1979) further reported that following the drought of 1973, rather poor yields occurred in 1974 to be followed by the rosette epidemic of 1975.

The progress from conventional breeding methods for increased drought tolerance without reducing productivity or quality of crop has been very slow. According to Gupta (1986, 1996), this has been so, because drought tolerance is governed by several factors, such as root numbers and extension; resistance to water flow; stomatal number, size and frequency; leaf water potential; absiscic acid and proline accumulation; cultivar resistance and waxyness, etc. He also stated that the productivity of the crop is governed by factors as number of stands, number of pods, individual kernel weight and stature

of the plant on the other. Heyne and Brunson (1940) and Gupta (1986), reported that drought tolerance is quantitatively inherited with complex physiological reactions.

Of the many investigations of groundnut responses to drought, very few have been able to establish generalized response pattern. The response may vary with the timing of drought. In India for example, results have not been consistent, because of differences in either genotypes or in growing conditions. For example, Billaz and Ochs, (1961), found that mid-season drought decreased yield more than end-of-season drought, while Pallas et al. (1979) and Nageswara Rao et al. (1985) reported the opposite.

The objectives of this study were:

1. To investigate groundnut plant reaction to water stress in the screen house.
2. To evaluate variations or differential response in genotypic resistance to end-of-season drought in the field.

CHAPTER 2

LITERATURE REVIEW

2.1 Physiological Responses to Moisture Stress

Since all plant processes take place in aqueous media, reduced water uptake and dehydration prove deleterious to most physiological processes. The effect of water stress on physiological processes has been extensively reviewed (Crafts, 1968; Hsiao, 1973; Gupta, 1986, 1996 and Reddy et al., 1990). Because water stress affects almost all life processes, the integrated effects make a study on a specific process very complex. Many processes, such as nutrient uptake, carbohydrate and protein metabolism and translocation of ions and metabolites are intimately linked with its effects on development. A number of these physiological processes contribute to the formation of grains in crops. Boyer and McPherson (1975), regarded photosynthesis and the translocation of photosynthates to the grain, cell division and enlargement and the accumulation and transport of nutrient elements for storage as the major physiological processes contributing to grain formation. This was also confirmed with groundnut in addition to other crops (Boote et al., 1986). These processes must occur during the appropriate stages of development and consequently, the timing of each contribution is important. Superimposed on this set of circumstances is the suitability of the environment for supplying light, water and nutrients for the completion of each stage of development.

In drought conditions, soil water deficit slows down leaf expansion, and partitioning between roots and shoots is affected through lowered relative turgidity (Slatyer, 1955; Allen et al., 1976; Vivekannandam and Gunasena, 1976 and Boote et al., 1986). The effect of water deficit on cell enlargement is also related to the ultimate source and sink capacity.

Gautreau (1977) reported that groundnut cultivars with high drought tolerance have low leaf water potential, associated in most cases with high relative transpiration. Maintenance of higher leaf water potential under stress has been found in several cases to be associated with yield advantage. Variations in leaf water potential among plant genotypes under water stress have been recorded in wheat (Kaul, 1967), Soyabean (Boyer et al., 1980) and in groundnut (Reddy et al., 1990). Reddy et al. (1990) and Subrammanian and Maheswari (1990) reported that leaf water potential, transpiration and photosynthetic rates decreased with decreasing soil moisture content. Lower leaf water potential, according to Erickson and Ketring (1985), gives groundnut a greater resistance to dehydration under conditions of high soil water deficit and evaporative demands. However, Keim and Kronstad (1981) and Sojka et al. (1981) reported that drought resistant plants possesses a greater capacity for maintaining a higher leaf water potential, and a greater capacity for osmotic adjustment.

Transpiration provides an essential function of temperature control and is a necessary corollary of CO_2 absorption for photosynthesis and oxygen escape (Craft, 1968 and Gupta, 1992). No transpiration will occur if there is no water potential gradient in the soil/plant/ atmosphere system (Owonubi and Yusuf, 1986). Except the root pressure, the gradient becomes increasingly negative from the soil up through the plant and into the atmosphere. Thus, all transpiring plants are under some degree of water tension. Diurnal fluctuations in transpiration rate occur when the evaporative demand of the atmosphere changes and plants respond to these changes. According to Kassam et al., (1975), and Nageswara-Rao et al. (1985), the amount of dry matter accumulated in a crop is closely related to the amount of water transpired.

Stomata are important in regulating transpiration and water stress to a certain degree in plants. Under moisture stress condition transpiration will be reduced. When the water deficit reaches a critical value characteristic for the species, turgor induced changes in stomatal aperture occur (Ketellapper, 1963 and Bhagsari et al., 1976). The stomata, according to Bhagsari et al. (1976), act as physical barrier to movement of water vapour out of the leaf. They reported that groundnut showed adaptation to drought stress by reducing the stomatal conductance when relative water content decreases below 80 percent. The daily duration and degree of opening of

stomata are important in maintaining the optimal balance between transpiration and CO_2 exchange.

A lot of discussions on the strategies that annual plants may adopt with respect to transpiration control in the face of soil water shortage has been extensively reviewed in literature. Looking at most of the breeding strategies, Gupta (1986, 1995, 1997) argued for breeding for more water conservative behaviour in crop plants and suggested that this may be based on selection for root numbers and deep root extension, resistance of roots to water flow, low leaf water potential, accumulation of abscisic acid and proline accumulation among other factors. According to Arjunan et al. (1988), some groundnut cultivars have high root: shoot ratio under moisture stress, however, cation concentration was reduced and cultivar with higher root: shoot ratio accumulated high amount of K^+ compared to cultivars which avoided excess moisture loss by the regulation of stomatal opening.

Cell division is also sensitive to moisture stress. The observation that leaves of plants which have undergone period of stress, may contain a similar number of cells to unstressed controls suggests that the ability for resumed activity upon relief of stress may remain unimpaired. Cell division tend to "overshoot" and in some cases, surpass levels of well watered controls (Gardener and Newman, 1964). Where stress is more severe or is prolonged, the rate of development is markedly reduced and the flowering and maturation delayed. In

addition, the characters of both vegetative and floral development can be seriously affected.

Cell enlargement is sensitive to even slight levels of stress and is one of the first observable signs of water stress (Meyer and Boyer, 1972). This is the main cause of stunting observed under field conditions. Slower rates of cell enlargement are generally associated with smaller cell size.

Water deficits have an indirect effect on photosynthesis. Levels of available CO_2 are reduced because of stomatal closure. Direct effects on the photosynthetic apparatus appear only at relatively higher stress levels. Water stress may also affect photosynthesis through its effect on sink size (Boote et al., 1986). Under stress, more assimilates are found in leaves, and there is a slower but more prolonged movement of nutrients out of leaves (Boote et al., 1986).

Respiration seems less affected than photosynthesis by water stress. Photorespiration appears to increase with moderate moisture stress. This could be due to an indirect increase in internal temperature caused by stomatal closure (Slatyer, 1969).

Sugar utilisation and starch hydrolysis appear to decrease and increase respectively when water stress occurs. This increase in sugar content has been suggested to be a survival mechanism in plants by maintaining turgidity by decreasing the solute potential.

Generally, translocation is reduced with increased stress. However, the translocation pathway appears to be capable of functioning efficiently under water stress, and effects on translocation arise indirectly by the effects of stress on source and sink capacities (Bidinger, 1977).

The effect of water stress on mineral nutrition is difficult to resolve clearly. Although mineral nutrient uptake is frequently reduced to a considerable degree in stressed plants (Williams and Shapter, 1955; Williams et al., 1985), nutrient uptake is not directly dependent on water uptake (Russell and Barber, 1960). Soil nutrient availability per se is not necessarilly affected by soil water stress (Fawcett and Quirk, 1962 and Yayock et al., 1986) at least in the available soil water range.

The effect of water stress on plant hormones may affect leaf senescence and protein synthesis, as well as stomatal opening and closure (Slatyer, 1969; Hsiao, 1973 and Gupta, 1992, 1995). Since the intensity of plant response to water stress varies with plant age and growth conditions, the possibility is that endogenous hormone levels which are influenced by plant age and its growth conditions, act as modulators of plant response (Itai and Benzioni, 1974 and Vaadia, 1976). Cytokinin (Ck) production in the shoots and roots is very sensitive to water stress. Water stress causes a reduction in cytokinin activity. Numerous reports show that a decrease in water potential results in a marked increase in

absciscic acid (ABA) level. This increase occurs, whether the changes in water potential are due to soil drought, a desiccating environment or osmotic agents (Dewdeney and Mcwha, 1978). Higher ABA and lower Ck levels in water stressed plants appear to have an effect on stomatal closure (Levine and Vaadia, 1972 and Gupta, 1995). The interaction of all plant hormones is involved in the regulation of plant performance. This would imply that levels of other hormones such as gibberellins, auxins and ethylene are also involved in the regulation of plant response to water stress. So far, however, there is no evidence of the effect of water stress on the endogenous levels of auxin and gibberellins, except the indirect evidence of changes in auxin level deduced from the study of the activity of indoleacetic acid (IAA) oxidase (Mills and Todd, 1973).

Effects of water deficit on nitrogen and carbon metabolism and protein synthesis are related to continued development, since water deficits have negative effects on the productivity and final yield of biomass in plants, whose main constituents are carbon and nitrogen, might therefore be directly affected by water stress.

Free amino acids, especially proline, increase in plants subjected to water stress (Balasubramanian and Yayock, 1981; Gupta, 1986). Free proline may act as a storage compound for carbon and nitrogen when starch and protein synthesis are reduced under stress conditions. Protein synthesis is also

affected by nucleic acid levels. Although DNA content is not affected until severe stress, RNA levels are sensitive to lower stress levels.

2.2 TEMPERATURE REPONSES TO MOISTURE STRESS

Temperature is the dorminant factor controlling the rate at which groundnut develops (Fortainer, 1957, DeBeer, 1963 and Cox, 1979). Considering plant growth and development, the diurnal cycle is more important than either the regular seasonal cycle or the random effects of weather in the tropics (Monteith, 1977). Even more important for plant processes are the effects of micro-climate since soil temperature commonly exceeds 40°C in many parts of the tropics, especially when the soil surface is dry (Virmani and Singh, 1985). The extremes of temperature over a period of days or hours may severely reduce the growth and development of many crops. For example, Garcia - Huidobro et al. (1985) found that exposure of imbibed pearl millet seeds to 50°C for one hour reduced the germination rate and the percentage germination by 14%. However, similar information is not available for groundnut.

Temperature has an essential role on all aspects of plant growth and development (McCloud, 1984). However, field temperatures often exceed those optimum for groundnut growth, and estimates of optimum light and dark temperature regimes for vegetative growth of groundnut plants under controlled environments range from 30 and 26°C (Cox, 1979) to 35 and 25°C

(Ono et al., 1974). Under field conditions groundnut growth rate, leaf area and total dry matter produced were greatest with mean daily maximum temperatures (29.7^{0}C) and minimum temperatures of 17.3^{0}C (Williams et al., 1975).

Ong (1984) reported that when different leve stress were imposed by growing groundnut plants on stored moisture at a mean temperature ranging from 19-31^{0}C and at varying levels of saturation vapour pressure deficit, pod : shoot weight ratio was maximum at 22^{0}C and decreased as temperature i sed to 31^{0}C. According to Musingo l. (1989), seed soluble and total carbohydrate content increased during drought and temperature stresses. However, protein and oil contents were not affected after exposure to drought and temperature stress. In addition, drought and temperature stresses increased the accumulation and or synthesis of carbohydrates and certain polypeptides.

Greenberg and Ndunguru (1989) reported that considerable differences exist between genotypes for canopy and air temperatures. This is because they are related to leaf water potential. The optimum mean air temperature for vegetative growth of groundnut is in the range of 25-30^{0}C, while temperature for reproductive growth may be similar or somewhat lower, in the range of 20-25^{0}C (Williams et al., 1975). However, higher yields were obtained at a mean temperature of 20.1^{0}C where intermediate peg number and seed growth rate

occurred. Canopy temperature and air temperature equally increased with drought (Sanders et al., 1982).

Although temperature is regarded as a factor affecting the phenology of groundnut, there is no information on whether high temperature (> 40°C) for only a few hours in the day has a major effect on crop development. It is evident that high soil temperatures can reduce seedling establishment and limit reproductive yield in many areas of the tropics (Mohamed, 1984).

2.3 VEGETATIVE AND REPRODUCTIVE PHASE GROWTH RESPONSES TO MOISTURE STRESS

At certain stages during the vegetative or reproductive phase of groundnut, water stress may be detrimental for crop development. Ravindra et al. (1990) and Rao et al. (1982), observed very injurious effects of water stress during flowering and pod formation, compared to stress during vegetative phase. A reduction in seed yield from 28-96% was recorded when stress was imposed during flowering and pod formation (Rao et al., 1985). Kulkarni et al. (1988) also reported a preponderance of yield reduction in pods, number of mature pods per plant, number of nodules per plant, plant dry matter and nitrogen uptake when water stress occurred at flowering and peg development stages, than at vegetative stage. However, Balasubramanian and Yayock (1981) reported that moisture stress during pegging and podding also lowered

the uptake of nitrogen, increased the production of unfilled pods and drastically reduced the overall yields, but moisture stress during peak flowering was less harmful to pod filling and subsequent yield. High crop water deficits during pegging and pod development lowered the uptake of assimilates and reduced reproductive potential (Wright and Bell, 1992). According to Stansell and Pallas (1985), pod yield in groundnut could be increased in plants depending on soil water by reducing plant density, however, it is the timing of water-use and not total amount of water used that determines pod yield. Stansell and Pallas (1985), further noted that plant utilization of profile water stored at depths is apparent and explains to some extent, the drought tolerance of most groundnut cultivars. Another adaptive drought resistance factor is root respiration which is high under normal conditions and lower under water stress in cultivar JL-24. According to Dhopte et al. (1991), and Dhopte and Ramteke (1991), JL-24 in addition to modified root respiration during stress, has a lower leaf area and high water use efficiency under water stress, especially at later stages of development.

According to Khatrijj and Patel (1983), the critical stages in groundnut plant affected by water stress are: germination, vegetative development and full pegging to pod development stages. But Roy et al. (1988) enumerated three phases as very critical:- early to full flowering; late flowering to pod formation and pod filling stages. Generally,

results indicated that late flowering to pod formation stages are more sensitive to water stress and moisture stress, at this stage, reduced yield more than stress at other stages. When water stress occurred during seed filling, genotypic yield potential accounted for about 90% of the pod yield (Roy et al., 1988).

The number of flowers are not a constraint for productivity during water stress, although Janamatti et al. (1986) reported that total number of pegs decreased and the percentage of total pods decreased markedly. A significant burst in flowering on alleviation of stress, was the unique feature in the pattern of flowering under moisture stress.

Excess moisture stress at all growth stages in cowpea have been reported to reduce pod number and seed weight (Kamara, 1976). Rajendrudu and Williams (1987) reported that pod initiation was not greatly influenced under moisture stress, but pod initiation was affected when moisture stress was imposed after flowering.

Drought stress, early or late, in the growing season of groundnut had little or no effect on seed oil, protein and mineral contents, but mid-season drought affected all the seed components (Conkerton et al., 1989). Drought stress directly and physically reduces plant vegetative growth by reducing cell turgor (Hsiao, 1973 and Hsiao and Acevedo, 1974). Growth of leaves, stems and roots is reduced.

Long term drought stress, when crops are grown under rainfed conditions, results in both reduced vegetative (shoot

and root) and reproductive growth. However, under drought stress there may be an increase in the root : shoot ratio. This may be due to the ability of the root to adjust osmotically in order to maintain growth (Hsiao, 1973). Extensive rooting with the ability to explore a larger soil volume for moisture is possibly a trait that can delay dehydration (Ketring et al., 1982 and Ketring, 1984, Gupta, 1996).

A severe water deficit can delay the onset of flowering and rapid pod growth (Billaz and Ochs, 1961 and Billaz, 1962). Yield is often reduced by drought even when plant stress is relieved, because pod maturation is delayed, and it is not always possible to delay harvesting. Boote and Hammond (1981), reported a delay of 11 days in flowering when drought was imposed between 40-80 days after sowing. Stansell and Pallas (1979) found that the percentage of mature kernels of most cultivars was reduced to 34% of the control when drought was imposed 36-105 days after sowing. Using the groundnut genotype 28-206, Billaz and Ochs (1961), found that drought during pod setting caused more yield loss than drought during seed filling phase. However, Pallas et al. (1979) found that for Florunner groundnut, the seed filling phase was more sensitive to drought than was the pod initiation phase. Nageswara et al. (1985), using Robut 33-1, reported a yield advantage of 13 to 19% resulting from drought during the preflowering phase. This wide variation in the effects of drought might be due to differences in genotype, timing and intensity of drought, as well as interactions between these factors.

Klepper (1973) reported a reduction in pod yield to the tune of 50% when the crop suffered moisture stress during peak flowering (50-80 days after sowing), the most moisture sensitive period. Su and Lu (1963) observed the critical period of water deficiency as the peak flowering and early fruiting in sandy soils. Bhan (1979) found the stages of pegging and pod filling to be highly susceptible to moisture stress. Water deficit depressed the economic yield much more during pod formation and maturity than during other periods (Lenka and Misra, 1973). Sensitivity to drought during pod filling is closely associated with yield potential of genotype in well watered environments (Nageswara Rao et al., 1988).

2.4 GENOTYPIC RESPONSES TO MOISTURE STRESS

Inadequate moisture is the most limiting factor in groundnut production, as most cultivars are not resistant to drought (Stansell et al., 1976). Drought stress in groudnut depends primarily on the stress pattern as genotypic variation is usually of secondary significance: the timing of drought has a large impact on the variation in the mean response (Williams et al., 1985). In general, the response of a genotype to drought increases with yield potential (long maturity periods), increasing with the closeness of drought-end to final harvest.

