GENETIC ANALYSIS OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS RELATED TO DROUGHT TOLERANCE IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)

BY

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JULY, 2020

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Nafisa ABDURRASHEED B. Agric (ABU) 2015

(P16AGPS8001)

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN PLANT BREEDING

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JULY, 2020

DECLARATION

I hereby declare that the work presented in this Dissertation entitled "**GENETIC ANALYSIS OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS RELATED TO DROUGHT TOLERANCE IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)"** has been carried out by me in the Department of Plant Science, Ahmadu Bello University Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Dissertation was previously presented for another degree or diploma at this or any other institution.

Nafisa ABDURRASHEED _____ _____

Signature Date

CERTIFICATION

This Dissertation entitled "GENETIC ANALYSIS OF MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS RELATED TO DROUGHT TOLERANCE IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)" by Nafisa ABDURRASHEED meets the regulations governing the award of the degree of Master of Science in Plant Breeding of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research is dedicated to my parents who have been and will always be my source of inspiration and to the memory of my soul sister, Late Safiyyah Abdulrashid Yakubu, may Almighty Allah continue to shine His light on your grave, Ameen.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude and sincere appreciation to Almighty Allah (SWT) for giving me the knowledge, grace, wisdom, guidance, patience and strength throughout the period of my studies.

My sincere appreciation goes to the Chairman, Supervisory Committee of this dissertation, Dr. A. Usman for his invaluable contribution to the success of this work. His push, encouragement, advice, constructive criticism and untiring efforts in supervising my practical and subsequent analysis would forever be appreciated and would remain indelible in my memory. He has painstakingly read through my complete manuscripts and made valuable corrections where necessary. Indeed, he has set me on a solid course of reaching my goals. For that, I am eternally grateful. To my minor supervisor, Prof. U.S. Abdullahi I am grateful for your valuable contribution in ensuring the authenticity of this dissertation. I wish to acknowledge all my lecturers in the Department of Plant Science notably Prof C.A Echekwu, Dr. M. S. Mohammed, Dr. M. Oyekunle and Dr. M. Saba among others. Also in my list of acknowledgements are the entire technicians of the Groundnut Improvement Laboratory.

My sincere appreciation goes to my parents, siblings and all family members. I can't thank you enough for all the assistance and words of encouragements. I also will like to appreciate my friends, Aisha Hussaini, Amina Yusuf, Masud Owolabi, Hajara Isah, Hamza Muhammad, Gabriel Mowobi, Yaya Bala, Sabastina Zubairu, Susan Zarafi, and Christopher Musa. Thank you all.

ABSTRACT

Drought stress is one of the major constraints in groundnut producing areas of Sub-Sahara Africa as its yield is reduced by 56-85%. Mitigating this constraint requires the selection of resilient genotypes that withstand drought threats to groundnut production. The objectives of this study were to identify drought tolerant genotypes to be used for groundnut breeding program, to assess the mode of gene action controlling drought tolerance in groundnut and to determine the association of pod yield with morphological and physiological traits related to drought tolerance in groundnut. One hundred and seven (107) groundnut genotypes were screened for drought tolerance during 2018 dry season in a split-plot design arranged in a randomized complete block design under non-stress and water-stress conditions. The mean squares for the morphological and physiological traits showed a highly significant ($P \leq 0.01$) difference between the genotypes under water-stress and combined analysis. Based on the PCA ranking under water-stress condition, genotypes ICGV-IS-13115, RS006F4B1-45®, ICGV-IS-07853, ICGV-IS-13989 and RS006F4B-534 were the top 5 drought tolerant while genotypes ICGV-IS-07828, 12CS-010, ICGV-IS-07809, RS006F4B1-45(B) and ICGV-IS-07904 were the least 5 drought susceptible. Seven groundnut genotypes comprising of four drought susceptible and three drought tolerant were randomly selected from the results of screening experiment. The seven genotypes were crossed in a half diallel mating design to obtain 21 F_1 progenies. The parents, 21 F_1 progenies and two checks were evaluated in a randomized complete block design with two replications under both conditions. Data were collected on days to 50% flowering, plant height, pod yield, 100-seed weight SCMR at 40, 60 and 80 days after sowing (DAS) and harvest index (HI). The analysis of variance showed a highly significant ($P \leq 0.01$) difference among the genotypes for

plant height, number of pods per plant, pod yield and SCMR at 60 DAS under both conditions while a significant ($P \leq 0.05$) difference for seed weight under water-stress condition, 100-seed weight and HI under non-stress and water-stress condition was observed. Broad-sense heritability was high (67.45%) for plant height, moderate (46.23%) for 100 seed weight and (42.54%) for SCMR at 60 DAS under water-stress condition. General Combining Ability (GCA) effect for all the traits were significant ($P \leq 0.05$) in both non-stress and water-stress conditions, while Specific Combining Ability (SCA) effects were significant ($P \leq 0.05$) for all the traits in both non-stress and water-stress conditions. Highly significant GCA effects for all the traits were observed for ICG 5195 (P_6) under water-stress condition, while ICGV-IS-07841 (P_3) was a poor general combiner under the same condition. Highly significant positive SCA effects for number of pods per plant, seed weight and pod yield were observed with P_1 x P_6 and P_3 x P_6 crosses under water-stress condition. SCMR at 60 DAS had a moderate positive and significant (r =0.45, $P \leq 0.01$) relationship with pod yield; HI recorded a strong positive and highly significant (r =0.59, $P \leq 0.01$ and r =0.83 $P \leq 0.01$) relationship with number of pods per plant and pod yield. Although both additive and non-additive gene actions were involved in the expression of most traits, non-additive was more important than additive gene action under water-stress condition. The importance of non-additive effect under water-stress suggests the need to achieve acceptable progeny performance under drought stress condition. Therefore, cross P_1 x P_6 and P_3 x P_6 exhibit highest SCA effects for number of pods per plant, seed weight and pod yield which can be improved through pedigree selection. SCMR at 60 DAS and HI could also be used as an indirect selection for pod yield under drought stress condition.

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CHAPTER ONE

1.0 INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important oil crops that originated from South America. It is now cultivated in more than 100 countries covering tropical, subtropical and the warm temperate regions of the world (Upadhayaya *et al*., 2012). About 47.10 million metric tonnes of groundnuts in shell are produced globally from 27.9 million hectares with an average productivity of 1.4 metric tonnes per hectare. The major groundnut producing countries are: China (17.3 metric tonnes), India (7.9 metric tonnes), U.S.A (2.8 metric tonnes), Nigeria (2.6 metric tonnes), Sudan (2.2 metric tonnes) (FAOSTAT, 2018). Nigeria is the largest producer of groundnut in Africa. Many landraces and cultivars are localized in different parts of the country (Ladodo *et al*., 2015; Mshelmbula *et al*., 2017) where they are cultivated at both subsistence and commercial levels (ICRISAT, 2017). However, the productivity of Africa (913 $kgha^{-1}$) is very poor as compared to Asia (2373$kgha^{-1}$) and Americas (32.04 kg ha^{-1}) (FAOSTAT, 2018).

Groundnut oil is a rich source of vitamins A, B and E. Besides being an important source of vegetable oil, it is also used as an important source of food, feed, nutrition and fodder (Asibuo *et al*., 2008; Atasie *et al*., 2009). It contains on average 44 % edible oil, 20% carbohydrate and 25.3% easily digestible protein, which is about 1.3 times higher than meat, 2.5 times higher than eggs and 8 times higher than fruits (FAOSTAT, 2008). Groundnut improves soil fertility through nitrogen fixation, thereby increasing the productivity of other crops when used in rotation or as a mixture in cereal cropping system (Ajeigbe *et al*., 2014).

Drought is widely known as the major factor limiting groundnut production. In semiarid zones, especially West Africa, drought can occur at any stage of crop cycle and often leads to devastating effects in groundnut growth, development, metabolism, pod yield and pod quality Hamidou *et al*.(2013).

1.1 Problem Statement

Despite all the research effort in groundnut, pod yield under rain fed cultivated areas has been limited by drought spell and other growth parameters have been severally affected (Pimratch *et al*., 2008). Yield losses have been estimated to be 56-85% (Thakur *et al*., 2013) depending upon growth stages when the crop was expose to drought (Reddy *et al*., 2003), drought intensities and duration (Nigam *et al*., 2005). The use of drought tolerance and variation is an important strategy to combat drought problem, this variation should be able to provide high pod yield under dry condition. Direct selection for yield under water stress condition may be effective; however, the limitations of this approach are high resource investment and poor repeatability of the results due to the large genotype x environment (G x E) interaction that results in slow breeding progress (Wright *et al.*, 1996). Therefore, rapid progress may be achieved by considering physiological traits such as Specific Leaf Area (SLA), and SPAD chlorophyll meter reading (SCMR). Both SLA and SCMR have been used as surrogate traits for Water Use Efficiency (WUE) (Puangbut *et al.*, 2017).

Specific Leaf Area (SLA) and SPAD Chlorophyll Meter reading (SCMR) have been reported as an important physiological trait for tolerance to drought in groundnut (Pasupuleti *et al*., 2015). Studies by Wright *et al*. (1994) observed that SLA was closely and negatively correlated with Water Use Efficiency (WUE). These traits are significantly influence by factors such as time at

sampling and leaf age (Nageswara *et al*., 1995) suggesting the need for further study and the factors influencing water usage efficiency in groundnut (Nageswara *et al*., 2001). They further reported a highly significant relationship between SLA and SCMR in groundnut, suggesting that SCMR will be reliable and rapid measure to identify genotypes with low SLA and high WUE.

1.2 Justification

Genetic variability for drought tolerance has been reported in groundnut (Songsori *et al*., 2009). However, breeding for drought tolerance based on pod yield is lagging behind due to significant genotype x environment (G x E) interaction. Alternatively, breeding strategies using physiological traits have been proposed by some researches. Rapid progress in drought tolerance breeding have been achieved based on characters like Harvest Index (HI), Water Use Efficiency (WUE), Specific Leaf Area (SLA) and SPAD Chlorophyll Meter Reading (SCMR) (Nigram *et al*., 2005).

Information on the heritability of RWC, SCMR, SLA, HI, pod yield, pod number per plant, 100 seed weight and phenotypic correlation among these traits will be useful for planning suitable breeding strategies for improving drought tolerance in groundnut. Effective selection of traits under improvement depends on sufficient additive genetic variation of the traits that are expressed as heritability. Therefore, the present research was undertaken to achieve the following objectives:

i. to identify drought tolerant genotypes to be used for groundnut improvement.
ii. to assess the nature of gene action controlling drought tolerant traits in groundnut.
iii. to determine association between pod yield, and morphological and physiological traits associated with drought.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Groundnut

Cultivated groundnut or peanut (*Arachis hypogaea* L.) is a cleistogamous allotetraploid (2n=4x=40) leguminous annual crop with "AA" and "BB" genomes of 2891 Mbp (Holbrook and Stalker, 2003). All species, except the cultivated species *A.hypogaea* and *A. monticola* in the section *Arachis*, and certain species in Section Rhizomatosae, are diploid (2n=2x=20). The diploid progenitors; *A. duranensis* and *A. ipaensis*, contributed "AA" and "BB" genomes, respectively, to the cultivated groundnut (Kochert *et al*., 1996). A single hybridization event between the diploid progenitors followed by chromosome doubling about 3500 years ago led to origin of cultivated groundnut. Southern Bolivia and Northern Argentina are thought to be center of origin of this crop (Kochert *et al*., 1996). The center of diversity of the genus includes Western Brazil, Bolivia, Paraguay, and Northern Argentina (Gregory *et al*., 1980).

There are thousands of groundnut cultivars around the world. Certain cultivars groups are preferred for particular uses because of differences in flavor, oil content, size, shape and disease resistance. For many uses the different cultivars are interchangeable however, the most popular cultivars are Spanish, Runner, Virginia and Valencia. Most groundnuts marked in the shell are of the Virginia type, along with some Valencias selected for large size and the attractive appearance of the shell. Spanish groundnuts are used mostly for peanut candy, salted nuts, and peanut butter. Most Runner are used to make peanut butter (Arya *et al*., 2015)

2.2 Drought Stress

Drought stress is one of the most prevalent environmental conditions that severely impairs growth and development of field crops production and productivity (Edema, 2014). It differs from other abiotic stresses in a way that the effects of drought often accumulate slowly over a considerable period of time. Because of this, drought stress is termed as a "Creeping phenomena". It's impact is apparent to a lesser extent and spread over large geographical areas with greater damages that result from other natural stresses.

Drought is a worldwide problem. It decreases the global crop production seriously and recently global climate change has made this situation more serious (Pan *et al*., 2002). Current estimates indicated that 25% of the world's agricultural land is now affected by high levels of water stress (Jajarmi, 2009). It affects about 50- 85% of groundnut production area worldwide (Pfeiffer, 2005). In arid and semiarid regions, groundnut crop usually experience drought during the flowering and pod filling period. Drought stress at pod filling period causes pod shriveling which ultimately reduces pod yield. In rainfed agriculture, water limitation may prove to be a critical constraint to primary productivity under arid climates. In these areas drought spell is expected at any critical stage of plant growth (Zamurrad *et al.*, 2013).

2.3 Physiological Responses

The study of physiological responses of groundnut genotypes to water stress is a useful tool to understanding the mechanisms of drought resistance (Naeem *et al.*, 2015). Drought induces significant alterations in groundnut physiology. Some groundnut genotypes have a set of physiological adaptations that allow them to tolerate water stress conditions. Researchers linked various physiological responses of groundnut plant to drought with their tolerance mechanisms,

such as: high leaf chlorophyll content, high relative water content, cell membrane stability, high proline content and lower canopy temperature. Almeselmani *et al*. (2012) reported significant reduction in physiological, yield and yield contributing traits in the drought susceptible groundnut varieties compared to other varieties. Positive and significant association between the physiological and yield traits was observed. It is obvious from the results that all these parameters explained the drought tolerance mechanisms.

These drought tolerance mechanisms help in understanding the physiological responses that enable plants to maintain growth and productivity during stress period. Ultimately, indicating the importance of these traits in breeding programs for screening and selection of tolerant genotypes (Naeem *et al.,* 2015). Zaharieva *et al*. (2001) reported that physiological traits helped in the selection of best performing drought resistant groundnut genotypes in arid areas.

2.4 Effect of Drought on Groundnut Performance

2.4.1 Drought stresses reduce plant productivity

Drought stress has been a major environmental factor contributing to the reduced agricultural productivity and food safety worldwide. Drought stress perceived from plant surrounding environment varies spatially and temporally at several different scales. Drought affects membrane lipids and photosynthetic responses (Lauriano *et al*., 2000) and yield (Suther and Patel, 1992). Water deficit affects thylakoid electron transport, phosphorylation and carboxylation (Devaiah *et al.,* 2011). Changes in the lipid content and composition are common in water-stressed plants and this increases membrane permeability. This causes damage and membrane disruption as well as reduction in photosynthesis. Maintaining membrane integrity under drought conditions will determine the plants tolerance towards stress. Plants have several

mechanisms for adaptation to water and heat stress including stomatal conductance, paraheliotropism, and osmotic adjustments (Devaiah *et al.,* 2011). Arid and semi-arid environments typically have hot days and cool nights. Since there is a lack of water vapor in the air, the temperature at night drops making the night cooler, but the day hotter which can be stressful to the plant (Devaiah *et al.,* 2011).

2.5 Plant Responses to Drought

2.5.1 Photosynthesis

Canopy photosynthesis is reduced by moisture stress due to reduced stomatal conductance and a reduction in leaf area. As moisture stress increases, the stomata start closing as a mechanism to reduce transpiration and consequencely, the entry of carbon dioxide is also reduced (Kalariya *et al*., 2013). The decrease in the conductance of mesophyll cells due to moisture stress results in low conductance of carbon dioxide and a reduction in photosynthesis. Bhagsari *et al*. (1976) observed large reductions in photosynthesis and stomatal conductance as the relative water content of groundnut leaves decreased from 80 to 75%.

The main effect of soil water deficit on the leaf carbon exchange rate is exerted through stomata closure (Kalariya *et al*., 2013). These authors reported reduced carbon exchange rate, decreased transpiration and increased stomatal resistance within three days of withholding water in potted plants. Under field conditions, Allen *et al*. (1976) found reduced stomatal resistance after seven days of stress and significant differences within ten days between water-stressed and non-stressed plants.

2.5.2 Chlorophyll content

Severe drought stress inhibits the photosynthesis of plants by changes in chlorophyll content, affecting chlorophyll components and damaging the photosynthetic apparatus. Total chlorophyll content is found to reduce under water stress conditions. A decrease in chlorophyll content is faster in drought sensitive than in drought tolerant genotypes (El-Tayeb 2006). The chlorophyll content in leaves reflects photosynthetic activity and yield potential of groundnut plants. High chlorophyll content in different plant leaves was considered as a favorable trait in crop production under drought stress (Rong-hua *et al*., 2006).

Drought stress causes wilting to groundnut genotypes, hence reduce the green leaf area and water uptake from soil profile to some extent. Early studies reported that drought stress increases Soil Plant Analysis Development (SPAD) Chlorophyll Meter Reading (SCMR) in groundnut. Higher SCMR under water stress condition shows that, the groundnut genotypes could continue having high photosynthesis rate per unit leaf area regardless of water stress. In groundnut SCMR has strong relationship with pod yield and Transpiration Efficiency (TE) under water stress conditions (Boontang *et al*., 2010).

Reddy and Rao (1968) reported that severe drought stress decreased the levels of chlorophyll a, b and total chlorophyll. The decrease in chlorophyll was attributed to the inhibition of chlorophyll synthesis as well as to the accelerated turnover of the chlorophyll already present. However, mild drought stress increased the chlorophyll content (Moreshat *et al*., 1996). Stirling *et al*. (1989) reported that the leaves were the primary sites of 14C fixation, followed by stems and pegs. The fixation of carbon was low during drought stress but increased sharply when drought stress was relieved. Under drought stress, the stems were initially the major sinks for carbon dioxide but

their sink activity disappeared almost completely when stress was ameliorated. Dry matter accumulation was reduced by prolonged water deficit (Rao *et al*., 1985; Sivakumar and Sharma, 1986).

2.5.3 Flowering

The start of flowering is not delayed by drought stress (Boote and Ketring, 1990). The rate of flower production is reduced by drought stress during flowering but the total number of flowers per plant is not affected due to an increase in the duration of flowering (Gowda and Hegde, 1986; Janamatti *et al*., 1986; Meisner and Karnok, 1992). A significant burst in flowering on alleviation of stress is a unique feature in the pattern of flowering under moisture stress, particularly when drought is imposed just prior to re-productive development (Janamatti *et al*., 1986). When stress is imposed during 30–45 days after sowing the first flush of flowers produced up to 45 days do not form pegs during that time, however, flowers produced after re-watering compensated for this loss (Gowda and Hegde, 1986).

2.5.4 Pod formation

Groundnut plants may experience water stress during pegging and pod development and may have adequate amount of water (Jogloy *et al*., 1996). This would result in a drastic reduction of crop yield, and the magnitude of reduction would depend on peanut cultivars. Not only the yield of groundnut but also the quality of products decreases under drought stress (Rucker *et al*., 1995). Peg elongation, which is turgor dependent, is delayed due to drought stress (Boote and Ketring, 1990). Pegs fail to penetrate effectively into air-dry soil, especially in crusted soils. Often, within 4 days of withholding water, the soil surface becomes too dry for peg penetration.

Skelton and Shear (1971) reported that adequate root zone moisture could keep pegs alive until pegging zone moisture content is sufficient to allow penetration and initiation of pod development. Once pegs are in the soil, adequate moisture and darkness are needed for pod development. Adequate pod zone moisture is critical for development of pegs into pods and adequate soil water in the root zone cannot compensate for lack of pod zone water for the first 30 days of peg development. After 30 days of adequate pod zone moisture, the pods can continue normal growth in dry soil if the roots have adequate moisture.