Singh et al. (1991) reported that, out of 22 groundnut varieties evaluated under 11 patterns of drought, none of the

genotypes evaluated was insensitive to drought. Genotypes which were stable with high mean yield were identified in early and mid-season patterns, but not in the other patterns where genotypic sensitivity was strongly correlated with yield performance. However, in a cross combination (multilines), the genotypic blends performed better than the constituent pure stands (pure lines) in respect of several characters in both patterns (Ravindranath et al., 1987). Differences in crop growth rates exist in several groundnut varieties, but differences in the stability of partitioning to reproductive sinks are the dominant attributes of genotypes adapted to drought (Greenberg et al., 1992). Results in most literatures have indicated that differences in adaptation to drought in most groundnut genotypes were more attributable to tolerance of temperature and or humidity than water stress.

Despite severe droughts in most locations all over the world, several crop varieties can still perform better under stress conditions. Busalo-Bulafo (1992) reported of a variety that gave better yields under drought and recovered more quickly after drought stress. Gang et al. (1992) reported of a cowpea variety and a soyabean variety resistant to drought after they were subjected to water deficits. Gwathmey and Hall (1992) reported that a cowpea variety, 8517 was tolerant to drought compared to another variety CB5. Under drought condition, total reproductive duration of drought stressed 8517 was 50% greater than that of CB5, and 50% of its pod

production escaped the drought. Bockelee et al. (1974) and Patel et al. (1983) also observed groundnut resistant to water stress conditions. Bockelee et al. (1974) reported that the groundnut variety, 55-437 was superior to the variety 47-16, a creeping and drought - resistant late variety, even under low rainfall conditions, and was good with normal rainfall. A lot of groundnut varieties exist which are tolerant to drought and several varieties with relatively short maturity periods have been developed (Yayock et al., 1986). This early maturing characteristic makes a lot of crops to escape drought rather than being tolerant. Early groundnut varieties of short duration and drought tolerant include: 73-30 (Gautreau, 1982); 55-437 (Bockelee et al., 1974); 206, SBX1 and HG10 (Sanjeevi:h, 1972). Other mid/late groundnut varieties have been developed which are drought tolerant, even though, they are more adapted to the Sahelian areas with similar climate (Gautreau et al., 1980).

Johnson and Asay (1978) enumerated different methods of screening for drought resistance which include: germination under condition of drought and recovery of seedling from drought and drought stress using turgor pressure. Kushirenko et al. (1978) reported changes in the content of total and band chlorophyll, number of components of structural and soluble proteins in the leaf chloroplast before and after exposure of groundnut plants to droughts as methods of determining drought resistance.

Under normal and stressed conditions, Bhatia et al. (1984) found that groundnut cultivar M-13 produced more pegs per plant than cultivar, J-11. The high pegs produced by M-13 was as a result of high capacity for withstanding drought and high compensation during revival after rainfall. With JL-24, its drought tolerance has been attributed to its high root respiration under water stress (Dhopte and Ramteke, 1991). The drought tolerance of JL-24,according to Dhopte et al. (1991) was also as a result of its lower leaf area index and higher water use efficiency. In another trial, cultivar Comet showed significantly higher yields than other genotypes like Florunner and OK-FH15, and it was concluded that the lower leaf water potential, greater changes in osmotic potential and higher apoplastic water fraction in Comet as compared to the other genotypes, suggested that it had greater resistance to dehydration under conditions of high soil water deficit and high evaporative demand (Erickson and Ketring, 1985). According to Padma et al. (1991) groundnut cultivar K-3 followed by cultivar M-13 performed better under rainfed condition than JL-24 and Gangapuri if sowing was delayed. However, when sowing was delayed further, JL-24 and K3 gave the best performances. In a relative drought tolerance studies of 17 groundnut genotypes ICG-5266 and JL-24 had high yield potential at all moisture regimes, but the percentage of reduction in the yields with increasing moisture stress was higher than in other genotypes (Shashikumar et al., 1988).

Shashikumar et al. (1988) also observed that, the yield potential of ICG-4504 and GPHY-35 under good moisture regime was low but the percentage of reduction in their yield under increasing moisture stress was also less.

Rosario and Fajardo (1988) reported that at a soil moisture content of 21% (approx. 50% of field capacity), significant interaction between variety and water regime were observed for stomatal resistance, leaf water potential and root weight in most groundnut genotypes. According to Rosario and Fajardo (1988), groundnut cultivars Acc 847, 55-437 and GNP 1157 were the most drought resistant on the basis of yield, morphological and physiological characters. The high yields of most cultivars, especially 59-127 and 73-33 were associated with low leaf water potential and in most cases, with high relative transpiration. The semi-late cultivar 57-422, typical of those avoiding rather than tolerating dehydration, had higher potentials, while early cultivars which avoid the end-of-season drought by a short life cycle had intermediate leaf water potentials. Those with the lowest potentials had the highest yields (Gautreau, 1977). The groundnut variety TMV 2 is also tolerant to drought in terms of yield, but drought treatments resulted in lower chlorophyll and nitrogen contents in the leaves of TMV2 (Rao et al., 1972). Varieties NCA 17090, GG2 and CGC 4018 were tolerant to drought in terms of physiological attributes, (Ravindra et al., 1990a). Varieties Pearl Early Runner, X537B, Florunner

and X487A were tolerant to drought in terms of heat tolerance (Bennett and Hammonds, 1992). The heat tolerance was acquired as a result of exposure to natural water stress. Nimbalkar et al. (1987), reported that out of 11 varieties evaluated for drought tolerance, TMV10 had the highest yield and had the best moisture use efficiency, while cultivar 206 according to Sanjeeviah (1972) was tolerant to drought on the basis of its osmotic pressure, because out of 10 varieties germinated in solutions of three osmotic pressures, the variety gave the highest germination, suggesting that it may be the most drought resistant.

Among drought periods in Florunner groundnut, drought from 71-105 days after planting was most severe, followed by drought from 106 days after planting till harvest with a mean yield of 4521 kg/ha (Stansell and Pallas, 1993). Mid season 70 day drought (36-105 days after planting) reduced the average yield to 1387 kg/ha, while a 70 day drought from 71 day after planting through harvest reduced yields to 2592 kg/ha.

The responses of groundnut genotypes to drought have been shown to be influenced by the timing of drought relative to the phenological development and by yield potential in non-stressed conditions (Anon, 1985). The major variation between genotypes is associated with reproductive physiology, where the ability to initiate fruit despite drought, or to recover rapidly after drought provide opportunities for the genotypes

to better adapt to long term drought. Blum (1988) reported that early varieties of crops with a high yield potential were most likely to yield best under drought stress. The improvement of yield under stress must therefore combine a reasonably high yield potential with specific plant factors which will buffer yield against a severe reduction under stress (Blum, 1983). On the other hand, potentially lower yielding genotypes occasionally have been found to perform very well under drought stress conditions especially under severe drought stress (Blum, 1982 and Ceccarelli, 1987). One is left with the long standing practical conclusion of Reitz 1974, and Gupta (1994, 1996), that varieties fall into three categories: (a) those with uniform superiority over all environments, (b) those relatively better in poor environments, and (c) those relatively better in favoured environments.

When a long rainy season occurs, greater yield potential of the long duration genotypes can be achieved, but the resources of time and water are not fully utilized by the short duration genotypes (Nageswara-Rao et al., 1989). In years when the seasons end early, the yield potential of the long season genotypes is not achieved but the earlier maturing genotypes yield more by escaping the end-of-season drought (Nageswara Rao et al., 1989).

CHAPTER 3

MATERIALS AND METHODS

3.1 LOCATION

Experiments were conducted at the Institute for Agricultural Research farm at Samaru, Zaria, Nigeria (11°11'N 07°38'E, 686m above sea level) during the 1995 and 1996 rainy seasons.

Samaru lies in the Northern Guinea Savanna zone of Nigeria. It has an annual rainfall of about 1060mm, mostly distributed between the months of May and October, with a mean monthly minimum and maximum temperatures of 20°C and 30°C, respectively during this period. The soil is moderately deep, well drained and characteristically typical, sandy loam. The climatological data collected during the 1995 and 1996 growing seasons are presented in Appendix 1 and 2.

3.2 TREATMENT AND EXPERIMENTAL DESIGN

The treatments consisted of 16 groundnut genotypes: JL-24; SAMNUT-14 (55-437); SAMNUT-18 (RRB); SAMNUT-17 (48 -115B); ICG 221; ICG 4601; ICG 4790; ICGV 86745; ICGV 86708; ICGV 86742; ICG 4747; ICGV-SM 85045; ICGV 88023; ICGV 86124; ICGV 90127 and FLEUR 11. The treatments were laid out in a randomized complete block design with three replications. The gross plot size was $15m^2$. The gross plot was made up of 4 ridges, 75cm in width and 5m long. The groundnut genotypes have been described in Appendix 3.

3.3 FIELD EXPERIMENT AND TECHNIQUES

3.3.1 LAND PREPARATION

The land was ploughed, harrowed to a fine tilth and ridged at 75cm width. The field was marked out into 48 plots of 15m^2 (3mx5m) sizes each. Paths of 1m across the rows (ridges) and 75cm (one ridge) along the rows were made to separate adjacent plots.

3.3.2 FERTILIZER APPLICATION

Single superphosphate (SSP) was broadcast at the rate of 300 kg/ha P_2O_5 after ploughing.

3.3.3 PLANTING AND PLANTING MATERIALS

The genotypes were planted on 21st June, 1995 (Normal planting) and 1st September, 1995 (Late planting) for the 1995 season and on 6th June, 1996 (Normal planting) and 31st August, 1996 (Late planting) for the 1996 season. Sixteen genotypes of groundnut were used. The genotypes included early maturing, and medium/late maturing types. Two kernels were planted per hole on a ridge at 4-5cm depth, after treatment with Fernasan D at the rate of 3g a.i/kg of kernels.

3.3.4 WEED CONTROL

Galex 500 E.C. (metolachlor + metobromuron), a pre-emergence herbicide was used at the rate of 5 litres/ha to suppress weed growth. This was applied a day after sowing.

Subsequent weed control was done manually by hoeing as necessary.

3.3.5 HARVESTING

Harvesting was done 14 to 18 weeks after planting. Harvesting was done by hand and pods were kept in separate bags for each plot. The pods were later air-dried. The haulms were also kept for each plot and weighed after air-drying.

3.4 SCREEN HOUSE EXPERIMENT AND TECHNIQUE

The screen house experiment were conducted to study genotypic variability for sensitivity to drought in 16 groundnut genotypes. The treatments were laid out in a completely randomized design. Pot measuring 21cm in height with 23cm and 16cm upper and bottom diameters, respectively, were filled with sandy loam soil, leaving some top space to allow for watering. Fertilizer at the rate of 300 kg Super phosphate (P_2O_5)/ha was mixed with the soil and the pots were watered to field capacity. Two kernel of groundnut were sown in each pot after seed treatment (10 pots for drought treatment for each genotypes and 5 pots for control).

Drought was imposed when plants reached 50% flowering stage in the drought treatment, by watering only two times in a week, according to Erickson and Ketring, (1985). The control treatment received regular watering (watering every other day) throughout the growing period.

3.5 OBSERVATION AND DATA COLLECTION

Stand count was taken at two weeks after sowing. Assessment of characters such as days to first flowering and days to 50% flowering were done through daily monitoring from 3-4 weeks after sowing. Maturity determination was done according to Singh and Oswalt, (1991). Days to maturity was recorded when there was a change in the leaf colour from green to slight yellow. Number of plants at harvest was taken and recorded for each plot.

Characters assessed after harvest included: number of pods per plant (5 plants taken at random and the average of pods taken), haulm yield, pod yield, weight of 100 seeds (by taking 100 seeds at random) and the shelling percentage. The protein and the oil contents of the seeds were also determined in the laboratory, using Kjedahl's and Soxhlet's extraction methods, respectively.

3.6 ANALYSIS OF DATA

Data collected were subjected to analysis of variance and the means were compared by LSD at 5% level of probability. Data for the seasons were analysed individually and the corresponding seasons combined. Data for the years were analysed individually and the individual years combined to determine the significance of moisture stress and end-of-season drought on the genotypes. Phenotypic and genotypic correlations between pod yield and the various yield components were also tested at 5% level of probability, under moisture stress in the field and in the screen house.

The forms of ANOVA for the individual years and for the combined years are as shown in Tables 1 to 4.

Table 1. Form of ANOVA for the Individual years in the field.

Sources of variation	D.F	SS	MS	F
Replication	(r-1)	-	-	-
Genotypes	(g-1)	-	-	-
Error	(r-1)(g-1)	-	-	-
Total	(r x g)-1	-	-	-

Table 2. Form of ANOVA for the combined years in the field.

Sources of variation	D.F.	SS	MS	F
Year	(y-1)	-	-	-
Replication (year)	(r-1) x y	-	-	-
Genotype	(g-1)	-	-	-
Genotype x year	(g-1)(y-1)	-	-	-
Error	(yg-1)(r-1)	-	-	-
Total	Ygr-1	-	-	-

Table 3. Form of ANOVA for the individual years in the screen house

Sources of variation	D.F	SS	MS	F
Genotypes	(g-1)	-	-	-
Error	g(r-1)	-	-	-
Total	gr - 1	-	-	-

Table 4. Form of ANOVA for the combined years in the screen house

Sources of variation	D.F.	SS	MS	F
Year	(y-1)	-	-	-
Genotype	(g-1)	-	-	-
Genotype x year	(y-1)(g-1)	-	-	-
Error	yg(r-1)	-	-	-
Total	ygr-1	-	-	-

CHAPTER 4

RESULTS

4.1 AGRONOMIC PERFORMANCE UNDER NORMAL PLANTING AND ADEQUATE MOISTURE IN THE FIELD (MAY TO OCTOBER, 1995 AND 1996)

The means of all the characters evaluated in 1995 and 1996 are presented in Tables 6 and 8 respectively. The analysis of variance for the corresponding years are presented in Tables 5 and 7 respectively.

The analysis of variance for the year 1995 indicated that significant difference occurred ($p \geq 0.05$) among the genotypes in their number of plants at emergence, days to 50% flowering, days to maturity, number of plants at harvest, pod yield, shelling %, 100-seed weight and oil content (Table 5). But there was no significant difference among the genotypes for the other parameters not mentioned, at the same level of probability.

The mean performance (Table 6) indicated that number of plants at emergence ranged from 88 to 148 plants, with ICGV 86745 having the highest number of plants at emergence and 48 - 115B having the lowest. Generally, most of the genotypes performed above average in this parameter. Days to 50% flowering also varied among the genotypes significantly. Days to 50% flowering ranged from 28 to 34 days (Table 6).

Days to maturity among the genotypes also differed significantly ($p \geq 0.05$). JL-24 took longer days to maturity (122days), followed by ICG 4747 and ICGV 90127 which had 119

days each to maturity. However, RRB had the lowest days to maturity (100 days), meaning that it is early maturing. Other genotypes that are early maturing included ICG 4790 and 55-437 which had 106 and 107 days to maturity respectively.

Number of plants at harvest also varied among the genotypes in 1995 normal panting experiment. The mean performance indicated that the genotypes ICGV 86745 had the highest number of plants at harvest, with 144 plants (Table 6), followed by FLEUR-11, ICGV 88023 and ICGV 86124 which gave 141, 135 and 132 number of plants at harvest respectively. The lowest number of plants at harvest was given by 48-115B, which had only 65 plants at harvest. On the average most of the genotypes performed very poorly for number of plants at harvest and this could have a very drastic effect on pod yield.

Highest pod yield was recorded for ICGV 86124 under normal planting in 1995 (Table 6). The highest pod yield was 2298.00 kg/ha. Other genotypes that excelled included: FLUER-11 (2122.00), ICGV 90127 (2028.70), RRB (1973.40) and ICG 4601 which produced 1769.10 kg of pods/ha. The lowest pod yield on the other hand was produced by ICGV 88023 which had 962.20 kg of pods/ha. Lower pod yields was also produced by ICGV 86745 and 55-437 with 1009.70 and 1089.00 kg/ha respectively compared to the other genotypes.

Shelling % ranged from 64.67 to 74.00% among the genotypes under normal planting in 1995 (Table 6). Most of

the genotypes had higher shelling %. The genotype that gave the highest shelling % was 55-437, ironically, however, this genotype was one of the genotypes that had the lowest pod yield. ICGV 86124 which was among the higher pod yielders was also among the genotypes which had high shelling %. This genotypes had 73.33% as its shelling % and by that it ranked the third among the genotypes in shelling % (Table 6).

Significant variation occurred among the genotypes in their 100-seed weight (Table 5). 100-seed weight ranged between 23.70 to 49.10 gms among the genotypes. The genotype ICG 4790 had the highest 100-seed weight of 49.10gms, followed by ICGV 86124, ICGV 86708, and JL-24 which had 35.83, 35.33 and 34.37 gms respectively. The lowest 100-seed weight was given by 48-415B with 23.70gms. The 100-seed weight like most other parameter are determinant of yield in groundnut.

Oil content also varied significantly ($p \geq 0.05$) among the genotypes. The genotype that had the highest oil content was ICG 4601 with 55.97% while the lowest in oil content was ICGV 86708 with 45.33%. Less than half of the genotypes had more than average oil content (Table 6).

The mean performance of the groundnut genotypes under normal planting in the field in 1996 are presented in Table 8. The analysis of variance are presented in Table 7.

The analysis of variance indicated that significant difference occurred among the genotypes ($p \geq 0.05$) for days to 50% flowering, days to maturity, pod yield, shelling %, 100-

seed weight and haulm yield. No significant difference occurred among the genotypes for number of plants at emergence and the other agronomic parameters, at the same level of probability.

The mean performance showed that days to 50% flowering ranged from 29 to 32 days among the genotypes. 48 - 115B, had the highest number of days to 50% flowering (32 days). However, in the 1995 normal planting experiment, significant difference did not occur among the genotypes for this parameter. The lowest number of days to 50% flowering of 29 days, was recorded for FLUER-11.

Days to maturity ranged from 100-123 days among the genotypes. RRB had the lowest days to maturity (100 days). This same genotypes also had the lowest days to maturity in 1995 (Table 6). It is an early maturing genotype. The longest maturing genotypes was JL-24, which took 123 days to mature. On the over all the average maturity days among the genotypes was 111 days.

Pod yield was also significantly different ($p \geq 0.05$) among the genotypes (Table 7). The mean performance indicated that highest pod yield was produced by ICGV 90127 which had 970.80 kg/ha followed by ICG 4790 and ICGV 86124 with 966.00 and 920.60kg/ha respectively. Lowest pod yield was produced by ICG 221 with 227.80 kg/ha. On the average pod yield in 1996 (Table 8) was below that of 1995 (Table 6).

Highly significant difference ($p \geq 0.05$) occurred among the genotypes for shelling % (Table 7), that was also the case in the 1995 (Table 5). The mean performance revealed that shelling % in 1996 (Table 8) was lower compared to that of 1995 (Table 6). In 1996, highest shelling % was given by ICGV 86124 (Table 8), followed by JL-24, 55-437 and 48-115B which had 69.27, 68.83, and 65.07% respectively. Lowest shelling % was given by FLEUR-11 with 33.17%.

100-seed weight ranged from 20.60 to 43.00gms with ICG 4790 having the highest 100-seed weight and ICGV 86708 giving the lowest. Performance in 100-seed weight is very poor compared to that of 1995. Most of the seeds were shrivelled in the 1996 normal planting experiment in the field.

Haulm yield among the genotypes was also statistically different ($p \geq 0.05$). The overall performance in haulm yield was given by ICGV 86742 with 4068.90kg/ha followed by ICGV-SM 85045, ICGV 86124, ICG 4747, which gave haulm yields of 3540.00, 3275.60 and 3208.90kg/ha respectively (Table 8). However, no significant difference occurred among the genotypes in 1995 normal planting experiment (Table 5) for haulm yield.

The combined analysis of variance for the normal planting experiment of 1995 and 1996 are presented in Table 9. The combined mean performance are presented in Table 10. The combined analysis of variance indicated that there was no significant difference among the genotypes in days to first

flowering, number of pods/plant, protein content and oil content (Table 9), but significant difference occurred among the genotypes in the other parameters at 5% level of probability.

Significant difference occurred among the genotypes in their number of plants at emergence. Higher germination was achieved in most of the genotypes as indicated by their number of plants at emergence. The combined mean performance indicated that FLEUR-11 had the highest number of plants at emergence with 151 plants, which meant that 94.38% germination was achieved. Higher number of plants at emergence was also given by ICGV 86745, ICGV 90127, and ICGV 86124 with 148, 146, and 144 plants at emergence respectively. The lowest number of plants at emergence was recorded for 48 - 115B which had 118 plants (Table 10). The germination % of this genotype was 73.75% which was lower in comparison to the others.

Days to 50% flowering was also found to differ significantly ($p \geq 0.05$) among the genotypes (Table 9). The combined mean performance (Table 10) indicated that days to 50% flowering ranged between 29 and 33 days. The genotype ICG 221 had the highest number of days to 50% flowering, while ICGV 86745 had the lowest number of days to 50% flowering.

Days to maturity ranged between 100 and 122 days (Table 10). Few of the genotypes had lesser number of days to maturity, meaning that most of the genotypes are relatively late maturing. Highest number of days to maturity was

recorded for JL-24 which had 122 days. Other genotypes that took longer days to maturity were; FLEUR-11 with 119 days and ICGV 88023 with 117 days. Lowest days to maturity was given by RRB which had 100 days (Table 10). This genotype have been known to be early maturing.

Number of plants at harvest was also significantly different among the genotypes ($p \geq 0.05$) (Table 9). The combined mean performance revealed that FLEUR-11 had the highest number of plants at harvest with 142 plants, while the lowest plants at harvest of 103 was recorded for 48-115B. Other genotypes which had relatively higher number of plants at harvest; ICGV 86745, ICGV 90127 and ICGV 86124 which had 141, 138 and 137 plants at harvest respectively (Table 10).

The combined analysis of variance (Table 9) indicated that significant difference occurred between the genotypes in their pod yield. Pod yield on the average was good. The highest pod yields of 1609.30 kg/ha was produced by ICGV 86124. Higher pod yields was also produced by FLEUR-11, ICGV 90127, JL-24, ICG 4601 and ICG 4790, which had 1520.30, 1499.70, 1303.80, 1254.90 and 1229.80 kg/ha. Most of the genotypes performed creditably well for pod yield.

Variation in shelling % among the genotypes was also enormous statistically (Table 9). The combined mean performance indicated that shelling % was highest in the genotype ICGV 86124 which had 72.58%. Other genotypes that excelled in this parameter included; 55-437 (71.42%), JL-

24(68.47%), ICG 4790 (67.63%), 48-115B (67.20%) and ICGV 90127 (64.10%). The lowest shelling % was however, given by FLEUR-11 which had 52.08% (Table 10).

100-seed weight also varied significantly ($p \geq 0.05$) among the genotypes. Wider range existed, between 23.42 and 46.05gms. Highest 100-seed weight was given by ICG 4790 while lowest 100-seed weight was given by 48-115B (Table 10).

The combined analysis of variance indicated that significant difference occurred among the genotypes in their haulm yield (Table 9). From the combined mean performance (Table 10) it was observed that ICGV 86742 had the highest haulm yield of 3633.30 kg/ha. High performance in haulm yield was then followed by ICGV 88023,ICGV-SM 85045, ICG 4747, ICGV .6745 and ICG 4790 which had 3544.40 3301.70, 3220.00, 3073.30 and 2982.20 kg/ha respectively. However, other genotypes had lower haulm yields. The lowest haulm yield was given by ICG 221 with 1675.60 kg/ha.

Table 5: Analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1995.

Source of variation	DF	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of Plants at harvest	pod/plant	Pod yield (kg/ha)	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Replication	2	2462.771	0.271	2.771	0.750	3256.521	68.583	152060.739	56.271	3.769	1610339.46	10.931	10.676
Genotype	15	959.689*	2.889	7.533**	107.621**	1153.065*	21.221	523421.938**	30.489**	104.966**	995651.16	11.162	25.633*
Error	30	352.393	2.293	1.704	5.883	432.765	16.517	80031.656	8.093	10.281	578787.91	7.567	10.526
Total	47	3774.853	5.453	12.008	114.254	4842.351	106.321	755514.32	94.853	119.016	3184778.40	29.660	46.835

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 6 Mean performance of 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1995

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling%	100 seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
ICG 221	119.67	29.00	34.33	115.67	114.33	16.67	1242.50	66.00	33.17	1906.70	27.70	51.23
ICG 4601	110.00	25.00	28.67	112.00	100.33	17.67	1769.10	66.00	27.37	3322.20	27.03	55.97
ICG 4790	105.33	28.33	30.67	106.00	109.33	22.00	1493.60	73.67	49.10	2851.10	39.53	48.40
ICGV 86745	148.33	27.00	28.33	114.33	144.00	21.67	1009.70	66.33	35.07	3966.70	26.63	52.60
ICGV 86708	140.33	27.00	29.00	111.67	119.33	15.67	1272.00	65.67	35.33	3057.80	28.87	45.33
ICGV 86742	106.00	27.33	28.67	108.67	103.00	18.33	1422.70	65.67	33.80	3197.80	25.77	51.77
ICG 4747	127.67	27.67	29.00	119.00	123.33	19.33	1282.10	66.67	33.60	3231.10	24.67	48.53
JL 24	118.33	28.67	31.00	121.67	104.00	18.00	1759.90	67.67	34.37	2617.80	30.27	52.13
SAMNUT-18 (RRB)	120.33	27.00	28.67	100.00	101.67	19.00	1973.40	69.67	33.50	3071.10	25.23	47.76
SAMNUT-14(55-437)	142.00	28.33	29.67	106.67	120.1	17.00	1089.00	74.00	24.70	2595.60	25.20	51.06
SAMNUT 17(48-1158)	88.00	28.00	31.33	108.67	64.67	15.67	1186.70	69.33	23.70	2522.20	24.76	50.37
ICGV-SM85045	125.67	27.00	28.33	115.33	115.67	25.33	1531.40	65.00	31.47	3063.30	28.37	50.07
ICGV 88023	138.33	28.33	30.67	117.33	134.67	16.67	962.20	64.67	25.63	4384.44	28.40	49.53
ICGV 86124	140.67	28.00	29.33	118.33	132.00	22.00	2298.00	73.33	35.83	2686.70	25.27	53.23
ICGV 90127	139.67	27.33	29.67	119.00	131.00	19.67	2028.70	68.67	31.17	3280.00	28.10	48.50
FLEUR11	151.00	28.67	31.00	118.33	141.00	19.00	2122.40	71.00	33.60	3211.10	39.83	49.00
MEAN	126.33	27.67	29.92	113.31	116.15	18.97	1528.13	68.33	32.59	3060.33	27.19	50.81
C.V. %	14.86	5.47	4.36	2.14	17.91	21.41	18.51	4.16	9.84	24.86	10.12	6.39
LSD	31.30	2.53	2.18	4.04	34.68	6.78	471.67	4.74	5.35	1268.44	4.59	5.41

Table 7: Analysis of variance showing sources of variation, degree of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1996.

Source of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of Plants at harvest	pods/ plant	Pod yield (kg/ha)	Shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Replication	2	32.271	0.083	1.083	12.271	103.521	9.771	280322.133	55.498	1.673	134837.71	8.130	34.381
Genotype	15	52.054	0.699	2.132**	144.954**	125.506	15.321	200576.528**	337.264**	120.697**	1120215.83**	4.435	18.789
Error	30	53.338	0.661	0.528	10.471	67.876	13.238	72758.480	106.335	16.096	1004289.00	8.088	26.833
Total	47	137.663	1.443	3.743	167.696	296.903	38.33	553657.13	499.093	138.466	2259342.50	20.653	80.003

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 8 Mean performance of 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1996

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
ICG-221	153.00	28.33	31.67	109.33	138.33	2.33	227.80	61.17	29.77	1444.40	26.97	50.20
ICG 4601	144.33	27.33	30.33	110.33	137.33	6.67	740.70	54.27	27.37	2617.80	25.77	49.63
ICG 4790	144.00	28.33	30.67	109.00	141.00	7.33	966.00	61.60	43.00	3113.30	27.17	50.00
ICGV 86745	148.00	27.00	30.33	118.00	137.00	4.67	309.30	59.63	26.80	2180.40	26.60	49.00
ICGV 86708	146.00	27.33	30.00	113.67	143.00	7.67	616.00	44.67	20.60	2868.90	24.57	46.60
ICGV 86742	139.00	28.00	30.33	112.33	130.33	10.67	644.70	54.50	21.97	4068.90	26.23	51.17
ICG 4747	152.00	27.67	30.00	109.67	146.33	8.00	703.20	57.67	23.53	3208.90	26.90	49.13
JL-24	143.33	28.33	31.33	123.00	146.00	9.33	847.70	69.27	36.73	2924.40	24.40	45.07
SAMNUT-18 (RRB)	149.00	28.00	31.00	100.00	140.67	5.33	386.10	40.70	31.47	2140.00	25.77	47.90
SAMNUT-14(55-437)	140.00	28.00	31.67	102.00	126.67	5.33	632.10	68.83	28.20	2844.40	26.23	52.37
SAMNUT 17(48-115B)	148.67	28.67	32.00	101.00	140.67	3.33	380.60	65.07	23.13	3066.70	25.03	50.23
ICGV-SM 85045	146.33	27.67	30.00	100.33	133.00	6.33	295.60	62.43	36.40	3540.00	27.17	49.57
ICGV 88023	143.33	28.33	30.67	116.33	126.00	7.67	421.70	51.50	25.53	2704.40	25.13	48.33
ICGV 86124	146.33	27.67	29.33	114.33	142.33	5.67	920.60	71.83	32.43	3275.60	28.47	55.70
ICGV 90127	152.00	28.33	30.00	112.33	145.00	9.00	970.80	59.53	23.23	2673.30	24.87	48.90
FITURE1	150.33	27.33	29.00	118.67	143.00	9.00	918.10	33.17	35.07	2415.60	24.13	46.57
MEAN	146.60	27.89	30.32	110.65	138.54	6.77	623.82	57.24	29.08	2817.92	25.96	49.46
C.V. %	4.98	2.91	2.38	2.92	5.95	53.74	43.24	18.02	13.80	22.55	10.95	10.47
LSD	12.18	1.36	1.21	5.40	13.74	6.07	499.73	17.19	6.69	16.70	4.74	8.64

Table 9: Combined and analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1995 and 1996

Source of variation	DF	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of Plants at harvest	No of pods/plant	Pod yield kg/ha	shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Year	1	9861.70**	1.260	8.760**	170.667**	12037.760**	3577.042**	19626601.650**	2953.711**	295.753**	1410530.47	36.138*	43.740
Rep.(year)	4	1247.521	0.177	1.927	6.510	1680.021	39.177	216191. 44	55.882	2.721	408690.99	9.530	22.529
Genotype	15	542.560**	2.527	6.705**	209.619**	619.010**	19.567	559438.840**	206.994**	175.495**	1161648.47**	4.716	29.040
Genotype *Year	15	469.183*	1.060	2.960**	42.956**	659.560**	16.975	164559.630*	161.258**	50.168**	954218.52**	10.880	15.382
Error	60	202.865	1.477	1.116	8.177	250.321	14.877	76395.070	57.214	13.189	491354.95	7.827	18.680
Total	95	12323.890	6.501	21.468	437.929	15246.672	3667.638	20643187.00	3434.559	537.326	4066443.40	69.091	129.371

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 10 Combined mean performance of 16 groundnut genotypes grown under adequate moisture condition in the field between May and October at Samaru in 1995 and 1996

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100 seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
ICG 221	136.33	28.67	33.00	112.50	126.33	9.5	735.10	63.58	31.47	1675.60	27.33	50.72
ICG 4601	127.17	26.17	29.50	111.17	118.839	12.17	1254.90	60.13	27.37	2970.00	26.40	52.80
ICG 4790	124.67	28.33	30.67	107.50	125.17	14.67	1329.80	67.63	46.05	2982.20	28.35	49.68
ICGV 86745	148.17	27.00	29.33	116.17	140.501	13.17	659.50	62.98	30.93	3073.30	26.32	50.80
ICGV 86708	143.17	27.17	29.50	112.67	131.17	11.67	944.00	55.17	29.97	2963.30	26.72	45.96
ICGV 86742	122.50	27.67	29.50	110.50	116.67	14.50	1033.70	60.08	27.88	3633.30	26.00	51.47
ICG 4747	139.83	27.67	29.50	114.33	134.83	13.67	992.70	62.17	28.57	3220.00	25.78	48.83
JL-24	130.83	28.50	31.33	122.33	125.00	13.67	1303.80	68.47	35.55	2771.10	27.33	48.60
SAMNUT-18 (RRB)	134.67	27.50	29.83	100.00	121.17	12.17	1179.70	55.18	32.48	2605.60	25.50	47.83
SAMNUT-14(55-437)	141.00	28.17	30.67	104.33	123.33	11.17	860.50	71.42	26.45	2720.00	25.72	51.72
SAMNUT 17(48-115B)	118.33	28.33	31.67	104.83	102.67	9.50	783.60	67.20	23.42	2794.40	24.90	50.30
ICGV-SM 85045	136.00	27.33	29.17	107.83	124.33	15.83	913.50	53.72	33.93	3301.70	27.67	49.82
ICGV 88023	140.83	28.33	30.67	116.83	130.33	12.17	695.50	58.08	25.58	3544.40	26.77	48.93
ICGV 86124	143.50	27.83	29.33	116.33	137.17	13.83	1609.30	72.58	34.13	2981.10	26.87	54.47
ICGV 90127	145.83	27.83	29.83	115.83	138.00	14.33	1499.70	64.10	27.20	2976.70	26.48	52.67
FLEUR 11	150.67	28.00	30.00	118.50	142.00	14.00	1520.30	52.08	34.33	2813.30	26.98	47.53
MEAN	136.47	27.78	30.22	111.97	127.34	12.87	1075.98	62.79	30.83	2939.13	26.58	50.13
C.V. %	10.44	4.37	3.50	2.55	12.42	29.96	25.69	12.05	11.78	23.85	10.53	8.62
LSD	22.79	1.94	1.69	4.58	25.32	6.17	442.33	12.10	5.81	1121.78	4.48	6.92

4.2 AGRONOMIC PERFORMANCE UNDER LATE PLANTING AND INADEQUATE MOISTURE IN THE FIELD (AUGUST TO DECEMBER, 1995 AND 1996)

The mean performance of the genotypes under end-of-season drought in 1995 are presented in Table 12. The analysis of variance of the same period is presented in Table 11. The analysis of variance indicated that significant difference occurred among the genotypes ($p \geq 0.05$) in their days to first flowering, days to 50% flowering, days to maturity and in their number of plants at harvest under end-of-season drought. Analysis of variance also showed significant difference for number of pods/plant, 100-seed weight, haulm yield and oil content (Table 11). But no significant difference was found for pod yield and the other remaining agronomic parameters at the same level of probability.

Days to first flowering ranged between 25 and 29 days. 48-115B had the longest days to first flowering and ICGV 86745 had the lowest number of days to first flowering. However, in the 1995 normal planting experiment, significant difference did not occur among the genotypes under end-of-season drought. Days to 50% flowering ranged from 26 to 31, with JL-24 having 31 days and ICGV 86745 having 26 days to 50% flowering (Table 12). Days to 50% flowering was also found to differ significantly among the genotypes in the 1995 normal planting experiment. On the average, a reduction of about 2 days in the number of days to 50% flowering was observed due to end-of-season drought. Meaning that, genotypes flower earlier

under moisture stresses condition.

Days to maturity ranged from 98 to 117 (Table 12). The genotype ICG 221 took longest days to maturity while 55-437 had the lowest days to maturity. 55-437, have been known to be early maturing. On the average, the genotypes took lesser number of days to maturity under end-of-season drought (Table 12) than under normal moisture conditions (Table 8). Genotypes that are early maturing based on their days to maturity included; RRB (100 days), 48-115B (101 days) and ICGV-SM 85045 with 103 days.