Wright *et al*. (1994) reported that pod formation was affected by a dry pod zone. Soil water deficits in the pegging and root zone decreased pod and seed growth rates by approximately 30% and decreased weight per seed from 563 to 428 mg. Peg initiation growth during drought stress demonstrated ability to suspend development during the period of soil water deficit and to re-initiate pod development after the drought stress was relieved (Sexton *et al*., 1988). It has frequently been reported that under water stress, pegging and seed set responses of various groundnut cultivars varied substantially, this leads to a large reduction in pod yield, and the reduction percentage also varies among groundnut cultivars (Nageswara Rao *et al*., 1989).

Soil water deficits in the root zone during pegging decreased pod and seed growth rates by approximately 30% as well as seed weight from 563–428 mg. The number of pods per plant may be low due to increases in soil resistance caused by prolonged drought (Sharma and Sivakumar, 1991). Drought reduces pod yield primarily by decreasing the duration of the pod development phase (Stirling and Black, 1991). Water deficits during kernel or seed development reduce the pod and seed weight. The shelling percentage is reduced by moisture stress during seed development (Janamatti *et al.*, 1986).

2.6 Multivariate Analysis

Multivariate analysis (MVA) is the statistical analysis of many variables at once. The analysis of large multivariable dat sets is a major challenge for life science research. MVA has been made much easier with the development of inexpensive, fast computers, and powerful analytical software (Fredrick, 2013). It is used to assess the extent and pattern of variability within a genetic resource collection or population in a plant breeding program and also to identify quantitative traits which explain most the variability of the genotypes, (Jankulovska *et al*., 2014). Multivariate techniques have been used by various scientists for studying divergence in different crops such as: Groundnut (*Arachis hypogaea* L.) (Upadhyaya *et al*., 2009 and Sudhir *et al*., 2010), winter rapeseed (*Brassica napus* L.) (Sharafi *et al*., 2015), rice (*Oryza sativa*) (Maji and Shaibu, 2012). According to Aremu *et al*., (2007) and Sunday and Omolayo (2010), accurate cultivar evaluations and ability to differentiate between cultivars in respect of genetic parameters associated with adaptation in cultivated plants and their wild progenitors are critical to any plant breeding program. Multivariate statistical techniques which simultaneously analyze multiple measurements on each individual under investigation, are widely used in analysis of genetic diversity irrespective of whether it is morphological, biochemical or molecular marker-based and subsequently, classification of germplasm collections. Among the multivariate techniques, cluster analysis, PCA, principal co-ordinate analysis (PCoA) and Multi-Dimensional Scaling (MDS) are at present, most commonly employed and appear particularly useful (Maji and Shaibu, 2012)

2.6.1 Principal component analysis (PCA)

PCA is one of the several techniques of multivariate that reduced the data into two dimensions (Smith, 2002). According to Maji and Shaibu (2012), principal Component Analysis (PCA) may be used to reveal patterns and eliminate redundancy in data sets as morphological and physiological variations routinely occur in crop. This is done by compressing them and reducing the number of dimensions into fewer dimensions which show the most variability (Martinez-Calvo *et al*., 2008) without much loss of information; thus eliminating redundancy in the data set. Each variable represents a principal component; therefore the principal component can be computed as many as the variables (Mustsaers *et al*., 1997).

The eigenvalue is the contribution of each principal component to the overall variation observed in the evaluated materials while the eigenvector (own vector) of the correlation matrix represents the coefficient of the principal components which shows the magnitude of the contribution of each trait and the direction in each principal component (Mustsaers *et al*., 1997). The scaling of eigenvalues range from -1 to +1; hence importance is attached to any principal component for further analysis because of its eigenvalue which must be =1 or >1 and its contribution in explaining the overall variations observed (Mutsaers *et al*., 1997). Therefore those principal components with eigenvalues <1 are considered not important in contributing to the overall variance. PCA has been used frequently for genetic diversity analysis in many crops e.g groundnut (Upadhyaya *et al*., 2009).

2.6.2 Cluster analysis

Clustering is the process of grouping or making sets of similar or nearly similar type of physical or abstract objects. The groups thus formed are known as clusters (Mamta and Bharat, 2011). It

is the process of grouping the data into classes or clusters, so that the objects within the same cluster have higher degree of similarity in comparison to one another but are very much dissimilar to the objects in different clusters (Mamta and Bharat, 2011).

Cluster analysis is a convenient method for identifying homogenous groups of objects called clusters. Objects (or cases, observations) in a specific cluster share many characteristics, but are very dissimilar to objects not belonging to that cluster (Lokesh *et al.*, 2017). Cluster analysis is a tool for exploratory data analysis and based on grouping of relatively homogenous classes (Alicja, 2013).

Choice of parents with great genetic distance is the first steps in the plant breeding program that involves crossing (Joshi *et al*., 2004). Anand and Murrty (1968) reported that higher heterosis in progeny is observed when the progeny is a product of crosses between parents that are of higher genetic distance. Clustering is subdivision of data from different genotypes into groups of similar genotype (clusters) such that each cluster consists of genotypes that are similar between themselves and different to genotype of other clusters; and that genotype in a cluster is assumed and expected to behave the same way across locations (Albert, 2014). Thus genotype from different clusters can be selected as parents for breeding program owing to their genetic distance obtained through the clustering

2.6.3 Dendrogram

The dendrogram is a graphical representation of the results of hierarchical cluster analysis. This appears in the form of tree like plot where, each step of hierarchical grouping is represented as a fusion of two branches of the tree resolving into a single one. The branches represent

clusters obtained on each step of hierarchy. There are several clustering techniques includes partitioning methods, hierarchical methods, density-based methods, grid-based methods, model-based methods, methods for high-dimensional data and constraint-based clustering (Mamta and Bharat, 2011). Clustering has been used to study diversity in different crops such as; groundnut (Makinde and Ariyo, 2010), rice (Maji and Shaibu, 2012), wheat (Mostafa *et al.*, 2011) and genetic divergence was observed for these crops using cluster analysis

2.7 Genetic Variability under Drought Conditions

Genetic variability is a prerequisite for character improvement in any breeding program. Narasimhulu *et al.* (2012) reported a low magnitude of difference between Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) who observed SPAD chlorophyll meter readings to be less influenced by the environment. Mhike *et al.* (2011) reported significant differences in an across site analysis for environments, genotypes and genotype x environment interactions in groundnut under stress and non-stress conditions. The extent of variability is measured by GCV and PCV which provides information about relative amount of variation in different characters in groundnut. According to Roychowdhury and Tah (2011), the extent of variability is measured by GCV and PCV which provides information about relative amount of variation in different traits studied. Chaudhary (2001) found that GCV is not an absolute mean to know the heritable diversity present and should be considered together with heritability evaluations. A study of genetic diversity with suitable measures like GCV and heritability evaluations are essential to have an applicable breeding program (Al-Tabbal and Al-Fraihat, 2012). Bolanos and Edmeades (1996) suggested the use of secondary traits of adaptive value whose genetic variability increases under drought and could increase selection efficiency.

2.8 Heritability of Traits under Drought Condition

Heritability provides an idea to the extent of genetic control for expression of a particular trait and the reliability of phenotype in predicting its breeding value. Heritability is further divided into broad sense and narrow sense, depending whether it refers to the genotypic value or breeding value, respectively (Tazeen *et al.*, 2009). The ratio of genetic variance to phenotypic variance is called heritability in the broad sense. It expresses the extent to which individual phenotypes are determined by the genotypes. On the other hand, the ratio of additive variance to phenotypic variance is called heritability in the narrow sense (Tazeen *et al.*, 2009).

This expresses the extent to which phenotypes are determined by the genes transmitted from the parents. It also expresses the magnitude of genotypic variance in the population, which is mainly responsible for changing the genetic composition of a population through selection. High heritability indicates less environmental influence in the observed variation (Songsri *et al.*, 2008). High heritability for a given trait also indicates that it is governed by additive gene action and, therefore, provides the most effective condition for selection (Tazeen *et al.*, 2009).

Characters that are controlled largely by genes acting in an additive fashion have higher values of heritability than characters governed by genes with large non-additive effects (Dabholkar, 1992). Accordingly, it is important to note that heritability is a property not only of the character being studied, but also the population being sampled and the environmental circumstances to which individuals have been subjected. More variable environmental conditions reduce the magnitude of heritability while more uniform conditions increase it (Rosielle and Hamblin, 1981). Furthermore, in predicting response to selection, heritability estimates are used to identify optimum environments for selection (Singh and Ceccarelli, 1995).

Whether direct or indirect selection is superior depends upon the heritability of the selected trait in stress and non-stress environments and the genetic correlation between stress and non-stress environments (Zavala-Garcia *et al*., 1992). However, many investigators reported a decline in heritability for grain yield under water stress conditions (Rosielle and Hamblin, 1981). A number of reports on heritability are available for different traits of groundnut under drought stress.

Al-Yassin *et al*. (2005) reported broad sense heritability for pod yield of around 0.60, but fell to values near 0.40 at very low pod yield levels. In order for a trait to be more useful in selection of drought tolerance, the heritability estimates for the trait should be greater than the heritability for yield in the specific environment, so that selecting and advancing only the top few performers is likely to produce a greater genetic advance than selecting many moderate performers when heritability is low (Acquaah, 2007).

According to a study by Philipo *et al*. (2016), heritability estimates of HI, SCMR and number of pods per plant were higher than heritability estimates of pod yield per plant under water-stress condition. Therefore, it should be kept in mind that the estimate of heritabilities applies only to environments sampled (Hallauer and Miranda, 1988; Dabholkar, 1992). Thus, when planning to improve a locally available elite population, in addition to determining variability, priority should be given to estimation of heritabilities of the stress tolerant traits under targeted environmental conditions.

2.9 Diallel Mating

Diallel implies all possible crosses among a set of parents resulting in n^2 combinations in a

complete diallel (Griffing, 1956; Stuber, 1980; Christie and Shattuck,1992; Kearsy and Pooni, 1996). Diallel allows the estimation of GCA, SCA and gene action, that is, the additive and non-additive variance components (Griffing, 1956; Christie and Shattuck, 1992; Dabholkar, 1992).

Diallel mating types are type I, and II and Partial Diallel crosses (Dabholkar, 1992).

Type 1 is a factorial mating design with all possible crosses between ***f*** male and ***m*** female parents.

Type II entails ***n*** parents crossed to produce $\boldsymbol{n}^2$ single cross progeny and selfs (Griffing, 1956).

Partial diallel only uses a sample of the crosses.

Type II diallel with reciprocal F_1's excluded is the half diallel (Jones, 1965)

Type II with parents excluded is the modified diallel (Griffing, 1956)

Table 2.1: Form of Diallel Method 2 Reciprocals excluded (nothing below the diagonal) from Hallauer *et al*., 1981

Females/Males	A	B	C	D	E	**Mean female**
A	Y_{AA}	Y_{BA}	Y_{CA}	Y_{DA}	Y_{EA}	Y_{-A}
B		Y_{BB}	Y_{CB}	Y_{DB}	Y_{EB}	Y-B
C			Y_{CC}	Y_{DC}	Y_{EC}	Y-C
D				Y_{DD}	Y_{ED}	Y-D
E					Y_{EE}	Y-E
Mean male	YA^-	YB^-	YC^-	YD^-	YE^-	μ

Source: (Hallauer *et al*., 2010)

2.9.1 Combining ability and gene action under drought conditions

Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitative traits and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). GCA refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas SCA is the performance of a parent in a specific cross in relation to GCA (Sharief *et al*., 2009). SCA is due to genes showing non-additive effects. Selection of parents based on combining ability has been used as an important breeding approach in crop improvement. Developing of high yielding hybrids along with other favorable traits is receiving considerable attention (Karim *et al.,* 2018).

The combining ability and gene effects of yield and its components under non-stress and water stress conditions were studied by several researchers. Basbag *et al.* (2007) suggested that combining ability analysis is an important tool for selection of desirable parents together with the information regarding nature and magnitude of gene action controlling quantitative traits.

Coulibaly (2013) reported significant differences of general combining ability (GCA) effects of parents and that of specific combining ability (SCA) effects of progenies for morphological and physiological traits and that both additive and non-additive gene effects controlled most traits, but non-additive genetic effect was more prevalent in groundnut. Swe and Branch (1986) showed that both additive and dominance variances were important for biomass, harvest index and pod yield in groundnut and other traits under drought stress conditions and that the ratios of GCA to SCA variances were less than unity for all studied traits which showed the predominant role of

non-additive gene action in the inheritance (Isleib *et al.*, 1980). Bansal *et al.* (1991) also reported that both additive and non-additive gene actions were responsible for the control of traits evaluated but the effects of non-additive genetic actions were preponderant in respect of the genetic control of pod yield and yield component traits.

Atif *et al.* (2012) reported that both GCA and SCA variances were highly significant for most of the traits studied in groundnut, indicating the importance of additive as well as non-additive types of gene action in controlling the traits. Moreover, variances due to SCA were higher in magnitude than GCA for yield and yield components except SCMR at 80 DAS. GCA to SCA ratios were less than one for all the traits measured indicating preponderance of additive over non-additive gene action. Betran *et al.* (2003) reported that under drought, additive effects were more important and the importance of additive effects increased with intensity of drought suggesting the need for drought tolerance in both parental lines to achieve acceptable hybrid performance under severe drought.

2.10 Correlation of Traits under Drought Conditions

Yield in groundnut is the net result of several genetic factors and their individual or combined interplay with environmental factors. Therefore, character association among themselves or with grain yield is important. It provides information such that selection for one trait will result in progress for all positively correlated characters. When there is positive association of major yield characters, simultaneous selection would be very effective for variety development (Nemati *et al.*, 2009).

According to a study by Philipo *et al*. (2016), under non-stress condition, a moderate positive significant relationship (r =0.2, P≤0.05) was observed between SCMR at 60 DAS and pod yield/plant, suggesting that the value of SCMR at 60 DAS gives little information for predicting pod yield in groundnut under non-stress. Under water-stress, SCMR at 60 DAS had moderate positive and highly significant relationship (r =0.38, P≤0.01) with pod yield (g/plant). This means that understanding the values of SCMR at 60DAS in groundnuts genotypes reveals significant information on pod yield/plant under water-stress condition.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The research was conducted at the Research Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Samaru-Zaria (11°11'N, 07°38' E and 686 m above sea level) in the Northern Guinea savannah ecological zone of Nigeria (A.B.U., 2018) The second site was the screen house of Department of Plant Science (11°11'N, 07°38' E and 686 m above sea level) in the Northern Guinea savannah ecological zone of Nigeria ecological zone of Nigeria (Olanuga, 1979). The research was carried out during the 2018/2019 dry and raining seasons.

3.2 EXPERIMENT I

3.2.1 Screening for drought

A total of one hundred and seven (107) groundnut genotypes were selected from IAR Groundnut Breeding unit in Department of Plant Science. The genotypes were screened for drought tolerance under both non-stress and water-stress conditions. The first treatment was non-stress (NS), in which the genotypes were irrigated until maturity whenever soil moisture was depleted to 30% field capacity. The second treatment was drought stress (DS), in which the genotypes were irrigated regularly up to 30 days after sowing and watered at 2 weeks interval until maturity.

3.2.2 Experimental Design

A split – plot design arranged in a randomized complete block design (RCBD) with two replications was used for both water stress and non- water stress. Two soil moisture levels (non-stress and water-stress) were assigned in main plots, and groundnut genotypes were laid out in

sub-plots. Each genotype was planted in one row of 5 m plot with a spacing 0.75m between rows and 0.25m within the row. The total experimental field was 1199 m^2.

3.2.3 Crop Management

Across both treatments, land was prepared for sowing by harrowing to fine filth followed by ridging. Three seeds were planted per hill, and the seedlings were thinned to two plants per hill at 14 days after sowing (DAS). Phosphorus (P_2O_5) fertilizer in form of SSP was applied at the rate of 18 kg ha^{-1} one week after seedling emergence. Manual weeding was carried out when necessary.

3.3 Data Collection

Data was collected on the following parameters;

Days to 50% flowering: This was calculated by counting from date of sowing till when half of the plants in each plot had flowered.

Number of pods per plant: The number of pods per plant was counted from five randomly selected plants in each plot

Number of seeds per pod: The number of seeds per pod was counted from five randomly selected plants in each plot.

Seed weight per plant: The pods from each plant were threshed and the seeds obtained weighed using a digital balance device and recorded in grams.

Hundred- Seed weight: One hundred (100) sound kernels were counted from the threshed pods weighed and measured in gram.

SPAD Chlorophyll Meter Reading (SCMR) mmol/cm^2: This was recorded twice on each leaflet of the tetra foliate leaf along the mid-rib at 40, 60 and 80 days after sowing (DAS) using

SPAD chlorophyll meter. Five plants from each sub-plot were randomly sampled and the third fully-expanded leaves from the top of the main stems were used for SCMR assessment between 08:30 am and 10:00 am. This record was taken during this interval because there is high stomatal conductance to allow photosynthesis, while evaporation was low particularly in stressed groundnut genotypes (Smartt, 1994). SCMR was recorded by a Minolta SPAD-502 meter (Tokyo, Japan) on the four leaflets of each individual leaf as described by (Nageswara Rao *et al*., 2001).

Leaf Area Index: This was measured using an ACCUPAR LP-80 useful for determining light interception. A ceptometer; is an AccuPAR LP-80 which is a lightweight, portable, linear Photosynthetically Active Radiation (PAR) sensor, used for measuring canopy PAR interception and calculating Leaf Area Index (LAI) within the plant or forrest canopy. It uses radiation measurements and other parameters to accurately calculate LAI non-destructively in real time, in the field (Cohen *et al*., 2000).

Harvest Index = Harvest index was calculated per plot based on the following relationship (Fageria *et al*., 2011):

$$\text{Harvest Index (\%)} = \frac{\text{Pod yield (g)}}{\text{Pod yield (g)+ Haulm yield(g)}} \times 100$$

3.4 Statistical Analysis

Analysis of variance was performed for each parameter following a split-plot design using Statistical Analysis System (SAS) package (SAS, 2002). Where there was significant difference between treatment means ($P \leq 0.05$) Fisher's protected Least Significant difference (LSD) test was used for comparison (Gomez and Gomez, 1984). Homogeneity of variance was tested for all

characters using Bartlett test (Snedecor and Cochran, 1989). The linear model used for split plot design is as follows:

$$Y_{ijk} = \mu + \alpha_i + \gamma k + (\alpha\gamma)_{ik} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Table 3.1: Form of ANOVA for split plot design for one condition for random model

Source of variation	DF	MS	EMS
Replication	$(r-1)$	MS_R	
Water Condition (C)	$(c-1)$	MS_W	$\sigma^2_{e_a} + r\sigma^2_{gc} + rg\sigma^2_c$
Error a	$(r-1)(c-1)$	MS_{EW}	$\sigma^2_{e_a}$
Genotype (G)	$(g-1)$	MS_G	$\sigma^2_{e_b} + \sigma^2_{gc} + rc\sigma^2_g$
(G x C)	$(g-1)(c-1)$	MS_{WxG}	$\sigma^2_b + r\sigma^2_{gc}$
Error b	$c(r-1)(g-1)$	MS_{EG}	σ^2_b
Total	$cgr-1$		

Where; r = number of replication, c = number of water condition, g= number of genotypes;

σ^2_b = Variance due to environmental error (b)

σ^2_{gc} = Variance due to genotype x water condition effect

σ^2_g = Variance due to genotypic effect

σ^2_c = Variance due to water condition effect.

3.5 Principal Component Analysis (PCA)

The Principal component analysis was performed using XLSTAT (2007) programming package to determine which traits of the plants variation to arise among the groundnut genotypes and contributions that the various traits made to the total variability in the genotypes.

The PCA ranking was used to determine the drought tolerance and susceptible status of the genotypes. The PCA ranking values of each genotype as described by (Zhu *et al*., 2014) was computed as follows:

Ranking value = [(% Contribution of PC1 + PC1) + (% Contribution of PC2 + PC2) +(% Contribution of PC3 + PC3)]

3.6 Cluster Analysis

Dendogram for the groundnut genotypes was also generated from the XLSTAT (2007) package and cluster analysis was used in grouping the genotypes as described by Hair *et al*., (1995).