Number of plants at harvest also differed significantly ($p \geq 0.05$) among the genotypes (Table 11). The mean performance indicated that number of plants at harvest was badly affected due to end-of-season drought. In most of the genotypes especially ICGV 86742, 48-115B, and ICG 4747, a reduction of 71.39%, 66.67% and 60.99% in number of plants at harvest was observed due to end-of-season drought in relation to the number of plants at emergence. The genotype ICGV 88023 had the highest number of plants at harvest. On the average and in comparison to the normal planting experiment, end-of-season drought reduced the number of plants at harvest by 34.64%. A reduction of number of plants at harvest would normally affect the final pod yield.

Number of pods/plant was also significantly different among the genotypes under end-of-season drought (Table 11). However, significant difference ($p \geq 0.05$) did not occur for the

number of pods/plant under the normal planting of the same period.

The mean performance (Table 12) indicated that RRB, 55-437, and ICGV 86124 had the highest number of pods per plant. The lowest number of pods/plant was given by ICG 221 which had only 2 pods/plant. Number of pods/plant was reduced by 77.65% as a result of end-of-season drought. Effect of end-of-season drought on number of pods/plant was devastating (Table 11).

100-seed weight was also adversely affected by end-of-season drought. Moisture stress during terminal growth of groundnut reduced 100-seed weight by about 61.95%. The mean performance (Table 12) indicated that ICGV 86124 had the highest 100-seed weight of 34.67gms, while lowest 100-seed weight of 21.33gms was given by ICGV 86742. The adverse effect of moisture stress on 100-seed weight have been observed in the shrivelled appearance of the kernels.

Haulm yield under end-of-season drought ranged between 466.70 and 1566.70 kg/ha. Highest haulm yield was produced by ICGV 86124, even though this genotype did not produced the highest number of plants at harvest (Table 12). This particular genotype have been found to grow profusely compared to the other genotypes. The lowest haulm yielder was by 48-115B. On the average, moisture stress reduced haulm yield by about 66.53%. Most genotypes was found to have died or their leaves totally desiccated under moisture stress and end-of-

season drought.

Variation in oil content of the genotypes was also observed under moisture stress. Oil content ranged between 44 to 56% among the genotypes, with ICGV 86124 giving the highest oil and ICGV 86708 giving the lowest oil content. The mean performance of the genotypes in the 1996 end-of-season experiment are presented in Table 14. The analysis of variance are presented in Table 13. The analysis of variance indicated that significant difference occurred among the genotypes, for all the parameters, except for pods/plant, pod yield, and protein content.

The mean performance (Table 14) indicated that number of plants at emergence ranged from days to 50% flowering ranged from (27 to 30 days) and (29 to 32 days) respectively. 55-437 had the longest days to first flowering and this same genotype also had the longest days to 50% flowering (Table 14). The lowest days to 50% flowering was given by ICGV 221.

Days to maturity among the genotypes also varied significantly among the genotypes under moisture stress. Under moisture stress, plants on average took longer days to maturity (115 days) (Table 14), compared to normal planting experiment which took only 111 days.

Number of plants at harvest was affected significantly (Table 13). Number of plants surviving upto harvest was drastically reduced by moisture stress. In ICG 4790 for example, the number of plants at harvest was 133, but only 90

survived upto harvest (Table 14). Meaning that 32.33% died probably, but certainly due to moisture stress. In comparison to the normal planting experiment, on average, a reduction of 9.25% resulted due to moisture stress.

Shelling % differed significantly among the genotypes (Table 13). The mean performance indicated that performance in shelling % ranged from 51.03 to 70.13% (Table 14). Highest shelling % of 70.13% was given by 55-437 under moisture stress. This genotype was also one of the genotypes that produced high shelling % under normal planting (Table 8). Other genotypes that gave high shelling % are; 48-115B (68.47%), ICGV-SM 85045 (66.13%), ICGV 86124 (65.87%) and JL-24 (65.47%). The lowest shelling % was given by ICG 4747 (Table 14). Surprisingly, howeve , shelling %, on average under moisture stress (Table 14) was higher than that of normal moisture condition (57.24%) (Table 8).

Analysis of variance also indicated that significant difference existed among the genotypes in their 100-seed weight ($p \geq 0.05$) (Table 13). The mean performance showed that , highest 100-seed weight was given by FLEUR-11 with 39.63gms, followed by JL-24 and ICGV 86124 which had 37.63gms each. Lowest 100-seed weight was recorded for ICGV 86708. This genotype have been known to have smaller kernels and the kernels most at times looked shrivelled.

Haulm yield ranged from 1248.90 to 2317.80 kg/ha. Haulm yield have been found to be seriously affected due to end-of-

season drought. A reduction on average of 34.35% in haulm yield was recorded due to moisture stress. ICGV 86745 had the highest haulm yield while JL-24 had the lowest haulm yield.

Variation also occurred in oil content (Table 13). Oil content ranged between 42.60 to 55.90% (Table 14). The combined mean performance of the groundnut genotypes grown under end-of-season drought in the field are presented in Table 16. The combined analysis of variance for the same period are presented in Table 15. The combined analysis of variance indicated that significant difference ($p \geq 0.05$) existed among the genotypes for all the parameters except for number of plants at emergence, protein content and oil content (Table 15). Similar trend also occurred in the normal planting experiment (Table 9). The genotype x year interaction among the genotypes was significant ($p \geq 0.05$) for days to first flowering, days to 50% flowering, days to maturity, number of plants at harvest, 100-seed weight, haulm weight and oil content. But no significant genotype x year interaction occurred at the same level of probability for pod yield, number of plants at emergence, number of pods/plant, shelling % and protein content (Table 15). Groundnut yields have been reported to be variable from year to year because of the large inter-annual variations in rainfall.

The combined mean performance indicated that days to first flowering ranged from 26 to 29. The genotypes that had the highest number of days to first flowering were ICG 4790,

JL-24, and 48-115B with 29 days each. The genotypes which had the lowest days to first flowering were; ICGV 86745, ICG 4601 and ICGV 86124 which had 26 days each. Days to 50% flowering, however, ranged from 28 to 31 days (Table 16). It has been observed that the genotypes on average had longer number of days to 50% flowering under normal moisture (30 days) (Table 10) than under end-of-season drought (29 days) (Table 16). The lowest number of days to 50% flowering was given by ICG 4601.

Days to maturity was also statistically different among the genotypes under end-of-season drought (Table 15). The combined mean performance indicated that some few of genotypes matured earlier than the others. For example, genotypes RRB, 48-115B and 55-437 matured in 101, 101 and 104 days respectively compared to genotypes like FLEUR-11, ICGV 86745 and ICGV 86124 which took longer days of 119, 119 and 118 days to maturity, respectively. Under end-of-season drought genotypes on the average took almost the same number of days to maturity to that of the normal planting experiment.

Number of plants at harvest was found to be significantly affected by end-of-season drought. In ICG 221 for example a reduction of 30.74% was observed due to moisture stress during the terminal stages of development of the genotype. The combined mean performance indicated that ICGV 88023 had the highest number of plants at harvest and probably the less affected by moisture stress. The genotype that gave the

lowest number of plants at harvest was ICGV 86742 (84 plants) (Table 16). On the average, a reduction of 10% of plants at harvest occurred among the genotypes as a result of moisture stress. It should be noted however, that reduction in number of plants reaching harvest could be caused by other factors like diseases or pest and not necessarily and solely by moisture stress alone. Reduction in plants at harvest therefore could be due to moisture stress and not absolutely to its effects alone.

Pods/plant which is also a determinant of pod yield was also drastically affected by moisture stress. This was also the case with pod yield under the same condition (Table 15). The combined mean performance indicated that highest number of pods/plan. and pod yield was given by ICGV 86124 and ICG 4747 respectively. The highest pods/plant and pod yield were 7 pods and 704.01 kg/ha respectively. Moisture stress have been found to reduce pods/plant on the average by 60.37% and pod yield by 49.76%. The lowest pod yields was given by ICG 4790 with 376.94 kg/ha. This genotype could be very susceptible to drought.

The combined analysis of variance ($p \geq 0.05$) (Table 15) indicated that significant difference occurred among the genotypes for shelling % under end-of-season drought. The combined mean performance indicated that the shelling % ranged between 45.80 to 65.23% (Table 16). The genotype 55-437 had the highest shelling %, followed by JL-24, ICGV 86124, and

ICGV-SM 85045 which had 62.40, 59.60 and 59.57% respectively (Table 16). Comparatively, shelling % under end-of-season drought was less than that of the normal planting experiment.

Haulm yield from the combined analysis, significantly differed ($p \geq 0.05$) among the genotypes (Table 15). The combined mean performance indicated that ICGV 86124 had the highest haulm yield of 1898.90 kg/ha followed by ICGV 86745, ICGV 88023, ICGV 90127, FLEUR-11, and 55-437 which had haulm yields of 1752.20, 1698.90, 1691.10, 1502.20, and 1497.80 kg/ha respectively. The lowest haulm yield of 1127.80 kg/ha was produced by ICGV 86708. The effect of end-of-season drought on haulm yield was enormous. A reduction of 51.10% was observed in haulm yield due to end-of-season drought. End-of-season drought have been found to be very detrimental on haulms, through desiccation of leaves and plant mortality.

The combined analysis of variance have also indicated that 100-seed weight was affected significantly among the genotypes ($p \geq 0.05$) (Table 15). The combined mean performance also indicated that 100-seed weight ranged between 21.90 and 36.15gms among the genotypes. Highest 100-seed weight was given by ICGV 86124 (Table 16).

Higher 100-seed weight was also given by FLEUR-11, JL-24, ICGV-SM 85045 and ICG 4790 with 35.82, 32.65, 30.07 and 30.05gms respectively. The lowest 100-seed weight of 21.90 gms was given by ICGV 86742. Effect of end-of-season drought on the genotypes in relation to 100-seed weight was glaring. A reduction of upto 10.34 in 100-seed weight was recorded as a result of end-of-season drought on average among the genotypes.

Table 11 Analysis of variance showing sources of variation degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1995

Sources of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flow ering	Days to maturity	No of plant at harvest	pods/ plant	Pod yield Kg/ha	Shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Replication	2	844.750	0.146	1.021	1.188	694.021	68.250	361504.168	58.688	9.161	34957.36	0.983	2.456
Genotype	15	60.332	4.217**	5.943**	115.810**	1468.378**	10.378*	23370.344	107.200	38.350**	344678.76**	9.861	25.890*
Error	30	97.461	1.013	0.376	4.143	230.799	3.761	23313.847	120.088	13.223	46901.54	6.648	12.116
Total	47	1002.543	5.376	7.340	121.141	2393.198	82.389	408188.30	285.976	60.734	426537.66	17.492	40.462

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 12 Mean performance of 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1995

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
ICG 221	139.67	28.00	30.33	117.00	62.00	1.67	336.00	55.33	26.17	697.80	28.37	49.77
ICG 4601	135.33	25.67	26.67	108.33	67.33	5.00	215.80	51.00	24.67	893.30	26.13	53.47
ICG 4790	141.67	27.00	28.33	107.33	81.00	4.00	129.80	45.33	26.00	1160.00	28.93	52.30
ICGV 86745	134.67	24.67	26.00	116.67	73.00	4.67	342.70	48.00	29.00	1186.70	28.20	50.37
ICGV 86708	132.33	27.00	28.33	107.00	55.00	1.67	201.00	44.33	23.33	671.10	28.17	44.00
ICGV 86742	131.67	25.67	27.00	110.00	37.67	2.33	220.40	43.674	21.33	711.10	25.50	50.60
ICG 4747	133.33	26.67	28.67	110.67	52.00	2.67	422.90	40.67	25.67	622	24.43	48.17
JL-24	146.00	28.00	31.00	115.00	92.00	2.67	177.2	59.33	27.67	1177.80	30.67	52.50
SAMNUT-18 (RRB)	132.67	26.33	28.33	100.00	74.67	7.33	273.70	51.00	23.67	804.40	26.57	48.53
SAMNUT 14(55-437)	140.67	25.67	27.33	98.33	86.00	6.67	286.20	60.33	25.00	1073.30	25.40	52.83
SAMNUT 17(48-115B)	137.33	28.67	30.00	101.33	45.67	3.67	139.50	41.67	23.00	466.70	24.83	51.93
ICGV-SM 85045	141.00	24.67	26.67	103.00	71.67	6.33	366.70	53.00	28.67	1095.60	26.13	51.23
ICGV 88023	144.00	25.33	27.00	115.00	110.67	5.00	144.70	54.00	26.00	1511.10	25.03	50.70
ICGV 86124	142.67	25.33	28.33	115.00	104.00	7.00	273.70	53.33	34.67	1566.70	26.23	56.10
ICGV 90127	140.00	26.00	28.33	110.33	98.00	3.33	162.50	53.33	22.00	1360.00	25.33	55.13
FLEUR 11	140.00	26.00	27.33	116.00	104.00	4.00	247.10	54.00	32.00	1393.30	28.77	48.40
MEAN	138.31	26.29	28.10	109.44	75.92	4.24	246.24	50.50	26	1024.44	26.79	51.00
C.V. %	7.14	3.83	2.18	1.86	20.01	45.63	62.01	21.70	13.89	21.14	9.62	6.82
LSD	16.46	1.68	1.02	3.39	25.33	3.23	254.58	18.27	6.06	361.08	4.30	5.80

Table 13. Analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1996

Sources of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plant at harvest	pods/plant	Pod yield Kg/ha	Shelling %	100-seed weight (g)	Haulm yield kg/ha	protein content (%)	Oil content (%)
Replication	2	617.333	0.438	2.646	2.083	42.583	8.896	172691.492	64.333	0.8177	494645.03	11.478	20.346
Genotype	15	169.897*	4.354**	2.754**	147.710**	510.988*	1.728	42237.560	106.716**	106.022**	258742.52*	6.812	35.689*
Error	30	63.444	0.438	0.513	6.039	193.317	3.540	25727.183	17.102	1.868	108754.51	11.183	16.750
Total	47	850.674	5.230	5.913	155.832	746.888	14.164	240656.230	178.151	108.708	862142.06	29.473	72.785

* = Significant at 5% Level of probability

** = Significant at 1% Level of probability

Table 14 Mean performance of 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1996

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods Plant	Pod yield kg/ha	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
ICG 221	138.67	27.67	29.3'	117.00	113.00	4.33	763.10	62.70	32.17	1956.60	28.53	51.50
ICG 4601	149.33	27.00	29.67	109.00	120.33	6.33	830.30	59.87	25.73	2093.30	26.53	55.90
ICG 4790	133.00	30.00	31.67	113.00	90.33	5.00	624.10	57.20	34.10	1482.20	28.70	50.93
ICGV 86745	155.67	27.33	29.00	121.00	125.33	6.33	1016.10	63.53	28.03	2317.80	29.20	50.40
ICGV 86708	147.33	29.67	30.67	118.33	130.00	5.33	846.20	51.27	20.70	1584.40	27.27	48.27
ICGV 86742	149.67	30.00	32.00	110.33	129.67	6.33	850.90	51.33	22.47	1706.70	25.27	45.07
ICG 4747	147.00	29.00	29.67	123.33	121.33	5.67	985.10	51.03	20.80	2004.40	26.97	46.47
JL 24	154.33	29.33	30.00	119.67	127.33	6.67	784.50	65.47	37.63	1248.90	25.13	50.13
SAMNUT-18 (RRB)	139.00	29.00	29.67	102.00	122.67	5.00	819.40	62.83	29.90	1677.80	26.57	51.73
SAMNUT-14(55-437)	148.67	30.33	32.00	109.67	124.33	6.33	806.10	70.13	25.27	1922.20	27.80	45.47
SAMNUT 17(48-115B)	*151.33*	*29.67*	*31.33*	*101.33*	*147.67*	*6.67*	*862.70*	*68.47*	*25.93*	*2164.40*	*26.87*	*47.97*
ICGV-SM 85045	146.67	29.67	30.67	116.00	134.00	5.33	741.90	66.13	31.47	1688.90	25.70	53.00
ICGV 88023	147.67	27.67	30.67	119.67	135.00	6.67	734.30	62.00	28.43	1886.70	27.86	46.70
ICGV 86124	155.67	27.33	30.00	121.67	138.00	7.00	1071.50	65.87	37.63	2231.10	26.10	42.60
ICGV 90127	145.67	29.67	31.33	121.67	137.67	5.00	698.50	58.43	25.67	2028.20	23.53	45.57
FLEUR 11	130.00	27.33	30.00	121.67	115.00	6.33	924.60	60.03	39.63	1611.10	25.47	47.83
MEAN	146.23	28.81	30.48	115.35	125.73	5.96	834.96	61.02	29.10	1849.86	26.72	48.72
C.V. %	5.45	2.30	2.33	2.13	11.06	31.58	19.21	6.78	4.70	17.83	12.52	8.40
LSD	13.28	1.10	1.1[0]	4.10	23.18	3.14	267.43	6.89	2.28	549.84	5.58	6.82

Table 15 Combined analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1995 and 1996.

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of plants at harvest	pods/ plant	Pod yield kg/ha	shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Year	1	1504.167**	152.510**	135.375**	840.167**	59550.844**	70.042**	8317942.461**	2655.458**	204.750**	16351504.17**	0.135	124.898**
Rep (year)	4	731.042	0.292	1.833	1.635	368.302	38.573	267097.830	56.510	4.990	392474.51	6.230	11.401
Genotype	15	113.997	5.460**	4.100**	230.442**	960.833**	7.108*	48265.020*	172.875**	120.349**	300275.83**	9.542	25.749
Genotype *Year	15	116.233	3.110**	4.597**	33.078**	1018.533**	4.997	17342.885	41.042	24.022**	303145.45**	7.131	35.830**
Error	60	80.453	0.725	0.444	5.091	212.058	3.651	24520.520	68.595	7.545	77828.02	8.915	14.433
Total	95	2545.892	162.097	146.349	1110.413	62110.570	124.371	8675168.70	2994.48	361.656	17425227.98	31.953	212.311

* = Significant at 5% Level of probability

** = Significant at 1% Level of probability

Table 16 Combined mean performance of 16 groundnut genotypes grown under in-adequate moisture condition in the field between August and December at Samaru in 1995 and 1996.