3.7 EXPERIMENT II

3.7.1 Population development

Genetic materials for the population development comprised of four drought susceptible groundnut genotypes (ICGV-IS-07813, RS006F_4B_1-50, ICGV-IS-07841 and ICG 12989) and three drought tolerant genotypes (SAMNUT 23, ICG 5195 and ICG 3312) which were randomly selected from the screening experiment. The parents were crossed in a half diallel mating design as described by Dabholkar (1992). The F_1 seeds harvested were multiplied to obtain enough F_2 seeds for evaluation as suggested by Hallauer *et al.* (1992) for self-pollinating crops.

3.7.2 Hybridization activities

During hybridization, care was taken to avoid pollen contamination among the selected groundnut genotypes for the population development. The emasculation exercise was carried out between 4.00pm – 6.30pm depending on the prevailing environment (Nigram *et al*., 2009).

Pollination was done in the morning (6.00am- 7.30am). In both activities, different colored nylon threads were used to mark the emasculated and pollinated buds. One nylon thread denoted that the bud had been successfully emasculated. The hybridization activities lasted for three weeks. Harvesting of the F_2 seeds started 60 days after the last pollination. All the pods (mature and immature) originating from the nodes that had pollinated nylon thread on their upper internodes were picked as hybrid pods. All selfed pods were discarded. The hybrid pods were dried for 15 days at ambient air temperatures in well labeled muslin bags to avoid direct exposure to the sun. The dried pods were manually shelled with caution.

3.7.3 Evaluation

The seven (7) parents, 21 F_1s along with two checks were evaluated under non-stress and water-stress conditions in the screen house of the Department of Plant Science, A.B.U, Zaria. The experiment was laid out in a randomized complete block design with two replications. Two pots each were allocated for the F_1 progenies and the parents. A total of four healthy seeds from each genotype were sown at 2 cm depth in dark loamy soil in each pot and two healthy and vigorous seedlings in each pot were retained after seedling emergence. Evaluation of 7 parents, 21 F_1s along with two checks were as described for screening experiment.

3.7.4 Data collection

The same data were collected as for the screening experiment:

3.7.5 Data analyses

The data collected were subjected to analysis of variance (ANOVA) using General Linear Model procedure of Statistical Analysis System (SAS) package (SAS, 2002). Fisher's protected Least Significant difference (LSD) test were used for mean comparison (Gomez and Gomez, 1984).

Linear model that was used for RCBD analysis: $y_{ijk} = \mu + r_i + g_j + \varepsilon_{ijk}$

Where: y_{ijk} = Observed effect for i^{th} replication j^{th} genotype and k^{th} block.

μ = grand mean of the experiment.

r_i = effect due to i^{th} replication.

g_j = effect due to j^{th} genotype.

ε_{ijk} = effects due to the residual or random error of the experiment.

Table 3.2: Form of ANOVA and expected mean square (EMS) of RCBD for one condition

Source of variation	Df	MS	EMS
Replication	$(r-1)$		
Genotype	$(g-1)$	MS_2	$\sigma_e^2 + r\sigma_g^2$
Error	$(r-1)(g-1)$	MS_1	σ_e^2

For the individual condition, variance components were computed from mean squares and expected mean squares as follows: $MS_2 - MS_1 = \sigma_e^2 + r\sigma_g^2 - \sigma_e^2$, $MS_2 - MS_1 = r\sigma_g^2$,

$\sigma_g^2 = \frac{MS_2 - MS_1}{r}$, $\sigma_e^2 = \frac{MS_1}{r}$, $\sigma_p^2 = \frac{\sigma_g^2}{\sigma_e^2}$

MS_2 = mean squares due to genotypes σ_g^2 = genotypic variance MS_1 = error mean square σ_e^2 = error variance σ_p^2 = phenotypic variance g = number of genotypes r = number of replications

DF = Degree of freedom

Table 3.3: Form of ANOVA and expected mean square (EMS) of RCBD for two condition

Source of variation	DF	MS	EMS
Condition(C)	$(c-1)$		$\sigma_e^2 + r\sigma_{gl}^2 + rg\sigma_l^2$
Replication	$(r-1)$		
Genotype(G)	$(g-1)$	MS_g	$\sigma_e^2 + r\sigma_{gc}^2 + rc\sigma_g^2$
G x C	$(g-1)(c-1)$	MS_{gc}	$\sigma_e^2 + r\sigma_{gc}^2$
Error	$c(g-1)(r-1)$	MS_e	σ_e^2

For the combined analysis, variance components were computed from mean squares and expected mean squares as follows:

$$\sigma_g^2 = \frac{MS_g - MS_{gc}}{rc}, \quad \sigma_{gc}^2 = \frac{MS_{gc} - MS_e}{r}, \quad \sigma_p^2 = \sigma_g^2 + \frac{\sigma_{gc}^2}{c} + \frac{\sigma_e^2}{rc}$$

MS_{gc} = mean squares due genotype x condition σ_e^2 = error variance MS_g = mean squares due to genotypes, σ_g^2 = genotypic variance σ_{gc}^2 = genotype x condition variance MS_e = error mean square r = number of replications g = number of genotypes c = number of conditions, σ_p^2 = phenotypic variance

3.8 Estimation of Genetic Variability Parameters and Heritability

Phenotypic and genotypic coefficients of variation as well as broad sense heritability were computed using the formulae given by Singh and Chaudhary (1985).

(a) Phenotypic coefficient of variation (PCV %) = $\frac{\sqrt{\sigma_p^2}}{\overline{X}} \times 100$

(b) Genotypic coefficient of variation (GCV %) = $\frac{\sqrt{\sigma_g^2}}{\overline{X}} \times 100$

Where; $\overline{X}$ = mean of the character

GCV and PCV values were classified as low (<10%), moderate (10-20%) and high (>20%) as indicated by Siva-Subramanian and Menon (1973).

(c) Broad sense heritability $h_b = \dfrac{\sigma_g^2}{\sigma_g^2 + \dfrac{\sigma_{gc}^2}{c} + \dfrac{\sigma_e^2}{rc}}$

3.9 Diallel Analysis of Combining Ability and Gene Action

Mean squares were portioned into difference due to crosses and parents. The general combining ability (GCA) and Specific Combining Ability (SCA) among the crosses were estimated using a general linear model (GLM) procedure of SAS (SAS Institute, 2004).

The linear model for diallel mating design for Model II, Method II

The model for the analysis of variance is

$X_{ijk} = \mu + r_k + g_i + g_j + s_{ij} + p_{ijk}$

Where, $\mu =$ mean, $r_k =$ replication effect, g_i and g_j are GCA effects.

s_{ij} is the SCA effect and p_{ijk} is the experimental error for the X_{ijk} observation.

Table 3.4: Form of ANOVA for diallel mating design Model II, Method II for one condition

Source of variation	DF	MS	EMS
GCA	$n-1$	M_{GCA}	$\sigma_e^2 + \sigma_s^2 + (n+2)\sigma_g^2$
SCA	$n(n-1)/2$	M_{SCA}	$\sigma_e^2 + \sigma_s^2$
Error	m	M_E	σ_e^2

Where: n = number of parents, m = df error from experimental design

M_E = Mean square Error

M_{SCA}= Mean square of SCA

M_{GCA}= Mean square of GCA

σ_e^2 = Error variance; $\sigma_e^2 = M_E$

σ_S^2 = SCA variance; $\sigma_S^2 = M_{SCA} - M_E$

σ_g^2 = GCA variance; $\sigma_g^2 = M_{GCA} - M_{SCA} = \sigma_e^2 + \sigma_s^2 + (n+2)\sigma_g^2 - \sigma_e^2 + \sigma_s^2$

$M_{GCA} - M_{SCA} = (n+2)\sigma_g^2$

$$\sigma_g^2 = \frac{1}{n+2}(M_{GCA} - M_{SCA})$$

The relative importance, measured by GCA to SCA ratio were calculated according to Baker (1978) as follows: $\frac{2MS_{GCA}}{2MS_{GCA} + MS_{SCA}}$;

Where: MS_{GCA} and MS_{SCA} where the mean squares for GCA and SCA respectively.

3.10 Estimation of Narrow sense Heritability

Narrow sense heritability was estimated with the formula suggested by Ruming (2004) as follows:

$$h^2 = \frac{2\sigma_{GCA}^2}{2\sigma_{GCA}^2 + \sigma_{SCA}^2 + \sigma_e^2}$$

The heritability percentage was categorized according to Robinson *et al*. (1949) as 0-30% (low), 30-60 % (moderate), 60% and above (high).

3.11 Correlation Estimates

Pearson correlation coefficient was employed to estimate the relationships between yield and its related traits using standard procedure suggested by Cohen *et al*. (2003). SAS software version 9.0 (2002) was used in executing the analysis.

$$r_{xy} = \frac{Cov(xy)}{\sqrt{\sigma_x^2 \times \sigma_y^2}}$$

Where: r_{xy} = correlation of x and y; $Cov(xy)$ = covariance of trait x and y

σ_y^2 = variance of y σ_x^2 = variance of x

CHAPTER FOUR

4.0 RESULTS

EXPERIMENT I

4.1 Analysis of Variance

Analysis of variance (ANOVA) for the morphological traits (days to 50% flowering and number of pods per plants) screened under non stress and water stress conditions at Samaru in Table 4.1. The mean squares for the genotypes showed highly significant ($P \leq 0.01$) difference for the two traits measured under both conditions, except for number of pods per plant under non-stress condition which showed a non-significant ($P > 0.05$) difference. The physiological traits (SPAD Chlorophyll Meter Reading (SCMR) at 40, 60 and 80 DAS and Leaf Area Index) screened under non- stress and water stress conditions at Samaru are presented in Table 4.3. The mean squares for genotypes showed highly significant ($P \leq 0.01$) difference for all the traits measured, except for SCMR 40DAS, SCMR 60 DAS and LAI in non-stress condition which showed no significant ($P > 0.05$) difference.

Analysis of variance for days to 50% flowering and number of pods per plant and some physiological traits (SCMR for 40, 60 and 80 DAS and Leaf Area Index) under combined analysis are presented in Table 4.2 and 4.4. The results of analysis of variance for genotype, as well as the interaction between water conditions and genotype were highly significant ($P \leq 0.01$) for both morphological and physiological traits Tables 4.2 and 4.4, respectively.

Table 4.1: ANOVA for morphological traits measured under non stress and water stress conditions at Samaru 2018

Source of Variation	DF	DFF		NPPT	
		NS	WS	NS	WS
Replication	1	<0.001**	48.57**	2.00	158.79**
Genotype	106	45.43**	9.36**	28.70	79.49**
Error	106	1.75	<0.001	11.87	3.57

****:** highly significant difference at (P≤0.01) probability level, *DF*= Degree of freedom, DFF= Days to 50% flowering, NPPT= Number of pods per plant, NS= Non-Stress condition, WS= water-stress condition.

Table 4.2: ANOVA for morphological traits measured under combined analysis at Samaru 2018

Source of variation	DF	DFF	NPPT
Replication	1	93.99	98.23**
Water Condition(C)	1	171.15**	80.80**
Error a	1	90.43	10.56
Genotype (G)	106	590.39**	54.28**
G x C	106	586.85**	53.92**
Error b	213	56.71	7.98

****:** highly significant difference at (P≤0.01) probability level, *DF*= Degree of freedom, DFF= Days to 50% flowering, NPPT= Number of pods per plant

Table 4.3: ANOVA for physiological traits measured under non stress and water stress conditions at Samaru 2018

Source of Variation	DF	SCMR 40DAS		SCMR 60DAS		SCMR 80DAS		LAI	
		NS	WS	NS	WS	NS	WS	NS	WS
Replication	1	6.95	16.18**	25.43	17.17	2.75	17.17**	<0.001**	<0.001**
Genotype	106	54.59	120.20**	64.05	152.10**	88.56**	152.12**	<0.001	<0.001**
Error	106	64.72	0.77	80.12	1.34	57.03	1.34	0.02	<0.001

****:** highly significant difference at (P≤0.01) probability level, *DF*= Degree of freedom, NS= non stress condition, WS= water stress condition, SCMR= SPAD Chlorophyll Meter Reading, DAS=Days after sowing and LAI= Leaf Area Index.

Table 4.4: ANOVA for physiological traits measured under combined analysis at Samaru 2018

Source of variation	DF	SCMR 40DAS	SCMR 60DAS	SCMR 80DAS	LAI
Replication	1	0.96	62.42	16.84	0
Water Condition(C)	1	709.83**	1295.62**	262.43**	0.01**
Error *a*	1	45.36	57.68	25.89	<0.001
Genotype (G)	106	83.77**	75.69**	114.69**	<0.001**
G x C	106	91.02**	98.32**	125.99**	<0.001**
Error *b*	213	32.69	40.25	29.06	<0.001

****:** highly significant difference at (P≤0.01) probability level, *DF*= Degree of freedom, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

4.2 Mean Performance of 107 Groundnut Genotypes Screened under Non-stress and Water-stress Conditions at Samaru 2018 using Rank Summation Index

The result of top 15 best performing and 10 least performing genotypes based on number of pods per plant, SCMR at 40DAS, 60DAS and LAI rated using rank summation index under non stress and water stress conditions are presented in Tables 4.5 and 4.6. Under non stress, the three best performing genotypes: ICG 12189, ICG-SM-07541 and ICG 5236 had number of pods per plant greater than the mean performance of all the genotypes by 42%, 46% and 72% respectively. On the other hand, among the 10 least performing genotypes, eight genotypes had number of pods lower than the overall mean while genotypes ICGV-IS-07855 and RS006F_4B_1-(B) had number of pods greater than the overall mean. For SCMR at 40 DAS and 60 DAS, all the top performing genotypes were higher than the overall mean by 7%-30% and 10%-38% respectively while all the least performing genotypes were lower than the overall mean (40.99 and 39.35) respectively. For LAI, four (4) genotypes ICGV-IS-13990, ICG 12189, RS066F_3B_1-57(B) and ICG 6813 ranked below the overall mean 0.08 with a value of 0.07 (Table 4.5).

Under water stress condition, 10 of the top performing genotypes had number of pods per plant greater than the overall mean. Seven out of the 15 best performing genotypes had number of pods per plant greater than the mean performance of all the genotypes by 33%-87%. For SCMR at 40 DAS only 3 ICGV-IS-07841, ICGV-IS-13112 and ICG-IS-07919 of the top performing genotypes recorded values lower than the overall mean 43.56. The three best performing genotypes are ICGV-IS-07843, ICG 9777 and ICG 1519 which had SCMR at 40 DAS greater than the mean performance of all genotypes by 16-19%. While among the 10 least performing genotypes, eight (8) of the genotypes recorded lower values than the mean except for genotypes ICGV-IS-07828 and ICGV-IS-13007 which recorded values greater than the overall mean.

Table 4.5: Rank summation index of some groundnut genotypes screened under non-stress condition at Samaru 2018

Genotypes	NPPT	SCMR 40 DAS (nmol/m^2)	SCMR 60 DAS (nmol/m^2)	LAI	Ranking
Top 15 genotypes					
ICGV-IS-13990	5(16)	53.11(2)	47.12(9)	0.07(3)	1
ICG 12189	13(8)	47.14(11)	46.35(12)	0.07(3)	2
ICGV-IS-07803	8(13)	50.26(5)	45.8(15)	0.09(1)	2
ICG 231	7(14)	46.18(18)	51.52(2)	0.08(2)	3
ICGV-IS-07813	8(13)	48.25(8)	46.2(13)	0.08(2)	3
ICG 10346	7(14)	45.34(20)	54.39(1)	0.08(2)	4
ICGX-IS-13011	10(11)	46.23(17)	47.67(8)	0.09(1)	4
ICGV-IS-03323	1(20)	51.55(4)	46(14)	0.09(1)	5
ICGV-IS-07815	8(13)	49.29(7)	44.3(18)	0.08(2)	6
RS066F3B1-57(B)	4(17)	44.68(23)	48.36(4)	0.07(3)	7
ICGV 07805	9(12)	46.54(15)	43.7(22)	0.09(1)	8
ICG 5236	25(3)	45.68(19)	43.13(28)	0.08(2)	9
ICGV-IS-13007	2(19)	46.85(13)	43.63(24)	0.09(1)	10
ICG-SM-07541	19(5)	43.78(34)	43.8(20)	0.08(2)	11
ICG 6813	12(9)	44.24(29)	43.67(23)	0.07(3)	12
Least 10 genotypes					
ICG 9905	4(17)	31.2(105)	36.3(72)	0.08(2)	70
ICGV-IS-07887	2(19)	37.99(72)	26.93(103)	0.08(2)	71
RS006F4B1-49	2(19)	34.15(97)	35.25(80)	0.08(2)	72
RS006F3B1-22®	0(21)	35.56(87)	33.37(88)	0.06(4)	73
ICGV-IS-07883	3(18)	35.22(89)	30.8(97)	0.08(2)	74
ICGV-IS-07809	1(20)	34.34(96)	32(93)	0.09(1)	75
RS006F4B1-31	1(20)	34.47(95)	29.99(99)	0.08(2)	76
ICGV-IS-07855	9(12)	31.78(103)	27.4(100)	0.08(2)	77
ICGX-5M-00018/5/4/P2	1(20)	33.03(101)	30.88(96)	0.09(1)	78
RS006F4B1-4(B)	8(13)	30.03(106)	27.31(101)	0.05(5)	79
Mean	**7.00**	**40.99**	**39.35**	**0.08**	
CV (%)	**16.5**	**19.63**	**22.75**	**15.90**	

NPPT= Number of pods per plant, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing, ranking values in bracket () and mean performance value outside the bracket

Table 4.6: Mean performance using rank summation index for some morphological and physiological traits in groundnut screened under water-stress condition at Samaru 2018

GENOTYPES	NPPT	SCMR 40DAS	SCMR 60DAS	LAI	Ranking
Top 15 genotypes					
ICGV-IS-07902	3(8)	51.41(13)	46.58(34)	0.07(3)	1
ICGX-5M-00017/5/P5/P2	4(7)	49.44(23)	46.67(33)	0.08(2)	2
ICGV-IS-13978	23(1)	51.01(15)	36.79(76)	0.06(4)	3
ICGV-IS-13112	2(9)	33.25(76)	41.83(62)	0.07(3)	4
ICGV-IS-07843	1(10)	52.3(9)	49.35(16)	0.09(1)	5
ICG 9777	3(8)	52.5(8)	51.13(9)	0.05(5)	6
ICGV-IS-07815	5(6)	44.66(47)	47.18(28)	0.05(5)	7
ICG 1519	3(8)	53.5(5)	48.66(19)	0.07(3)	8
ICG-IS-07919	4(7)	39.7(67)	48.46(21)	0.07(3)	8
ICGV-IS-07887	2(9)	45.16(42)	43.71(50)	0.06(4)	9
ICGV-IS-07841	7(4)	24.81(88)	39.26(68)	0.08(2)	9
ICGV-IS-078513	4(7)	46.35(37)	44.01(47)	0.06(4)	10
ICG 9905	2(9)	50.92(16)	50.24(12)	0.09(1)	11
ICG 6813	2(9)	49.72(22)	50.44(11)	0.09(1)	12
SAMNUT 25	4(7)	50.52(17)	49.65(15)	0.05(5)	13
Least 10 genotypes					
ICG 5195	1(10)	41.49(60)	27.89(89)	0.08(2)	74
ICGV-IS-07828	7(4)	49.13(25)	30.56(85)	0.07(3)	75
ICGV-IS-13007	2(9)	53.1(6)	55.48(1)	0.06(4)	75
RS066F3B1-57(B)	0(11)	36.13(73)	33.63(82)	0.09(1)	76
ICGX-IS-13011	1(10)	32.55(78)	36.4(79)	0.08(2)	77
ICG-SM-07541	6(5)	31.46(79)	43.52(51)	0.08(2)	78
ICG 10346	4(7)	28.88(82)	26.31(93)	0.08(2)	79
RS006F4B-534	0(11)	27.59(85)	28.29(88)	0.06(4)	80
ICGV-IS-13938	1(10)	39.2(70)	44.31(45)	0.06(4)	81
RS006F4B1-45(B)	2(9)	41.09(61)	44.01(47)	0.07(3)	82
Mean	**3.00**	**43.56**	**42.83**	**0.07**	
CV (%)	**18.90**	**2.02**	**2.01**	**2.02**	

NPPT= Number of pods per plant, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing, ranking values in bracket () and mean performance value outside the bracket

For SCMR at 60 DAS, twelve of the top performing genotypes had SCMR at 60 DAS greater than the mean performance of all the genotypes by 3%-16% except for genotypes ICGV-IS-13978, ICGV-IS-13112 and ICGV-IS-07841which recorded values lower than the overall mean on the other hand six of the least performing genotypes had lower SCMR values than the overall mean with the exception of genotypes ICGV-IS-13007, ICG-SM-07541, ICGV-IS-13938 and RS006F_4B_1-45(B) which had SCMR values greater than the overall mean . For LAI, nine (9) genotypes ranked above the overall mean (Table 4.6).