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100 seed weight (g)	Haulm yield (kg)	Protein content (%)	Oil content (%)
ICG 221	139.17	27.83	39.85	117.00	87.50	3.00	549.54	59.02	29.17	1326.70	28.45	50.63
ICG 4601	142.33	26.33	28.17	108.83	93.83	5.67	523.04	55.43	25.20	1493.30	26.33	54.65
ICG 4790	137.33	28.67	30.00	110.17	85.67	5.00	376.94	57.27	30.05	1321.10	28.82	51.62
ICGV 86745	145.17	26.00	27.50	118.83	99.17	5.50	679.43	55.77	28.52	1752.20	28.70	50.38
ICGV 86708	139.83	28.33	29.50	112.67	92.50	3.50	523.61	47.80	22.02	1127.80	27.72	46.13
ICGV 86742	140.67	27.83	29.50	110.17	83.67	4.33	535.65	47.50	21.90	1208.90	25.38	47.83
ICG 4747	140.17	27.83	29.17	117.00	86.67	4.17	704.01	45.80	23.23	1313.30	25.70	47.32
JL 24	150.17	28.67	30.50	117.33	109.67	4.67	480.85	62.40	32.65	1213.30	27.90	51.32
SAMNUT-18 (RRB)	135.83	27.67	29.00	101.00	98.67	6.17	546.53	56.92	26.78	1241.10	26.57	50.13
SAMNUT-14(55-437)	144.67	28.00	29.67	104.00	105.17	6.50	546.15	65.23	23.13	1497.80	26.60	49.15
SAMNUT 17(48-1158)	144.33	29.17	30.67	101.33	96.67	5.17	501.09	55.07	24.47	1315.60	25.85	49.95
ICGV SM 85045	143.83	27.17	28.67	109.50	102.83	5.83	554.29	59.57	30.07	1392.20	25.92	52.12
ICGV 88023	145.83	26.50	28.83	117.33	122.83	5.83	439.47	58.00	27.22	1698.90	26.45	48.70
ICGV 86124	149.17	26.33	29.17	118.33	121.00	7.00	672.62	59.60	36.15	1898.90	26.17	49.35
ICGV 90127	142.83	27.83	29.83	116.00	117.83	4.17	430.54	55.72	23.83	1691.10	24.43	50.35
FLEUR 11	135.00	26.67	28.67	118.83	109.67	5.17	585.83	57.02	35.82	1502.20	27.17	48.12
MEAN	142.27	27.55	29.29	112.40	100.82	5.10	540.60	55.76	27.64	1437.15	26.76	49.86
C.V. %	6.30	3.09	2.28	2.01	14.44	37.43	28.97	14.85	9.94	19.41	11.16	7.62
LSD	14.35	1.36	1.07	3.61	23.30	3.06	250.60	13.25	4.40	446.46	4.78	6.08

4.3 PERFORMANCE UNDER CONTROLLED MOISTURE CONDITION IN THE SCREEN HOUSE

The mean performance of the groundnut genotypes under adequate moisture condition in the screen house in 1995 and 1996 are as presented in Tables 18 and 20. In 1995, the average of means for number of plants at emergence, days to first flowering, days to 50% flowering and days to maturity were 9.97, 28.50, 29.95 and 113.09 respectively. Also the average of means for number of plants at harvest, pods/plant, pod yield, shelling %, 100-seed weight, and haulm yield were 9.56, 12.91, 614.00, 70.37, 29.79 and 2499.31 respectively. While the average of means of protein and oil content were 27.12 and 50.67 respectively (Table 18).

The analysis of variance indicated that significant difference occurred among the genotypes in their days to maturity, pods/plant, pod yield and haulm yield ($p \geq 0.05$) (Table 17). However, no significant difference was found among the genotypes for the other parameters at the same level of probability.

The mean performance of the genotype indicated that RRB gave the highest pod yield of 933.30 kg/ha followed by ICGV 86708, ICGV 86745, ICGV 88023, ICG 4601, 55-437 and ICG 4747 which gave pod yields of 752.30, 725.30, 720.00, ,709.30, 682.70, and 677.30 kg/ha and most of the genotypes performed above average. However, FLEUR-11 had the lowest pod yield of 288.00 kg/ha (Table 18) and this particular genotype had

longer days to maturity.

Significant difference occurred among the genotypes in their days to maturity (Table 17). ICGV 86124 was found to have the longest days to maturity (122 days), while JL-24 and FLEUR-11 took 120 days each to mature. The genotypes that took relatively lower number of days to maturity were RRB (99 days), 55-437 (101 days), ICGV 86742 (106 days) and 48-115B (107 days) (Table 18). The maturity days ranged from 99 to 122 days under adequate moisture condition in the screen house.

Variation in performance was also observed among the genotypes in the number of pods that each genotype can produce per plant. The mean performance shows that, 55-437 produced the highest number of pods/plant (21), followed by RRB and 48-115B which gave 16 pods/plant each (Table 18). The lowest number of pods/plant was given by ICG 4601 with only 8 pods.

Significant difference ($P \geq 0.05$) was also found among the genotypes for haulm yield. The haulm yield under adequate moisture (Table 18) ranged from 1952.00 to 3524.00 kg/ha. Genotype 55-437 had the highest haulm yield (3524.00 kg/ha), followed by 48-115B and RRB which gave haulm yields of 3200.00 kg/ha), and 2677.30 kg/ha respectively. The average performance in haulm yield among the genotypes under normal moisture condition (Table 18) was 2499.31 kg/ha. Few of the genotypes performed above average for this parameter.

The mean performance of the genotypes under adequate moisture condition in 1996 are presented in Table 20. In 1996 the average of means of the genotypes for number of plants at emergence, days to first flowering days to 50% flowering, days to maturity, number of plants at harvest, and pods/plant were 9.94, 28.59, 30.47, 112.91, 9.59 and 11.75 respectively. While the average of means for pod yield, shelling %, 100-seed weight, haulm yield, protein and oil content were 638.74, 69.62, 29.84, 2544.66, 27.19 and 50.69 respectively.

The coefficients of variabilities for most of the agronomic characters and yield were low compared to that of the field experiments, where the genotypes were more exposed to harsher conditions.

The analysis of variance indicated that most of the parameters differed significantly among the genotypes (Table 19). Significant difference ($P \geq 0.05$) occurred in days to maturity, mature pods/plant, pod yield and haulm yield among the genotypes. This was almost a similar trend to the 1995 green house experiment under adequate moisture. However, there was no significant difference ($P \geq 0.05$) among the genotypes in the other parameters. The analysis of variance in 1995 (Table 17) followed similar trend or pattern to that of 1996 (Table 19).

The mean performance in 1996 indicated that RRB gave the highest pod yield of 952.47 kg/ha under adequate moisture condition (Table 18). The same RRB gave the highest pod yield

in 1995 (Table 187). High pod yield after RRB was followed by ICG 4601 (811.30), ICGV 86708 (783.00), ICGV 86745 (760.30), ICGV 88023 (731.30),
55-437 (715.13),and 48-115B (700.00 kg/ha). The average of the mean performance in pod yield in 1996 in the screen house was 638.74 kg/ha and quite a number of the genotypes performed below average, while a few others excelled. The lowest pod yield was given by FLEUR-11 which gave pod yield of 310.00 kg/ha. Other genotypes that gave lower yields were: ICGV9012 (316.5), ICGV8612 (456.13), JL-24 (580.00) and ICG 4790 (580.30 kg/ha).

Significant difference was observed ($P \geq 0.05$) among the genotypes in their days to maturity (Table 19). The days to maturity ranged from 100-121 days (Table 20), with the average of the means of 113 days and a coefficient of variability of 28.19%. It could be seen from Table 20 that the genotype which matured early had the highest pod yield (RRB, matured in 100 days and produced highest pod yield of 952.47 kg/ha). On the other hand, genotypes with longer maturity days, had the lowest pod yield (FLEUR-11 matured in 119 days and produced 316.50 kg/ha of pods, and ICGV 90127 matured in 117 days and produced 456.13 kg/ha of pods).

Number of mature pods/plant also significantly differed among the genotypes. Pods/plant ranged from 8 to 18 (Table 20). The highest number of pods/plant was produced by 55-437, which incidentally was among genotypes which produced high pod

Table 17 Analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under adequate moisture condition in the screen house at Samaru in 1995.

Sources of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plant at harvest	pods/plant	Pod yield Kg/ha	Shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.031	1.867	3.325	91.481**	0.525	22.215**	51078.05*	21.908	11.843	35569.68**	6.481	17.777
Error	16	0.062	1.867	12.000	10.299	5.000	136.462	430496.250	208.065	89.186	6229465.57	3.088	293.197
Total	31	0.093	3.734	15.325	101.710	5.525	148.677	481574.30	229.973	101.029	6585162.20	9.560	310.974

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 18 Mean performance of 16 groundnut genotypes grown under adequate moisture condition in the screen house at Samaru in 1995

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowring	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100-seed weight (g)	Haulm yield (kg)	Protein content (%)	Oil content (%)
ICG 221	10.00	28.50	30.50	114.50	10.00	14.50	586.70	67.00	27.10	2277.30	25.70	49.20
ICG 4601	10.00	29.00	31.00	115.00	9.50	7.50	709.30	71.00	31.05	2037.30	27.50	48.85
ICG 4790	10.00	28.50	29.00	114.00	10.00	12.00	576.00	70.50	31.05	2107.50	28.75	57.10
ICGV 86745	10.00	29.00	31.00	112.00	10.00	12.50	725.30	70.00	29.70	2122.70	27.05	51.45
ICGV 86708	10.00	29.00	31.00	111.00	9.50	9.00	752.30	74.00	25.80	1952.00	28.80	49.80
ICGV 86742	10.00	28.00	30.00	106.00	9.00	9.00	576.00	67.50	26.75	2650.70	25.60	51.25
ICG 4747	10.00	28.00	30.00	117.00	10.00	9.50	677.30	68.50	29.50	2480.00	24.50	49.35
FL-24	10.00	26.00	29.00	120.00	10.00	15.00	549.30	75.00	31.45	2480.00	29.35	48.10
SAMNUT-18 (RRB)	10.00	27.50	29.50	99.00	9.50	15.50	933.30	72.50	30.00	2677.30	25.80	50.25
SAMNUT-14(55-437)	10.00	28.50	29.00	101.00	10.00	20.50	682.70	77.50	35.25	3524.00	26.60	48.70
SAMNUT 17(48-115B)	10.00	29.50	30.00	106.50	10.00	15.50	640.00	72.00	29.30	3200.00	25.70	51.50
ICGV-SM 85045	9.50	29.50	30.00	117.00	9.00	12.00	613.30	69.50	30.85	2400.00	28.55	53.55
ICGV 88023	10.00	29.00	30.50	117.50	.00	9.50	720.00	67.50	29.30	2394.70	26.55	43.50
ICGV 86124	10.00	29.00	30.50	121.50	9.00	12.00	474.70	71.25	28.60	2565.30	27.40	52.70
ICGV 90127	10.00	28.50	30.00	117.50	8.50	14.00	320.00	65.40	28.30	2512.00	25.00	53.30
FLEUR 11	10.00	30.00	32.50	120.00	8.50	10.50	288.00	66.65	29.80	2240.00	31.10	52.00
MEAN	9.97	28.50	29.95	113.09	9.56	12.91	614.00	70.37	29.79	2499.31	27.12	50.67
C.V. %	2.50	4.79	11.57	2.84	23.39	8.70	10.69	20.50	31.70	10.19	6.48	33.79
LSD	0.53	2.50	7.34	6.43	4.73	23.82	138.94	29.56	19.89	399.38	3.72	36.26

Table 19: Analysis of variance showing source of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown und adequate moisture condition in the screen house at Samaru in 1996.

Source of variation	DF	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of Plants at harvest	pods/plant	Pod yield (kg/ha)	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.029	1.833	3.412	90.392**	0.523	21.422**	52082.05*	19.837	12.920	356642.82**	6.492	17.734
Error	16	0.05	1.903	12.243	10.128	4.983	120.424	451082.30	199.582	100.816	6288971.75	3.216	290.146
Total	31	0.079	3.786	15.655	100.52	5.506	141.846	503164.35	219.419	113.736	6645614.57	9.708	307.88

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 20 Mean performance of 16 groundnut genotypes grown under adequate moisture condition in the screen house at Samaru in 1996

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowring	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
ICG 221	10.00	28.50	30.00	112.00	9.50	13.50	590.47	69.23	34.00	2340.00	25.90	49.10
ICG 4601	10.00	29.00	31.00	114.00	9.50	8.00	811.30	70.00	26.50	2945.00	27.40	49.69
ICG 4790	10.00	27.00	29.00	111.00	10.00	11.00	580.30	70.50	32.00	2111.30	29.00	56.50
ICGV 86745	10.00	28.00	29.50	113.50	10.00	13.00	760.30	70.00	28.90	2241.70	27.50	50.91
ICGV 86708	10.00	28.00	31.00	108.00	10.00	9.50	783.00	72.50	25.30	2000.00	28.16	49.63
ICGV 86742	10.00	29.00	31.00	116.00	9.00	8.00	591.11	63.40	27.10	2761.80	26.00	51.25
ICG 4747	10.00	29.50	30.50	116.00	10.00	10.00	659.32	69.00	30.00	2542.30	23.90	50.00
JL-24	9.50	29.00	29.50	118.00	9.50	13.50	580.00	74.50	31.39	2943.50	29.25	48.30
SAMNUT-18 (RRB)	10.00	28.50	30.00	100.00	10.00	14.50	952.47	71.50	29.80	2677.00	26.25	51.30
SAMNUT-14(55-437)	10.00	28.00	30.00	103.00	10.00	18.00	715.13	76.00	35.20	3602.00	26.70	48.10
SAMNUT 17(48-115B)	10.00	28.00	30.00	105.00	10.00	13.50	700.00	72.00	29.10	3184.70	25.80	51.00
ICGV-SM 85045	10.00	28.00	30.00	116.00	9.00	10.00	682.50	65.50	29.95	2510.10	28.65	54.55
ICGV 88023	10.00	29.00	31.00	117.00	10.00	12.00	731.30	66.50	29.40	2400.50	27.10	44.10
ICGV 86124	10.00	29.00	31.00	121.00	9.00	14.00	456.13	71.30	29.00	2601.00	26.90	50.50
ICGV 90127	9.50	29.50	32.50	116.50	9.00	9.00	316.50	66.00	28.60	2532.10	24.60	54.20
FLEUR 11	10.00	29.50	31.50	119.00	9.00	10.50	210.00	66.00	31.20	2221.50	32.00	51.60
MEAN	9.94	28.59	30.47	112.91	9.59	11.75	638.74	69.62	29.84	2544.66	27.19	50.69
C.V. %	2.25	4.82	11.48	28.29	28.28	9.30	10.50	20.29	33.65	9.86	6.60	33.60
LSD	0.46	2.92	9.41	6.74	4.72	2.45	449.76	29.91	21.26	531.05	3.79	36.06

Table 21 Combined analysis of variance showing source of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under adequate moisture condition in the screen house at Samaru in 1995 and 1996

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of plants at harvest	pods/plant	Pod yield kg/ha	shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.091	2.411	2.823	192.624*	0.521	28.441*	53287.96**	82.863*	17.402	30051.17*	7.613	18.641
Year	1	0.254	1.499	4.531	7.335*	1.234*	79.562**	50126.54**	101.121*	62.516*	83404.44**	1.520	379.548
Geno * year	15	0.091	2.966NS	2.604	19.145NS	0.423	4.593*	34345.89**	32.146	32.177	263240.73*	5.320	22.436
Error	32	0.339	6.833	15.834	122.548	10.966	893.423	684851.40	5591.782	60.17	14676784.15	10.815	65.066
Total	63	0.775	13.709	25.792	341.652	13.556	1006.019	822611.79	5897.913	172.265	1565480.48	25.268	485.691

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 22. Combined mean performance of 16 groundnut genotypes grown under adequate moisture condition in the screen house at Samaru in 1995 and 1996

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowring	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100 seed weight (g)	Haulm yield (kg)	Protein content (%)	Oil content (%)
ICG 221	10.00	28.50	30.25	113.25	9.75	14.00	588.70	68.12	33.95	2308.65	25.80	49.15
ICG 4601	10.00	29.00	31.00	114.50	9.50	7.75	760.30	70.50	26.80	2041.15	27.45	48.93
ICG 4790	10.00	27.75	29.00	112.50	10.00	11.50	578.15	70.50	31.53	2109.40	28.88	56.80
ICGV 86745	10.00	28.50	30.25	112.75	10.00	12.75	742.80	70.00	29.30	2182.20	27.28	51.18
ICGV 86708	10.00	28.75	31.00	109.50	9.75	9.25	767.65	73.25	25.55	1976.00	28.48	49.72
ICGV 86742	10.00	28.50	30.50	111.00	9.00	8.50	583.56	65.45	26.93	2706.25	25.80	51.25
ICG 4747	10.00	28.75	30.25	116.50	10.00	9.75	668.31	68.75	29.75	2511.15	24.20	49.68
JL 24	9.75	27.50	29.25	119.00	9.75	14.25	564.65	74.75	31.42	2895.75	29.30	48.20
SAMNUT 18 (RRB)	10.00	28.00	29.75	99.50	9.75	15.00	942.89	72.00	29.90	2677.15	26.03	51.78
SAMNUT 14(55 437)	10.00	27.75	29.50	102.25	10.00	19.25	698.93	76.75	35.23	3563.00	26.65	48.90
SAMNUT 17(48-115B)	10.00	28.25	30.00	105.75	10.00	14.50	670.00	72.00	29.20	3192.35	25.75	51.25
ICGV SM 85045	9.75	28.75	30.00	116.50	9.00	9.50	647.90	67.50	30.40	2455.05	28.60	54.05
ICGV 88023	10.00	29.00	30.50	117.25	10.00	10.75	725.65	67.00	29.35	2397.60	26.83	43.80
ICGV 86124	10.00	29.00	30.75	121.25	9.00	13.00	465.42	71.28	28.80	2583.15	27.15	51.60
ICGV 90127	9.75	28.00	31.25	117.00	8.75	11.50	318.25	65.70	28.45	2522.05	24.80	53.75
FLEUR 11	10.00	29.75	32.00	119.50	9.00	10.50	299.00	66.33	30.50	2230.75	31.55	51.80
MEAN	9.96	29.00	30.21	113.00	9.58	12.33	626.37	70.00	29.82	2521.99	27.16	50.68
C.V. %	5.85	9.01	13.17	9.80	34.57	24.24	13.21	10.68	26.01	48.04	12.11	15.92
LSD	1.14	5.12	7.79	21.76	6.48	5.85	162.02	4.62	15.19	750.10	6.44	15.79

yields. However, the lowest number of pods/plant was given by ICGV 90127. Few genotypes performed creditably well in number of pods/plant and most of these genotypes were those that matured early as indicated by their maturity days.