4.3 Principal Component Analysis

The results from principal component analysis performed on the correlation matrix for the morphological and physiological traits measured under non-stress and water-stress are presented in Table 4.7. The total variance of the first three principal component (PC) axes accounted for 70.04% and 70.81% for the morphological and physiological traits of the genetic variation among the groundnut genotypes under non stress and water stress conditions, respectively. PC1 explained 35.92% and 34.73% and PC2 17.36% and 20.33% while PC3 accounted for 16.76% and 15.75% of the total variation under non-stress and water-stress conditions, respectively. For morphological traits, under non stress condition, number of pods per had the high score for PC1, while days to 50% flowering recorded the highest score for PC2 (0.10) and PC3 (0.11). For physiological traits, SCMR 40, 60 and 80 DAS had higher score under PC1, while SCMR 80 DAS and leaf area index had higher scores in PC2 and SCMR 80 DAS and LAI had higher score in PC3. Under water stress condition, for morphological traits, number of pods per plant was

Table 4.7: Principal component analysis based on correlation co-efficient matrix of morphological and physiological traits screened under non stress and water stress condition at Samaru 2018

Traits	PC1		PC2		PC3	
	NS	WS	NS	WS	NS	WS
DFF	0.24	0.22	0.10	0.52	0.11	0.78
NPPT	0.48	0.46	-0.25	-0.60	-0.22	-0.02
SCMR 40 DAS	0.82	0.77	0.01	0.08	-0.06	0.03
SCMR 60 DAS	0.77	0.74	0.01	0.18	0.01	-0.32
SCMR 80 DAS	0.81	0.83	0.17	0.05	0.11	-0.01
LAI	-0.02	-0.11	0.94	0.75	0.19	-0.48
Eigen value (EV)	2.16	2.08	1.04	1.22	1.01	0.95
Proportion of variation (%)	35.92	34.73	17.36	20.33	16.76	15.75
Cumulative Variation (%)	35.92	34.73	53.28	55.06	70.04	70.81

DFF= Days to 50% flowering, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing, LAI= Leaf Area Index, NPPT= Number of pods per plant.

Table 4.8: Principal component analysis ranking of 107 groundnut genotypes screened under non stress condition at Samaru 2018

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
Top 15 Best Genotypes					
SAMNUT 26	1.45	1.69	0	17.98	1
ICGV-IS-07812	3.32	3.18	3.41	15.13	2
ICG 3312	0	0.21	1.28	10.18	3
RS006F4B1-45(B)	3.73	0.91	0	9.92	4
ICGV-IS-07813	0.54	0.74	5.49	9.68	5
ICGV-IS-07904	1.54	1.98	0.52	9.62	6
ICG 297	0.68	1.32	0.22	8.68	7
ICGV-IS-07828	0.95	1.97	0.12	8.25	8
ICGX 11003	1.15	0.17	0.08	8.22	9
ICGV-IS-07842	2.36	0.09	3.15	8.03	10
ICGX-5M-00018/5/4/P2	0.79	0.01	1.32	7.71	11
RS006F4B1-4(B)	1.23	0.96	1.68	7.56	12
ICGV-IS-07902	0.45	0.22	0.28	7.49	13
ICGV-IS-13878	1.71	1.4	0.02	7.48	14
ICG 3584	0.08	0.02	1.2	7.06	15
Least 15 Genotypes					
ICG 6813	1.49	0.4	0.22	1.43	93
RS006F4B1-22	1.65	0.54	0.52	1.41	94
ICGV-IS-07853	3.06	3.31	1.11	1.4	95
SAMNUT 25	0.22	0	0.99	1.36	96
ICGV-IS-07891	2.05	0.1	0.14	1.3	97
ICGV-IS-13050	2.39	0.21	0.32	1.2	98
ICGV-IS-07883	0.09	0.83	0.09	1.01	99
RS066F3B1-57(B)	0.56	0	1.15	1.01	100
ICG-SM-07539	0.15	0.18	0.42	0.95	101
ICGV-IS-13989	2.01	1.11	2.05	0.78	102
ICGV-IS-07895	3.83	0.15	1.08	0.77	103
ICGV-IS-13982	0.06	0.09	1.84	0.75	104
ICG 1519	0.59	0.85	0.07	0.66	105
ICG 3421	0.18	0.04	0.79	0.58	106
ICGV-IS-13112	0.78	0.02	0.8	0.4	107

Table 4.9: Principal component analysis ranking of 107 groundnut genotypes screened under water stress condition at Samaru 2018

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
Top 15 Best Genotypes					
ICGV-IS-13115	5.91	20.61	1.11	27.64	1
RS006F4B1-45(R)	14.31	4.78	0.00	19.10	2
ICGV-IS-07853	8.97	8.78	0.41	18.16	3
ICGV-IS-13989	12.17	0.18	5.46	17.81	4
RS006F4B-534	10.37	0.12	0.2	10.69	5
ICG 3312	0.02	10.21	0.1	10.32	6
ICGV-IS-13978	1.95	7.16	1.13	10.24	7
ICG 10346	7.03	0.08	1.77	8.88	8
ICG 5195	3.77	0.82	3.98	8.57	9
RS006F4B1-17	0.16	0.81	6.45	7.42	10
ICG 15236	4.48	1.69	1.14	7.32	11
ICGV-IS-13990	5.19	0.01	2.02	7.22	12
ICGV-91283	6.30	0.18	0.17	6.65	13
ICGV-IS-03323	5.42	0.08	0.37	5.86	14
ICGV-IS-07843	4.33	1.05	0.01	5.39	15
Least 15 Genotypes					
ICG 4911	0.58	0.20	0.42	1.20	93
ICGV-IS-07803	0.32	0.82	0.03	1.18	94
ICGV-IS-07845	0.08	0.05	1.03	1.16	95
ICGV-IS-07815	0.96	0.00	0.00	0.97	96
ICGX-5M-00017/5/P5/P2	0.27	0.62	0.01	0.90	97
ICG 12989	0.00	0.59	0.26	0.85	98
ICGV-IS-07841	0.46	0.25	0.13	0.84	99
RS006F4B1-50	0.00	0.12	0.57	0.69	100
RS006F4B1-53(B)	0.07	0.09	0.47	0.63	101
ICGV-IS-07813	0.23	0.06	0.12	0.41	102
ICGV-IS-07904	0.04	0.27	0.08	0.39	103
RS006F4B1-45(B)	0.10	0.24	0.05	0.38	104
ICGV-IS-07809	0.03	0.09	0.19	0.30	105
12CS-010	0.02	0.09	0.15	0.27	106
ICGV-IS-07828	0.17	0.01	0.00	0.18	107

with high score under PC1, days to 50% flowering were with high scores in PC2, while days to 50% flowering. For physiological traits, SCMR 40, 60 and 80 DAS were with high score under PC1, leaf area index and SCMR 60DAS were with high scores in PC2 while SCMR 40DAS and LAI were with high score in PC3.

The principal component scores of the 107 groundnut genotypes based on the morphological and physiological traits measured under non-stress and water-stress is presented in Tables 4.8 and 4.9, respectively. The results showed the contributions of each genotype to the principal components. The best genotypes with higher values in percentage were considered as contributing most of the effects of each component.

The results under non-stress condition indicated that SAMNUT 14 (13.29), ICG 12189 (8.99) and RS006F_4B_1-49 (8.09) had the highest contributions in PC1, while ICGV-IS-07803 (6.35), ICG 1274 (5.62) and ICG-SM-07541 (4.6) had the highest impact on the traits in PC2 (See appendix). On PC3, ICGV-IS-07803 (7.31), ICGV-IS-07813 (5.49) and ICGV-IS-07947 (4.98) had highest character contribution. Under water stress condition, the first three principal components shows that in principal component 1, RS006F_4B_1-45(R) (14.31), recorded the highest score closely followed for ICGV-IS-13989 (12.17) and RS006F_4B-534 (10.37). PC 2 has ICGV-IS-13115 (20.61), with the highest score followed for ICG 3312 (10.21), ICGV-IS-07853(8.78) while RS006F_4B_1-17 (6.45), ICGV-IS-13989 (5.46) and ICG 5195(3.98) had the highest score in PC3. Under non-stress condition, genotypes with the highest pooled ranking were SAMNUT 26 (17.98), ICGV-IS-07812(15.13) and ICG 3312 (10.18), while the least were ICGV-IS-13112(0.4), ICG 3421(0.58) and ICG 1519(0.66). Under water-stress condition, highest pooled ranking was recorded for ICGV-IS-13115 (27.64), followed for RS006F_4B_1-

45(R) (19.1) and ICGV-IS-07853 (18.16) while genotypes with the lowest pooled ranking were ICGV-IS-07828 (0.18), 12CS-010 (0.27) and ICGV-IS-07809 (0.3). Seventy (70) genotypes were found to be drought tolerant while thirty-seven (37) were found to be drought susceptible. Based on the PCA ranking, the following genotypes (ICGV-IS-13115, RS006F4B1-45(R), ICGV-IS-07853, ICGV-IS-13989 and RS006F4B-534) were more drought tolerant and genotypes (ICGV-IS-07828, 12CS-010, ICGV-IS-07809, $RS006F_4B_1$(B) and ICGV-IS-07904) were more relatively more sensitive to drought.