Haulm yield differed significantly ($P \geq 0.05$) among the genotypes under adequate moisture condition in 1996. The highest haulm yield was given by 55-437 which gave 3602.00 kg/ha of haulm (Table 20), followed by 48-115B and JL-24 with the haulm yields of 3184.70 and 2996.50 kg/ha respectively. Haulm and pod yield were better in 1996 (2544.66 and 638.74 kg/ha respectively) than in 1995 with haulm and pod yields of 2499.31 and 614.00 kg/ha respectively.

The mean performance of the groundnut genotypes for pod yield and the other agronomic parameters, under moisture stress in the screen house in 1995 and 1996 are presented in Tables 23 and 26 respectively. The corresponding analysis of variance for the mean performance in 1995 and 1996 are presented in Tables 24 and 25 respectively.

In 1995, the analysis of variance indicated that significant difference ($P \geq 0.05$) occurred among the genotypes for days to maturity, number of pods/plant, pod yield, shelling % and haulm yield (Table 24), but there was no significant difference for the other parameters at the same level of significance (Table 24).

The mean performance in pod yield and the other parameters indicated that days to maturity ranged from 102 to

122 days (Table 23), with an average of 114 days. In comparison to the adequate moisture experiment of 1995 (Table 20), where the genotypes took 113 days to mature on average, it took the genotypes longer days to mature under moisture stress (114 days) (Table 23). Under moisture stress in the screen house in 1995 (Table 23), the genotype ICGV 86124 had the longest days to maturity (122 days), this same genotype took longest days to maturity (121 days), even under normal moisture condition (Table 20). The genotype that matured early under moisture stress in 1995 was RRB with 102 days followed by 55-437 with 104 days and ICGV 86742 with 107 days. Incidentally RRB, and 55-437 also matured earlier under normal moisture conditions (Table 20).

Number of pods/plant also significantly differed among the genotypes at 5% level of probability under moisture stress in 1995 (Table 24). The mean performance showed that pods/plant ranged from 4 to 15 (Table 23), where 55-437 gave the highest number of pods/plant and ICGV 86742 produced only 4 pods/plant which was the lowest. Performance in number of mature pods/plant under moisture stress was far below expectation as only few genotypes performed above average. The average of the means for mature pods/plant under moisture stress in 1995 was 7.91 (Table 23), which was far below that of the normal moisture condition average of the same year (11.75) (Table 20). A reduction of about 33% in the number of pods/plant was observed due to moisture stress.

Pod yield also differed significantly among the genotypes under moisture stress (Table 24). It has been found that 55-437 had the best pod yield in terms of weight under moisture stress, with 880.00 kg/ha followed by RRB, JL-24, ICGV 88023, 48-115B, ICGV-SM 85045 and ICGV 86745 which gave pod yields of 698.67, 688.00, 680.00, 602.67, 597.34 and 581.34 kg/ha respectively. The lowest pod yield was produced by ICG4970 with 298.67 kg/ha. Other genotypes produced lower pod yields. These genotypes included: ICGV 90127 (368.00), ICGV 86742 (281.87), FLEUR-11 (384.00) and ICG 4601 with 410.67 kg/ha (Table 23). The overall average pod yield under moisture stress in the screen house in 1995 was 531.50 kg/ha (Table 23) which was far below that of normal moisture condition (638.74) kg/ha (Table 20) of the same period. Prominent point that can be envisaged is that, genotypes which performed best under normal moisture condition, was never the ones performing under moisture stress. Interestingly however, genotypes that gave high pod yield under moisture stress were those that were early maturing (Table 23) e.g. 55-437 and RRB. A reduction of 16.79% in pod yield was recorded among the genotypes on average as result of moisture stress.

The shelling % among the genotypes ranged from 50.4 to 72.50%. Shelling % have been low under moisture stress in 1995 (Table 23), compared to that under normal moisture condition (Table 20) of 1995. Under moisture stress condition in 1995, 55-437 had the highest shelling % of 72.5% (Table 23)

and the same genotype had the highest shelling % under normal moisture condition in 1995, but unlike in 1995 moisture stress experiment, no significant difference was observed in shelling % among the genotypes in normal moisture condition in the same year. A reduction of 14.76% occurred on the average among the genotypes in shelling % due to moisture stress.

Haulm yield was found to differ significantly among the genotypes under moisture stress in 1995, that was also the case under normal moisture condition during the same period. The mean performance in haulm yield among the genotypes (Table 23) indicated that JL-24 produced the highest haulm yield, which was not the case under normal moisture condition during the same period. The highest haulm yield was produced by JL-24 (2720.0 kg/ha), followed by 48-115B, RRB and ICGV86124 which had haulm yields of 2656.01, 2560.01 and 2501.35 kg/ha respectively. Haulm yield under moisture stress in 1995 (Table 23) was much reduced compared to that of the normal moisture condition during the same period (Table 20).

The mean performance for yield and the agronomic parameters for the genotypes grown under moisture stress in 1996 are presented in Table 26. The analysis of variance for the corresponding season are presented in Table 25. The analysis of variance indicated that significant difference occurred ($P \geq 0.05$) among the genotypes in their days to maturity, pod yield and shelling %. However, no significant difference occurred at the same level of probability for the

other parameters.

The mean performance showed that, days to maturity ranged from 103 to 124 days (Table 26). FLEUR-11 took longer days to maturity relative to the other genotypes, while RRB had the lowest days to maturity. On average, days to maturity was longer in 1996 (116 days) (Table 26) moisture stress experiments compared to that of 1995 (114 days) moisture stress experiment. Under adequate moisture in 1996 (Table 20) genotypes on average took lesser days to maturity (113 days) than in 1996 moisture stress experiment where genotypes on average took longer days to maturity (Table 26).

Pod yield also significantly differed ($P \geq 0.05$) among the genotypes under moisture stress in 1996 (Table 25). The genotypes that gave the highest pod yield under moisture stress were 55-437 with 77.34 kg/ha, followed by RRB, JL-24, ICGV-SM 85045, 48-115B, ICGV 88023 and ICGV 86124, which gave yields of 714.67, 693.34, 640.54, 634.67, 605.87 and 605.34 kg/ha respectively (Table 26) while the lowest pod yield was given by ICG 4790 which had 298.67 kg/ha. Other genotypes that produced lower pod yields included. ICGV 86742, ICG 4601, and ICG 221 which had 381.87, 410.67, and 416.00 kg/ha respectively. Pod yield on average in 1996 was lower comparatively to that of 1995 of the same treatment (moisture stress). However, most importantly, was that, most of the genotypes performed above average in 1996 than the performance in 1995, both under moisture stress condition.

Shelling % among the genotypes also differed significantly ($P \geq 0.05$). The mean values for shelling % under moisture stress in 1996 (Table 26) indicated that 55-437 had the highest shelling % (65%), this was also the case in 1995 where the same genotype gave the highest shelling % of 72.5% among the genotypes under moisture stress. The lowest shelling % however, was given by ICGV86742 (43.50%) (Table 26). Most genotypes performed below average for shelling %.

The combined mean performance of the 16 groundnut genotypes under normal and controlled moisture condition in the screen house are presented in Tables 22 and 28. The combined analysis of variance for the corresponding periods are also presented (Tables 21 and 27). The combined analysis of variance for adequate moisture condition experiment in the screen house indicated that there was no significant difference ($P \geq 0.05$) occurring between the genotypes in their number of plants at emergence, days to first flowering, days to 50% flowering, number of plants at harvest, 100-seed weight, protein content and oil content (Table 21). However, significant difference at the same level of probability occurred among the genotypes, in days to maturity, number of mature pods/plant, pod yield, shelling %, and haulm yield. Significant genotype x year interaction was also observed among the genotypes in their number of pods/plant, pod yield and haulm yield (Table 21), indicating that difference existed for the parameters mentioned across the two years among the

genotypes evaluated.

The combined mean performance indicated that days to maturity ranged from 100-121 days (Table 22). The genotype RRB, had the lowest days to maturity under adequate moisture (100 days), while ICGV86124 had the highest number of days to maturity under the same condition.

Number of pods/plant was also significantly different ($P \geq 0.05$) among the genotypes evaluated under adequate moisture. The highest number of pods/plant was produced by 55-437 (19 pods), followed by RRB (15 pods), 48-115B (15 pods), JL-24 (14 pods) and ICG221 (14 pods) (Table 22), while the lowest number of pods/plant was produced by ICG4601 (8 pods). Most of the genotypes performed below average for this parameter.

The combined analysis of variance also revealed that significant difference existed among the genotypes for pod yield. Pod yield was highest in RRB which gave the yields of 941.89 kg/ha (Table 22), and this genotype has been known to be early maturing. Other genotypes that gave higher yields included ICGV 86708 (767.65), ICG 4601 (760.30), ICGV 86645 (742.80) and ICGV 88023 which gave the pod yield of 725.65 kg/ha (Table 22). The pod yield ranged from 299.00 to 942.89 kg/ha with FLEUR-11 giving the lowest pod yield.

The shelling % was also found to differ significantly ($P \geq 0.05$) among the genotypes. Shelling % as one of the determinant of yield in groundnut was found to be highest in the genotype 55-437 (76.75%), followed by JL-24, ICGV 86708,

RRB, 48-115B and ICGV 86124 which had shelling % of 74.5, 73.25, 72.00 and 71.28% respectively. The lowest shelling % was recorded for ICGV 86742 which had 65.45% (Table 22).

The combined analysis of variance (Table 21) indicated that significant difference existed among the genotypes in their haulm yields. The combined mean performance (Table 22) showed that 55-437 had the highest haulm yield of 3563.00 Kg/ha. This was then followed by 48-115B and JL-24 which gave haulm yields of 3192.35 and 2895.75 Kg/ha respectively. The lowest haulm yield was produced by ICGV 86708 which gave 1976.00 kg/ha.

The combined mean performance of the groundnut genotypes under moisture stress in the screen house are presented in Table 28. The combined analysis of variance for the same treatment are also presented in Table 27. The combined analysis of variance indicated that significant difference occurred ($P \geq 0.05$) among the genotypes in their days to maturity, pods/plant, pod yield, shelling % and haulm yield (Table 27). No significant difference were found for the other parameters at the same levels of probability.

Days to maturity ranged from 101 to 122 days. Genotype ICGV86124 and FLEUR-11 took longer days to maturity with 122 days each, while RRB had the lowest number of days to maturity with 101 days. Other genotypes that matured early included: 55-437 (103 days), ICGV86741 (109 days) and 48-115B with 109 days.

Number of pods/plant varied significantly. Pods/plant ranged from 6 to 16 (Table 28). Most of the genotypes produced fewer number of pods/plant, however, some of the genotypes had higher number of pods/plant. 55-437 had the highest number of pods/plant with 16, that was followed by 48-115B, RRB and JL-24 which had 12, 11, and 11 pods/plant respectively. Comparatively, however, pod/plant under adequate moisture (Table 22), did not differ significantly to that of the moisture stress condition (Table 27) as indicated by the non-significant interaction of genotype x year.

Highly significant difference was found among the genotypes for pod yield. The combined performance of the genotypes in pod yield under moisture stress (Table 28) was low, generally, compared to the combined performance under normal moisture condition in the screen house (Table 21). The combined mean performance for pod yield among the genotypes indicated that RRB produced the highest pod yield of 824 kg/ha, followed by 55-437, ICGV 88023, ICGV 86745, ICG 4747, 48-115B, ICGV 86708, ICGV-SM 85045 and JL-24 which produced pod yields of 728.00, 662.94, 653.34, 645.34, 637.34, 634.67, 629.94 and 621.34 kg/ha respectively. The lowest pod yield on the other hand was given by FLEUR-11 with 414.13 kg/ha (Table 28). On the average, a reduction of 6.26% was observed in pod yield due to moisture stress.

Haulm yield among the genotype also significantly differed among the genotypes under moisture stress (Table 27). Haulm yield ranged from 1714.70 to 3188.70 kg/ha (Table 28). Genotype 55-437 had the highest haulm yield, while ICGV 86708 had the lowest. The genotype x year interaction was not statistically significant ($P \geq 0.05$) and therefore means that haulm yield was not affected across the two years (1995 and 1996). The haulm yield on average was reduced by 2.31% due to moisture stress.

Table 23: Mean performance of 16 groundnut genotypes grown under moisture stress in the screen house at Samaru in 1995

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
ICG 221	10.00	29.50	31.00	114.50	9.00	8.50	416.00	62.50	35.10	2208.11	23.35	48.00
ICG 4601	10.00	29.50	30.50	116.50	9.00	5.50	410.67	63.00	28.60	2272.01	28.80	44.75
ICG 4790	10.00	28.50	30.00	115.50	9.00	8.50	298.67	55.50	28.25	1610.67	26.05	53.1
ICGV 86745	10.00	29.50	31.50	119.00	9.50	10.00	581.34	63.00	30.60	2218.68	28.40	49.50
ICGV 86708	10.00	29.00	31.50	109.50	9.00	6.00	517.34	64.50	30.15	1477.34	29.05	45.50
ICGV 86742	10.00	30.50	31.50	106.50	9.00	4.00	381.87	55.00	33.00	2453.35	26.85	48.60
ICG 4747	10.00	27.50	30.00	118.00	10.00	6.00	560.00	57.50	29.80	2416.01	27.85	48.40
JL-24	10.00	27.00	29.00	119.00	9.00	7.50	688.00	65.00	35.05	2720.01	29.30	46.75
SAMNUT-18 (RRB)	10.00	28.50	30.50	101.50	9.00	9.00	698.67	67.00	31.05	2560.01	25.60	47.50
SAMNUT-14(55-437)	10.00	28.50	29.50	104.00	10.00	15.00	880.00	72.50	33.90	2320.01	28.20	40.80
SAMNUT 17(48-115B)	10.00	29.50	31.50	109.00	9.50	11.00	602.67	59.50	29.30	2656.01	27.75	43.45
ICGV-SM 85045	9.50	29.00	30.00	113.50	9.00	6.00	597.34	60.05	29.15	2309.34	27.40	49.10
ICGV 88023	10.00	28.50	29.50	119.00	9.50	6.50	608.00	56.80	29.10	2352.01	26.60	45.95
ICGV 86124	10.00	28.00	30.50	122.00	8.50	6.50	512.00	56.75	26.45	2501.35	28.45	46.00
ICGV 90127	10.00	28.50	29.50	115.50	8.50	10.00	368.00	50.40	28.10	2453.35	25.60	45.75
FLEUR 11	9.00	30.50	32.50	121.00	8.50	6.50	384.00	50.65	30.15	2170.68	29.70	47.35
MEAN	9.88	28.87	30.53	114.06	9.13	7.91	531.50	59.98	30.48	2294.34	27.43	46.91
C.V. %	5.70	8.53	3.53	6.03	11.62	18.16	26.43	7.61	19.93	15.01	8.39	13.65
LSD	1.19	5.22	2.29	14.58	2.37	3.04	297.77	9.68	12.88	730.17	4.88	13.58

Table 24: Analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under moisture stress in the screen house at Samaru in 1995.

Source of variation	DF	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of Plants at harvest	pods/plant	Pod yield (kg/ha)	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.167	1.833	1.898	76.658**	0.433	14.481**	73022.23**	70.251**	12.903	67981.43**	5.637	15.510
Error	16	0.317	6.067	1.162	47.267	1.250	206.262	1972864.22	2083.899	36.887	11862473.70	5.297	41.012
Total	31	0.483	7.900	3.061	123.925	1.683	220.743	2045886.45	2154.15	49.79	11863153.51	10.934	56.522

** = Significant at 1% level of probability

Table 25 Analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under moisture stress in the screen house at Samaru in 1996

Sources of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plant at harvest	pods/plant	Pod yield Kg/ha	Shelling %	100-seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.148	1.592	1.281	74.192**	0.498	7.215	33667.19**	72.731**	15.583	473667.72	4.967	23.225
Error	16	0.429	5.050	1.529	21.467	1.029	6.062	233664.65	16.104	28.801	6308919.49	7.015	127.633
Total	31	0.577	6.642	2.810	95.659	1.527	13.277	267331.84	88.835	44.384	6782587.10	11.982	150.858

** = Significant at 1% level of probability

Table 26 Mean performance of 16 groundnut genotypes grown under moisture stress in the screen house at Samaru in 1996.

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
ICG 221	10.00	29.50	31.00	117.00	9.00	4.00	416.00	56.50	35.90	2208.00	24.80	49.90
ICG 4601	10.00	29.50	31.50	117.50	9.00	4.50	410.67	51.00	26.45	2272.00	29.10	51.30
ICG 4790	10.00	29.00	30.50	117.50	8.00	6.00	298.67	48.50	31.40	1616.00	23.95	49.10
ICGV 86745	10.00	30.00	31.00	114.00	8.50	6.00	581.34	51.50	29.45	2302.30	30.00	51.75
ICGV 86708	10.00	28.00	30.00	113.00	9.00	5.50	517.34	50.50	26.35	1477.30	29.05	38.55
ICGV 86742	10.00	30.00	30.50	111.50	8.50	3.50	381.87	43.50	31.00	2453.30	27.25	49.95
ICG 4747	10.00	28.50	30.50	120.00	10.00	3.50	613.34	46.50	25.90	2416.00	26.70	46.05
JL-24	10.00	27.50	28.50	121.00	8.50	7.00	693.34	58.00	26.35	2720.00	28.70	50.10
SAMNUT-18 (RRB)	10.00	28.00	30.00	103.00	9.00	7.00	714.67	60.00	31.00	2560.00	28.00	48.20
SAMNUT-14(55-437)	10.00	28.50	29.50	104.50	9.00	10.50	773.34	65.00	26.20	2853.40	28.30	45.25
SAMNUT 17(48-115B)	10.00	27.50	30.50	111.00	9.50	8.00	634.67	57.50	31.25	2656.00	26.60	44.90
ICGV-SM85045	10.00	28.50	31.00	113.50	9.50	5.00	640.54	52.55	30.75	2336.00	27.35	46.30
ICGV 88023	10.00	30.00	31.00	120.50	9.00	4.00	605.87	51.50	28.00	2352.00	26.95	51.60
ICGV 86124	9.50	29.50	31.50	123.00	9.00	4.00	605.34	51.00	31.85	2501.30	27.20	50.40
ICGV 90127	10.00	30.00	31.00	120.50	9.50	6.50	537.61	45.50	27.80	2453.30	26.65	46.05
FLEUR 11	9.00	29.00	31.50	123.50	8.50	4.50	540.27	44.00	29.55	3670.70	28.60	48.15
MEAN	9.90	28.94	30.59	115.69	8.97	5.59	560.30	52.07	29.33	2427.99	27.42	48.02
C.V. %	6.62	7.77	4.94	4.00	11.31	44.04	8.63	7.71	18.30	10.35	9.66	23.53
LSD	1.39	4.76	2.62	9.82	2.15	5.22	102.48	8.51	11.38	532.49	5.61	23.95

Table 27 Combined and analysis of variance showing source of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under moisture stress in the screen house at Samaru in 1995 and 1996

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of plants at harvest	pods/plant	Pod yield kg/ha	shelling %	100 seed weight (g)	Haulm yield (kg/ha)	Protein content (%)	Oil content (%)
Genotype	15	0.083	2.396	2.782	161.766**	0.449	25.33**	5239.20**	76.888**	16.909	605575.61*	7.409	17.730
Year	1	0.250	1.563	4.516	6.891	1.266*	76.563**	46140.11**	98.010*	54.951	81393.95	1.410	376.845*
Genox year	15	0.083	2.696*	2.516	17.624*	0.332	4.563	32354.99**	30.199	27.767	223788.89	4.128	19.789*
Error	32	0.318	6.785	15.213	118.730	10.647	789.059	664160.910	54.949	48.901	12538385.030	10.318	59.286
Total	63	0.734	13.440	25.027	305.011	12.694	904.515	795046.210	5677.047	148.888	13449138.00	23.265	575.520

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 28 Combined mean performance of 16 groundnut genotypes grown under moisture stress and moisture stress in the screen house at Samaru 1995 and 1996.

Genotypes	No of Plants at emergence	Days to first flowering	Days to 50% flowring	Days to maturity	No of plants at harvest	Pods/Plant	Pod yield kg/ha	Shelling percentage	100-seed weight (g)	Haulm yield (kg/	Protein content (%)	Oil content (%)
ICG 221	10.00	29.00	30.75	115.75	9.50	9.25	501.34	61.72	34.90	2242.70	25.25	49.55
ICG 4601	10.00	29.25	31.25	116.25	9.25	6.00	560.01	61.00	26.78	2154.70	28.30	50.08
ICG 4790	10.00	28.75	29.75	115.75	9.00	9.00	437.34	59.50	31.23	1861.80	26.35	53.10
ICGV 86745	10.00	29.50	31.00	113.00	9.25	9.25	653.34	60.75	29.58	2212.50	28.52	51.60
ICGV 86708	10.00	28.75	30.50	112.00	9.25	7.25	634.67	62.25	26.08	1714.70	28.93	44.20
ICGV 86742	10.00	29.00	30.25	108.75	8.75	6.25	478.93	55.50	28.88	2552.00	26.43	50.60
ICG 4747	10.00	28.25	30.25	118.50	10.00	6.50	645.34	57.50	27.70	2448.00	25.60	47.70
JL-24	10.00	26.75	28.75	120.50	9.25	11.00	621.34	66.50	28.90	2784.00	29.03	49.10
SAMNUT-18 (RRB)	10.00	27.75	29.75	101.00	9.25	11.25	824.00	66.25	30.50	2618.70	26.90	49.48
SAMNUT-14(55-437)	10.00	28.00	29.25	102.75	9.50	15.50	728.00	71.25	30.73	3188.70	27.45	46.98
SAMNUT 17(48-115B)	10.00	28.00	30.25	108.75	9.75	11.75	637.34	64.75	30.28	2928.00	26.15	48.20
ICGV-SM 85045	9.75	29.00	30.50	115.25	9.25	8.50	626.94	61.03	30.80	2368.00	27.95	49.93
ICGV 88023	10.00	29.50	30.50	119.00	9.50	6.75	662.94	59.53	28.65	2373.30	26.75	47.56
ICGV 86124	9.75	29.25	29.00	122.25	9.00	8.00	540.00	61.13	30.23	2533.30	27.30	51.55
ICGV 90127	10.00	29.25	30.50	119.00	9.00	10.25	428.81	55.45	28.05	2482.70	25.83	49.68
FLEUR 11	9.50	29.50	32.00	121.75	8.75	7.50	414.13	55.33	29.68	2955.30	29.85	50.08
MEAN	9.94	28.72	30.27	114.39	9.27	9.00	587.15	61.22	29.55	2463.63	27.28	49.34
C.V. %	5.67	9.07	12.89	9.53	35.20	31.21	13.88	12.08	23.66	14.44	11.77	15.61
LSD	1.20	5.31	7.12	22.21	6.65	5.72	166.09	15.08	14.25	721.65	6.55	15.69

Table 29: Phenotypic correlation coefficients between pod yield and yield characters in 16 groundnut genotypes grown under moisture stress in the field at Samaru in 1995 and 1996. N=96

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	0.230*											
3	0.309**	0.846**										
4	0.175	0.182	0.208*									
5	0.460**	0.434**	0.524**	0.393**								
6	0.227*	0.099	! 0.093	0.032	0.337**							
7	0.419**	0.333**	0.391**	0.399**	0.804**	0.298**						
8	0.378**	0.321**	0.328**	0.156	0.544**	0.363**	0.437**					
9	0.002	0.037	0.079	0.349**	0.240*	0.287**	0.207*	0.399**				
10	0.035	0.099	0.119	0.097	0.050	0.173	0.065	0.035	0.047			
11	-0.010	-0.311**	-0.304**	-0.185	-0.147	-0.021	-0.141	-0.054	0.033	0.036		
12	0.376**	0.483**	0.467**	0.359**	0.620**	0.506**	0.667**	0.475**	0.264**	-0.66	-0.270**	

Variables

1 Number of plants at emergence
2 Days to first flowering
3 Days to 50% flowering
4 Days to maturity
5 Number of plant at harvest
6 Number of mature pods/plant
7 Haulm yield
8 Shelling percentage
9 100-seed weight
10 Protein content
11 Oil content
12 Pod yield

* = Significant at 5% level of probability

** = Significant at 1% level of probability

Table 30: Phenotypic correlation coefficients between pod yield and yield characters in 16 groundnut genotypes grown under controlled moisture condition in the screen house, at Samaru in 1995 and 1996. N=64

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	-0.160											
3	-0.095	0.396**										
4	-0.219	0.241	0.109									
5	-0.254*	-0.101	-0.169	-0.104								
6	0.189	-0.330**	-0.379**	-0.353**	0.431**							
7	0.096	-0.347**	-0.351**	-0.244	0.377**	0.722**						
8	0.098	-0.301*	-0.238	-0.478**	0.427**	0.567**	0.484**					
9	0.200	-0.220	-0.332**	0.330**	0.436**	0.785**	0.683**	0.617**				
10	0.048	0.031	0.105	-0.104	0.048	0.015	0.046	0.022	0.091			
11	-0.091	0.015	-0.126	0.113	-0.081	0.104	-0.187	-0.025	-0.061	-0.071		
12	0.081	0.033	-0.092	0.046	-0.016	0.281*	0.258	0.032	0.299*	-0.032	-0.034	

Variables
1 Number of plants at emergence
2 Days to first flowering
3 Days to 50% flowering
4 Days to maturity
5 Number of plant at harvest
6 Number of mature pods/plant
7 Haulm yield
8 Shelling percentage
9 100-seed weight
10 Protein content
11 Oil content
12 Pod yield

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Table 31: Genotypic correlation coefficients between pod yield and yield characters in 16 groundnut genotypes grown under moisture stress in the field at Samaru in 1995 and 1996. N=96

	1	2	3	4	5	6	7	8	9	10	11	12
1	-											
2	0.070	-										
3	0.085	0.101	-									
4	0.022	0.010	0.010	-								
5	0.018	0.074	0.081	0.086	-							
6	0.137	0.026	0.022	0.003	0.113**	-						
7	0.179	0.062	0.066	0.030	0.192	0.109	-					
8	0.200*	0.074	0.068	0.015	0.161	0.164	0.140	-				
9	0.000	0.003	0.007	0.013	0.028	0.051	0.026	0.063	-			
10	0.028	0.035	0.038	0.014	0.023	0.120	0.032	0.021	0.110	-		
11	-0.006	-0.085	-0.075	-0.021	0.052	-0.011	-0.054	0.025	0.060	0.026	-	
12	0.225*	0.125	0.110	0.038	0.208*	0.258*	0.242*	0.213	0.047*	-0.455**	0.144	-

Variables

1 Number of plants at emergence
2 Days to first flowering
3 Days to 50% flowering
4 Days to maturity
5 Number of plant at harvest
6 Number of mature pods/plant
7 Haulm yield(kg/ha)
8 Shelling percentage
9 100-seed weight(gms)
10 Protein content(%)
11 Oil content(%)
12 Pod yield(kg/ha)

* = Significant at 5% level of probability
** = Significant at 1% level of probability

Table 32: Genotypic correlation coefficients between pod yield and yield characters in 16 groundnut genotypes grown under controlled moisture condition in the screen house at Samaru in 1995 and 1996. N=64

	1	2	3	4	5	6	7	8	9	10	11	12
1	-											
2	0.048	-										
3	-0.021	0.101	-									
4	-0.131	0.167	0.057	-								
5	-0.027	-0.012	-0.015	-0.025	-							
6	0.017	-0.035	-0.029	-0.074	0.016	-						
7	0.011	-0.045	0.033	-0.063	0.017	0.028	-					
8	0.006	-0.098	-0.012	-0.066	0.010	0.012	0.013	-				
9	0.060	-0.077	-0.083	0.227	0.053	0.083	0.088	0.043	-			
10	0.021	0.016	0.038	-0.103	0.008	0.002	0.009	0.002	0.045	-		
11	-0.025	0.005	-0.029	0.072	-0.009	-0.010	-0.022	-0.002	-0.020	0.033	-	
12	0.004	0.002	0.003	0.005	-0.000	0.005	0.005	0.000	0.016	-0.002	0.002	-

Variables
1 Number of plants at emergence
2 Days to first flowering
3 Days to 50% flowering
4 Days to maturity
5 Number of plant at harvest
6 Number of mature pods/plant
7 Haulm yield(kg/ha)
8 Shelling percentage
9 100-seed weight(gms)
10 Protein content(%)
11 Oil content(%)
12 Pod yield(kg/ha)

4.4 CORRELATION ANALYSIS

Phenotypic correlation coefficients between pod yield and the other agronomic parameters under moisture stress in the field experiments and the screen house are presented in Tables 29 and 30, respectively. The genotypic correlations coefficients on the other hand for field and screen house experiments under moisture stress are presented in Tables 31 and 32 respectively. Phenotypic correlation coefficients determines the association between pod yield and the other yield parameters.

The phenotypic correlation coefficients (Table 29) indicated that highly significant and positive correlations existed between pod yield with number of plants at emergence, days to first flowering, days to 50% flowering, days to maturity, number of plants at harvest, haulm yield and 100-seed weight. Pod yield was however, significantly correlated with oil content but not with protein content (Table 29).

On the other hand the screen house phenotypic correlation analysis (Table 30) indicated that, only number of mature pods/plant, haulm yield and 100-seed weight were significantly and positively correlated ($P \geq 0.05$). with pod yield. However, no significant phenotypic correlation existed between pod yield and the other variables.

The genotypic correlation coefficient between pod yield and the other yield parameters under moisture stress experiment in the field with number of plants at emergence,

number of plants at harvest, number of mature pods per plant, haulm yield and protein content are statistically significant (Table 31). However, no significant genotypic correlations was found between pod yield and other yield parameters in the screen house experiments under controlled moisture conditions (Table 32).

CHAPTER 5

5.0 DISCUSSIONS

All the 16 groundnut genotypes evaluated for end-of season drought were sensitive to moisture stress. Similar result was reported by Singh et al. (1991) on 22 groundnut cultivars. However, most of the genotypes evaluated in this study had more than average performance for most of the agronomic characters. Pod yield under moisture stress was generally below average compared to pod yield under adequate moisture condition.

Even though, none of the genotypes evaluated was insensitive to drought, some genotypes performed better than others, may be as a result of differences in crop growth rates which normally exist among genotypes. However, differences in stability of partitioning of nutrients to reproductive sinks may probably be the dominant attributes of genotypes adapted to drought. Other genotypes, however, could have escaped drought as a result of early maturity, as reported by Ketring (1986).

Superiority in performance of other genotypes could be due to their higher yield potential and/or morphological or physiological adaptation to drought.

Moisture stress at terminal stages of groundnut development was found to affect the number of plants surviving up to harvest, markedly. A 20% reduction in the number of plants at harvest could be observed when the

genotypes were subjected tc end-of-season drought. Reduction in the number of plants at harvest was as a result of plant mortality due to moisture stress or probably to diseases and pests. Genotypes ICGV 88023, ICGV 86124 and ICGV 90127 gave the highest number of plants at harvest, with 123, 121 and 118 plants/plot at harvest, respectively. Reduction in the number of plants at harvest, resulted into a reduction in pod yield. JL-24, a cultivar reported to be drought tolerant (Sashikumar et al., 1988) recorded more than average number of plants/plot at harvest, this could be due to its modified root respiration during stress, especially at later stages of development as reported by (Dhopte et al., 1991) and (Dhopte and Ramteke, 1991). The lowest number of plants at harvest was recorded for ICGV 86742 under moisture stress and incidentally, this genotype was among the lowest producers of number of plants at harvest even under normal moisture condition. This characteristic could be inherent of this genotype. Soil surface mositure is considered critical to peg entrance into the soil. As the soil dried, its mechanical resistance increased. For fruiting to occur, the gynophores must enter the soil. Hence the soil physical condition is of importance since the gynophores are able to exert a pressure equivalent to only 3-4g/cm^2 on the soil. The implications of increased-soil-penetration resistance under end-of-season drought and any other drought are reduced peg penetration into the soil, reduced peg development into pods and consequently a reduction

in the number of pods per plant which translates to poor pod yield.

Number of pods per plant was influenced significantly ($P \geq 0.05$) by end-of-season drought. Moisture stress reduced pods per plant by about 62% on average among the genotypes. This reduction could be due to poor pegging and pod initiation which was prevalent under moisture stress. Ravindra et al. (1990) and Rao et al. (1985) have reported very injurious effect of water stress during pod formation. Lesser development of pods could also be due to poor peg development and the inability of the pegs to penetrate hard and dry soils during moisture stress. Even where the pods were formed, the pods remained tender and the number of mature pods per plant was drastically affected.

The highest number of pods per plant was recorded for 55-437, and ICGV 86124 with 7 pods per plant each, while the lowest pods per plant under moisture stress was recorded for ICG 221 with only 3 pods per plant. The lower number of pods produced by this genotype may be due to poor pegging and poor pod initiation as earlier mentioned. This was so because, these stages are very susceptible to moisture stress. Kulkarni et al. (1988) have also reported a reduction in the number of mature pods in groundnut genotypes under end-of-season drought. Tender or immature pods were very many under moisture stress and this added to the haulm yield in most cases. Generally, most genotypes performed below average for

number of pods per plant under moisture stress.

The pod yield of almost all genotypes was affected significantly ($P \geq 0.05$) by end-of-season drought. This was as a result of fewer number of pods per plant and lower pod filling depicted by reduced 100-seed weight. Generally, the pod yield was reduced by about 50% on the average. Similar results were reported by Klepper (1973) when groundnut was subjected to moisture stress from peak of flowering to maturity. This marked reduction in pod yield, when water stress was imposed at later stages of groundnut development, could be attributed to reduced pod setting and pod filling caused by dehydration of pegs and or poor penetration of pegs into the soil, followed by reduced assimilate partitioning. Moisture stress during pod filling has been shown to reduce translocation of photosynthates from the leaves to pod which, subsequently leads to reduced pod yields (Conkerton et al., 1989). The highest pod yield of 704.01kg/ha under moisture stress in the field was recorded for ICG 4747, followed by ICGV 86745 and ICGV 86124 which gave pod yields of 679.43 and 672.62kg/ha, respectively. The high yielding potential of these genotypes, could not be as a result of early maturity, as these genotypes took longer number of days to maturity as against other genotypes. Rather the higher yield potential of these genotypes could be due to their high shelling percentage or high number of pods per plant and or high 100-seed weight, which arosed probably to their genetic yield potential. The

yield potential of the long season genotypes was not realized because of moisture stress which led to the production of immature pods caused by reduced assimilate partitioning. Nageswara Rao et al. (1985) reported that yield potential of long season groundnut was not achieved when moisture stress was imposed at later developmental stages. Under moisture stress, more water extraction takes place in the surface roots. But under this same condition of moisture stress the upper soil layer becomes dry and cracks, leading also to the crack of the roots which subsequently leads to a reduction in the moisture absorption ability of the plant. Full yield potential of early maturing genotypes was realized, may be because of their drought escaping ability. The average pod yield under end-of-season drought among the genotypes was 540.60kg/ha and most genotypes performed above average.

Haulm yield, (dry weight of the vegetative parts, the roots and the immatured pods) was adversely affected by end-of-season drought. The haulm yield was reduced by about 51%. Soil-water deficiency has been known to inhibit leaf expansion and stem elongation through lowered relative turgidity. The reduction in haulm yield could be attributed to reduction in cell division or cell enlargement and abscission of leaves due to lack of water. Gardner and Newman (1964) also reported marked reduction in dry matter as a result of moisture stress at terminal periods of development. Reduction in dry matter could be due to reduced water use efficiency and lower leaf

area index under water stress. Drought stress directly and physically has been known to reduce plant vegetative growth. Lower dry matter yield obtained during moisture stress could also be due to plant mortality and desiccation of leaves thereby affecting the carbon dioxide fixation ability. The highest dry matter production was obtained from ICGV 86124, which also had high pod yield, shelling percentage and the best performance in terms of 100-seed weight under end-of-season drought. The lowest dry matter was obtained from ICGV 86708, which also had the lowest 100-seed weight. This indicates therefore that dry matter production has a bearing on pod yield. The high positive correlation coefficient (r = 0.667) between these parameters under moisture stress attests to the matter.

The shelling percentage and 100-seed weight among genotypes were also affected by end-of-season drought. A reduction of 11 and 10%, respectively, was observed under moisture stress among the genotypes. Results indicated that some of the lines that were high in pod yield were lower in shelling percentage and 100-seed weight. The genotype ICG 4747 which was tolerant to moisture stress had lower shelling percentage and 100-seed weight when compared to those that were less tolerant to moisture stress. Generally, however, it has been found that the shelling percentage, haulm yield, mature pods/plant and number of plants at harvest determines the pod yield, because of the high positive correlation that

existed between these parameters and pod yield under moisture stress. However, Since there was no considerable limitation in moisture at the end of the season, it was rather difficult to relate pod yield to level of drought tolerance especially in the early maturing genotypes. The genetic yield potential of each genotype could therefore significantly determine its pod yield. Among the 16 genotypes 55-437 gave the highest shelling percentage, but had lower 100-seed weight, because of its smaller seed size. The lowest shelling percentage was obtained for ICG 4747 which gave the highest pod yield and was among the lowest haulm yielders. Water stress generally reduced biological yield but does not always decrease economic yield, this has been shown by variations obtained in coefficient of correlation between these parameters under normal and moisture stress. Depression in shelling percentage and 100-seed weight seemed to occur slowly when drought occurred at later developmental stages of groundnut. The 100-seed weight was one of the actual determinant of yield. Genotypes having higher 100-seed weight had well-filled seeds in contrast to those genotypes with lower 100-seed weight which were shrivelled, The average 100-seed weight was reduced by 10% under end-of-season drought. The reduction in 100-seed weight could be due to poor pod filling, as reported by Yayock (1984), which could occur due to reduced nitrogen uptake under moisture stress, in addition to the genotypic character.

Protein and oil contents were not significantly affected by moisture stress. Similar result was also reported by Conkerton et al. (1989) where they stated that protein and oil contents in groundnut were not affected by end-of-season drought. However, these parameters were affected by mid-season drought.

The screen house experiment did not follow the same pattern in yield reduction due to moisture stress, when compared to the field experiment; lesser yield reduction was observed in the screen house as a result of moisture stress. The effect of moisture stress in the field was more drastic. This may be due to the fact that the field experiment was much more under the influence of several environmental factors compared to the screen house experiment which was under a more controlled environment. Temperature and humidity could be the major factors. The lower positive correlation existing between pod yield and other yield components shown in the screen house experiment attests to the fact that screen house environment is not subjected to fluctuations as obtained in the field.

Pod yield, haulm yield, shelling percentage and pods per plant together with some other parameters among the genotypes were significantly ($P \geq 0.05$) affected by moisture stress. It was found that moisture stress later in groundnut development reduced pod yield by 32%, shelling percentage by 26% and haulm yield by 28%. The 100-seed weight was reduced only by 2%

indicating that it was less affected by moisture stress. This is because developing seed is a major sink and it attracts assimilates even at the cost of other organs.

The genotypes performed poorly under moisture stress for pod yield, with only one genotype performing above average compared to the others under adequate moisture. The genotype that gave the highest yield under moisture stress was RRB followed by 55-437. These genotypes are known to be early maturing and their high yields may be as a result of drought escape in the screen house. 55-437 has also been reported to have some degree of drought resistance, and is thus preferably widely grown in the Sahel regions of Nigeria and Senegal. Gautreau (1977) has reported that 55-437 can be grown in Sahel environment and is suited to northern Senegal and Nigeria.

None significant positive coefficient of correlation under moisture stress was found between pod yield with number of plants at emergence, days to first flowering, days to maturity, and shelling percentage and therefore these parameters can not be a very important attributes in pod yield. A significant positive correlation was found between pod yield with number of mature pods per plant, haulm yield and 100-seed weight, whereas negative correlation was found between pod yield with days to 50% flowering, number of plants at harvest, protein content and oil content. Under moisture stress, therefore, the higher positive correlations between most parameters and pod yield could be exploited to increase yield under end-of-season drought.

CHAPTER 6

SUMMARY AND CONCLUSION

In 1995 and 1996, field and screen house experiments on sixteen groundnut genotypes were conducted at the Institute for Agricultural Research, Samaru - Zaria, Nigeria to determine their agronomic performance and yield reaction under moisture stress and end-of-season drought.

In the field, genotypes were planted late so that their later developmental stages coincided with the end-of rain, and thus the plants were subjected to end-of-season drought. In the screen house, the genotypes were subjected to moisture stress from 50% flowering stage, while the control treatment received adequate moisture throughout the growing season, to maturity.

Several agronomic characters and yield parameters were determined. These included number of plants at emergence, days to first flowering, days to 50% flowering, days to maturity, number of plants at harvest, number of mature pods/plant, pod yield, haulm yield, shelling percentage, 100-seed weight, protein content and oil content.

Analysis of variance tests were conducted to determine traits for which genotypes significantly differed at 5% level of probability, by LSD. Correlation tests were also conducted between pod yield and other yield components under end-of-season drought and moisture stress.

Results of this study have shown that pod yield and other yield components with the exception of protein and oil content were significantly decreased by moisture stress. Genotypic variation (based on yield) in drought response was statistically significant ($P \geq 0.05$) under end-of-season drought. Significant positive correlation was found between number of pods/plant, haulm yield, 100-seed weight and pod yield.

The greatest reduction in pod yield due to moisture stress occurred in genotypes ICGV 90127 (71%), ICG 4790 (69%), JL-24 (63%), FLEUR 11 (61%), ICG 4601 (58%) and ICGV 86124, (58%). Lower pod yield reduction due to moisture stress were also observed in genotypes ICG 221, ICG 4747, 55-437, 48-115B and ICGV 88023. It could, therefore, be inferred that they escaped end-of-season drought rather than tolerated it and that could explain their lower yield reductions under moisture stress. Reduction in the number of mature pods per plant under moisture stress ranged between 45-75%. Genotypes ICGV 86742, ICG 4747, ICGV 90127 and ICG 221 exhibited reductions in pods/plant as high as 73%, 71%, 70% and 70%, respectively. This reduction indicated that they may be susceptible to drought. The soil water deficit occurring during the end-of-season drought has to be considered in the light of the indeterminate nature as well as the subterranean fruiting habit of groundnut. Soil water availability in the top 4 to 5cm of the soil profile is of critical importance for peg and

pod development. Fruit initiation continues after the start of the seed growth, so end-of-season drought reduces both the initiation and development of pods. Growth of pods could also be affected by inadequate moisture in the root zone and lack of nutrient uptake by developing pods. Increased evaporative demand during end-of-season drought resulted in increased intensity of drought stress, this being partly responsible for observed crop sensitivity.

Based on these investigations, it is concluded that, in environment prone to end-of-season drought, yield losses will be greater for genotypes with high yield potential. If farmers without irrigation adopt genotypes that have high yield potential (associated with greater drought sensitivity), yields will be less stable than if genotypes with lower yield potential were chosen. The choice of genotypes should therefore, take into cognisance, the probability with which end-of-season drought occurs. The best strategy may be to select for earliness. This will optimize the chance of escape from this type of drought. However, yield potential is also influenced by crop growth duration, so a compromise between yield potential and earliness of a genotype needs to be achieved.

In studies of crop responses to drought a lot of material constraints existed and therefore most parameters could not be evaluated. Parameters like root length, leaf area index, soil moisture content, leaf water potential and numerous others are

very important in the study of drought, if successful and generalized results are to be obtained.

So, future studies, must take into consideration, the material constraints and the multidimensional aspects of drought for successful results, especially for groundnut.

However with the available facilities it was possible to evaluate the genotypes response to end-of-season drought under regimented moisture stress.

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Appendix 1: Climatological data, during the cropping season of 1995 at Samaru.

1995

Months	Temperature (°C) Minimum	Maximum	Relative humidity(%) Morning	Afternoon	Vapour pressure (mb)	Rain fall (mm)
April	19.4	36.4	41.2	31.0	17.7	90.5
May	17.0	34.2	50.0	44.5	24.9	45.3
June	15.6	31.4	70.6	70.6	17.7	123.4
July	21.7	29.8	79.5	64.5	24.7	193.7
August	20.1	28.7	81.8	76.2	26.1	258.6
September	20.4	29.9	81.3	69.8	26.7	159.1
October	19.0	32.0	74.3	54.6	23.9	32.5
November	15.6	28.4	43.7	37.9	17.1	-
December	15.1	32.9	20.7	21.1	9.6	-
Total	162.9	283.5	543.1	470.2	188.4	903.1

Source: Samaru Meteorological Station, Zaria

Appendix 2: Climatological data, during the cropping season of 1996 at Samaru.

1996

Months	Temperature (°C) Minimum	Maximum	Relative humidity (%) Morning	Afternoon	Vapour pressure (mb)	Rain fall (mm)
April	23.0	27.4	55.8	31.7	21.1	Trace
May	27.7	34.2	69.8	47.5	24.3	158.7
June	19.5	30.2	77.5	62.6	25.1	143.3
July	19.0	27.7	79.4	60.5	25.3	156.7
August	19.9	27.7	82.0	72.7	25.6	171.1
September	19.9	30.1	81.5	69.6	27.4	136.2
October	18.5	31.4	65.5	55.1	22.6	51.2
November	13.1	30.5	25.2	21.5	8.8	-
December	11.7	32.6	18.2	17.5	5.3	-
Total	172.3	271.8	552.9	438.7	185.5	817.2

Source: Samaru Meteorological Station, Zaria

Appendix 3: Agronomic characteristics and descriptions of the 16 Groundnut genotypes used in the experiments.

Genotypes	Agronomic Characteristics and description.
Samnut-14(55-437)	- matures in about 100-110 days - tolerant to drought - average oil content is 50 - 52%
Samnut-17(48-115B)	- matures in 90 - 100 days - tolerant to drought - susceptible to rosette and leaf spot - oil content varies from 53 - 55%
Samnut-18 (RRB)	- matures in 90 - 100 days - drought tolerant - rosette-susceptible - oil content varies from 53 - 55%
JL-24	- Takes about 110 - 120 days to mature - it is a bunch spanish type - drought tolerant - average oil content is 50%
ICG 221	- matures in about 120 days - tolerant to mid-season drought - average oil content is 50 - 53%
ICG 4601	- matures in 110 - 115 days - oil content varies from 50 - 55%
ICG 4790	- matures in about 110 - 115 days - rosette susceptible - oil content, 48 - 50%
ICGV 86745	- spanish bunch type - matures in about 106 - 116 days - oil content, 48%
ICGV 86708	- matures in 116 - 123 days - tolerant to leaf spot - average oil content is 49%
ICGV 86742	- matures in 110 - 115 days - performs well under good management - average oil content, 51%
ICG 4747	- matures in about 110 - 120 days - shows good recovery from mid season drought - average oil content 48%
ICGV-SM 85045	- matures in about 115 days - rosette susceptible average oil content is 50%

ICGV88023	-	matures in 110-120 days susceptible to leaf spot and rosette. Oil content is 49% on average.
ICGV86124	-	matures in 110-120 days tolerant to peanut necrosis and peanut mottle virus diseases average oil content. 45%
ICGV90127	-	matures in about 120 days spanish bunch type oil content, 48%.
FIEUR, 11	-	matures in 110-118 days oil content, 48% protein content, 24%

Appendix 4: Combined analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under normal moisture condition and end-of-season drought in the field at Samaru in 1995

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plants at harvest	pods/ plant	Pod yield kg/ha	shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Replication	2	2948.698	0.042	3.573	1.344	1v24.406	127.542	182759.43	9.024	7.953	1.437	5.242	13.167
Genotype	15	544.722*	4.997*	11.322**	193.633**	2078.738*	22.305*	262192.79**	46.502**	86.351**	2.033*	17.778	81.022
Rep x Gen.	30	207.009	1.297	1.117	5.077	208.117	9.519	51982.80	18.562	15.253	0.685	7.419	76.389
Seasons	1	3444.010**	45.375**	78.844**	360.372**	38841.260**	5206.760**	39437794.51**	0.901	986.243**	222.224**	3.760	7632.667
Genotype x season	15	475.299	2.108	2.155*	29.797**	541.705	9.294	284599.49**	5.021	56.965**	0.989	3.245	56.667
Error	32	250.094	1.906	0.917	4.677	553.615	10.667	68827.88	4.082	8.046	0.8182	6.788	54.917
Total	95	7869.832	55.725	97.928	594.900	44148.841	5386.087	40288156.90	84.092	1160.811	228.186	44.232	7914.829

* = Significant at 5%Level of probability

** = Significant at 1% Level of probability

Appendix 5: Combined analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under normal moisture condition and end-of-season drought in the field at Samaru in 1996

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of plants at harvest	pods/ plant	Pod yield kg/ha	shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Replication	2	432.385	0.043	3.469	2.281	45.573	0.823	330023.823	100.639	0 613	2.519	19.224	2.887
Genotype	15	80 822	5.022*	2.911**	250.356**	289.760*	9.649	120699 902*	310 230**	206 403**	0.943**	7.547	17 156
Rep x Gen.	30	63 508	1.342	0.613	11.237	128.973	6.745	41532.487	52.732	9 464	0 398	8.032	23 623
Seasons	1	3.375	20.167**	0.042	532 041**	3939.844**	15.844	1069827.380**	342.770*	0.010	52.658**	13.726	13.054
Genotype x season	15	141.131*	1.722*	1.975**	42.308**	346.733**	7.400	122114.186*	133.750*	20.316*	1.105**	3.700	37.321
Error	32	63.521	0.563	0.417	5.697	130.240	10.521	61080.466	66.860	8 086	0.270	10.560	21.895
Total	95	784.921	28.859	9.427	843.921	4881.123	50.982	1745278 244	1006.981	244.892	57.893	62.789	115.936

* = Significant at 5%Level of probability

** = Significant at 1% Level of probability

Appendix 6: Combined analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under normal moisture condition and end-of-season drought in the field at Samaru in 1995 and 1996.

Source of variation	Df	No of Plants at emergence	Days to first flowering	Days of 50% flowering	Days to maturity	No of plants at harvest	pods/ plant	Pod yield kg/ha	shelling %	100-seed weight (g)	Haulm yield kg/ha	Protein content (%)	Oil content (%)
Replication	2	2715.021	0.161	1.443	0.109	968.193	60.193	17145.880	93.2699	3.784	2.916	21.248	5.236
Year	1	9534.422**	90.750**	106.505**	126.750**	62568.521**	1523.000**	1195224.540**	3.968	4.171	10.129**	20.345	158.232**
Rep. x year	2	666.063	0.328	5.599	3.516	1088.786	68.172	495637.370	20.536	4.782	1.040	3.218	7.595
Genotype	15	327.033**	5.867**	8.650**	422.083**	1099.367**	15.354	294705.730**	267.903**	238.420**	1.243**	10.380	39.104**
Gen. x year	15	298.511*	2.461**	5.583**	21.906**	1270.132**	16.600*	88186.970	123.350*	54.334**	1.733**	14.945*	24.554
Season	1	1615.880**	2.521	41.255**	8.333	33761.021**	2898.521**	13758302.320**	2370.235**	489.921**	245.617**	1.559	3.548
Season x year	1	1831.505**	63.021**	37.630**	884.083**	9020.083**	2324.083**	26749319.580**	5605.202**	496.332**	29.266**	15.928	10.407
Genotype x season	15	329.529**	2.121*	2.155**	17.978**	480.476**	11.321	312998.130**	111.469*	57.424**	0.869	3.878	15.685
Gen x season x year	15	286.905*	1.710	1.975**	54.128**	407.961	5.3721	93715.550	78.751	19.856*	1.226**	3.067	26.657
Error	124	146.380	1.703	0.763	6.624	258.033	9.403	56149.40	62.665	10.143	0.543	8.215	16.910
Total	191	17751.245	170.643	217.558	1545.510	110835.573	6732.019	43061385.474	8737.345	1379.167	294.582	102.783	307.928

* = Significant at 5% Level of probability

** = Significant at 1% Level of probability

Appendix 7: Combined analysis of variance showing sources of variation, degrees of freedom (df) and mean squares for yield and yield components in 16 groundnut genotypes grown under normal moisture and moisture stress in the screen house at Samaru in 1995.

Sources of variation	Df	No of plants at emergence	Days to first flowering	Days to 50% flowering	Days to maturity	No of plant at harvest	pods/plant	Pod yield Kg/ha	Shelling %	100-seed weight (g)	Haulm yield kg/ha	protein content (%)	Oil content (%)
Seasons	1	0.125	4.500	0.281	40.500*	0.125	205.031**	2838.811**	2065.638**	21.945	27086.281**	2.153	20.963
Genotype	15	0.167	1.833	1.900	76.658**	0.433	14.481**	405.523**	70.251**	12.903	1934.548**	5.637	15.510
Error	15	2.875	1.567	0.880	6.767	1.125	1.234	56.571	18.262	14.942	457.615	3.144	20.049
Total	31	3.167	7.900	3.061	123.925	1.683	220.746	3300.907	2154.151	49.790	29478.444	10.934	56.522

* = Significant at 5% Level of probability

** = Significant at 1% Level of probability

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