4.4 Clustering of Genotypes

The average linkage grouping method using the morphological and physiological variables identified for Principal Component Analysis (PCA) produced two major clusters and four clusters of the 107 groundnut genotypes screened under non-stress condition (Fig. 1). Cluster I was the largest, containing 35 genotypes (32.71%) followed for cluster II, which contained 20 genotypes (18.69%). Cluster IV has the smallest group containing 11 genotypes (10.28%). Genotypes with high degrees of yield adaptation under water stress were grouped in cluster I (Fig. 2) and those with low adaptation under water-stress were grouped in cluster IV. Genotypes 12CS-010 and ICGV-IS-07828 were grouped in cluster III. These genotypes showed the least yield adaptation under water-stress conditions. Genotypes ICVG-IS-07853 and ICGV-IS-13989 are genotypes that were not adapted under non-stress and highly adapted under water-stress conditions whereas genotypes ICGV-IS-07828, ICGV-IS-07813 and ICGV-IS-07904 were adapted under Non-stress and not adapted under water-stress.

Fig 1: Dendogram displaying genetic diversity among 107 groundnut genotypes screened under non-stress condition at Samaru 2018

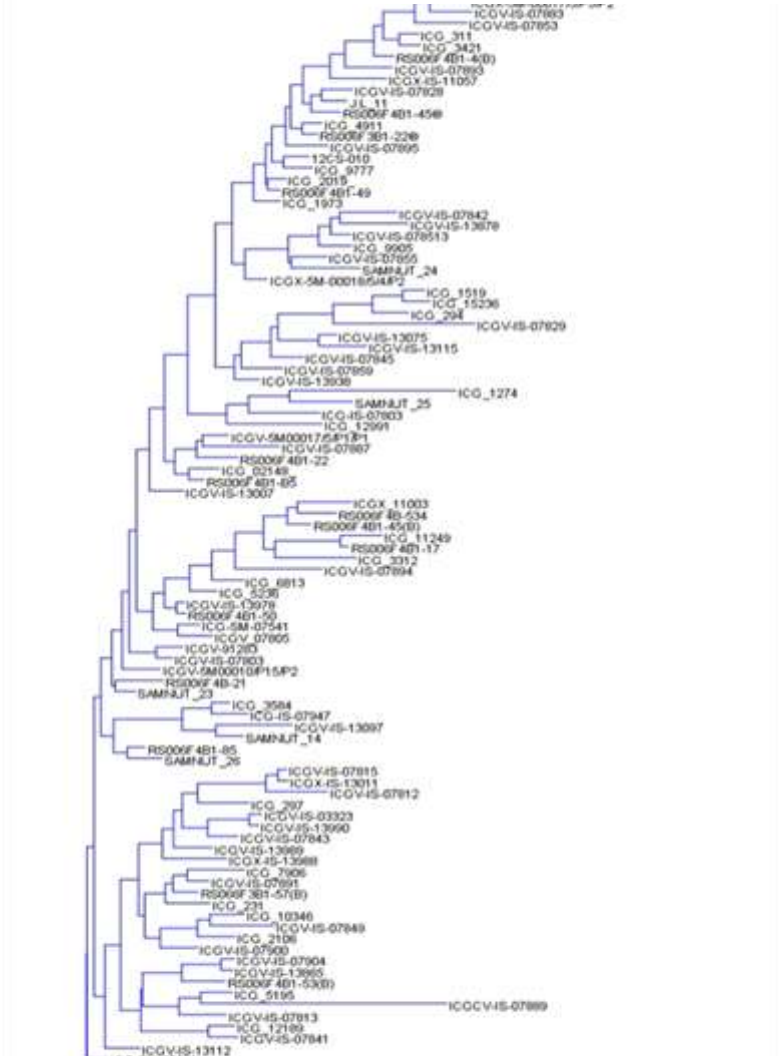
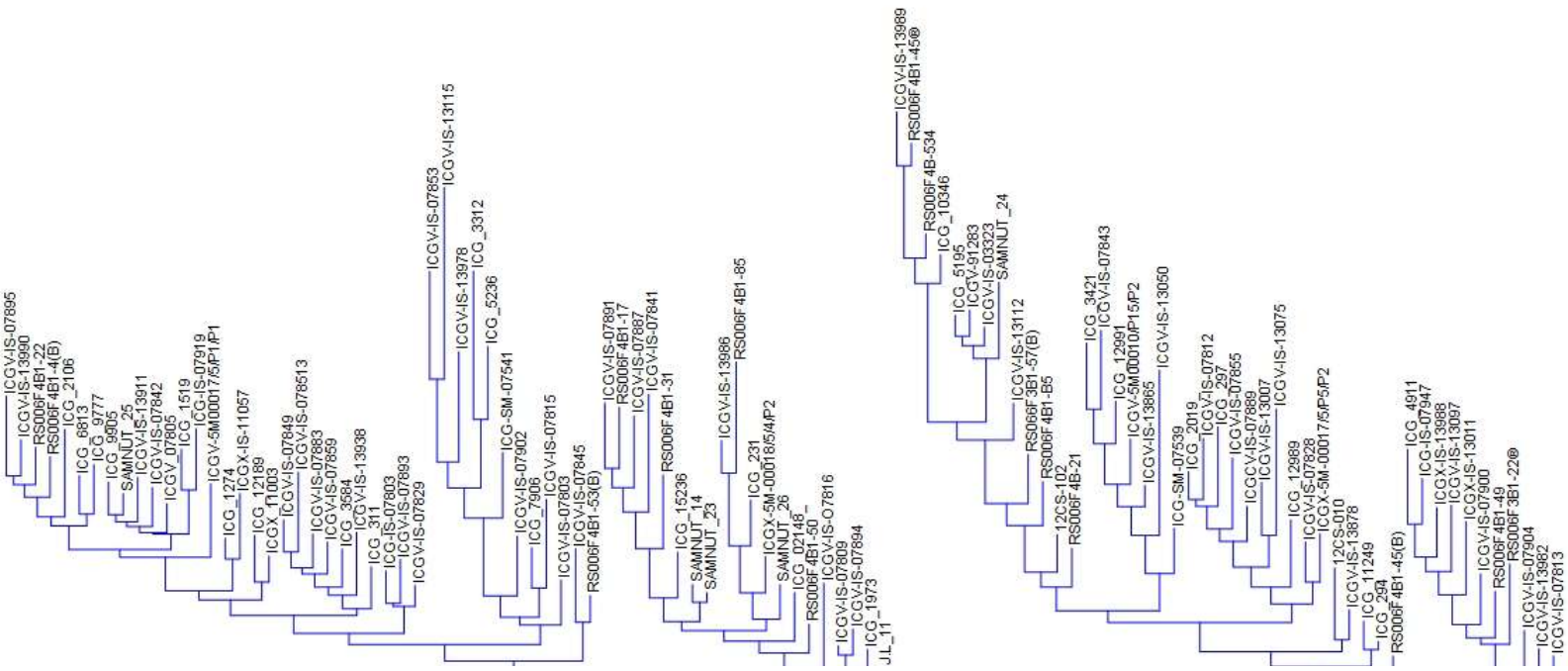


Fig 2: Dendogram displaying genetic diversity among 107 groundnut genotypes screened under water-stress condition at Samaru 2018.



EXPERIMENT II

4.5 Analysis of Variance

Analyses of variance for morphological and physiological traits of groundnut genotypes evaluated under non-stress and water stress conditions at Samaru are presented in Tables 4.10 and 4.12, respectively. For the morphological traits, the mean squares for the genotypes were highly significant (P≤0.01) for plant height, seed weight and pod yield under non-stress condition. The mean squares for genotype were also significant (P≤0.05) for 100 seed weight, seed weight and pod yield under water-stress condition, while 50% flowering under both conditions showed non-significant (P≥0.05) difference. For physiological traits, the mean squares for genotypes were significant (P≤0.05) for all the traits recorded under the non-stress and water-stress condition Table 4.12.

Combined analyses of variance for morphological and physiological traits of groundnut genotypes evaluated are presented in Table 4.11 and 4.13 below, respectively. For morphological traits, mean squares for condition were highly significant (P≤0.01) for all traits measured except hundred seed weight which showed significant (P≤0.05) difference. Mean squares of genotypes were highly significant (P≤0.01) for plant height and number of pods per plant, other traits measured showed significant (P≤0.05) except for days to 50% flowering which showed non-significant (P≥0.05) difference. Mean squares G x C were highly significant (P≤0.01) for plant height, all other traits showed significant (P≤0.05) difference except for days to 50% flowering which showed non-significant (P≥0.05) difference.

.

Table 4.10: ANOVA for morphological traits of groundnut genotypes evaluated under non-stress and water- stress conditions at Samaru 2019

Source of variation	DF	DFF		PHT (cm)		NPP		SWT(g)		PDY (g/plant)		100-SWT (g)	
		NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
Replication	1	5.40	15.00	29.94	19.85	8.82	20.42	0.56	0.05	11.88	0.05	15.14	83.30
Genotype	29	4.40	3.16	381.70**	198.21**	69.64*	37.05*	13.97**	5.68*	25.89**	8.17*	18.53*	107.38*
Error	29	4.02	3.586	145.19	163.62	41.02	25.24	8.73	3.59	10.37	9.48	166.05	77.2

***, **:** significant and highly significant difference at (P≤0.05) and (P≤0.01) probability level respectively, Df = Degree of Freedom, DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight and PDY= Pod yield

Table 4.11: ANOVA for morphological traits of groundnut genotypes evaluated under combined Analysis at Samaru 2019

Source of variation	DF	DFF	PHT (cm)	NPP	SWT	100-SWT	Pod Yield (g/plant)
Replication	1	1.20	33.06	28.03	0.48	24.34	6.77
Condition (C)	1	1.63	18.25**	74.03**	196.61**	101.12*	90.05**
Genotype (G)	29	5.24	45.65**	66.06**	8.68*	121.92*	17.07*
G x C	29	2.32	124.26**	40.64*	10.97*	16.20*	16.99*
Error	58	4.06	152.07	32.59	6.06	1398.22	9.85

***, **:** significant and highly significant difference at (P≤0.05) and (P≤0.01) probability level respectively, *DF* = Degree of Freedom, DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed weight

Table 4.12: ANOVA for physiological traits of groundnut genotypes evaluated under non-stress and water- stress conditions at Samaru 2019

Source of		SCMR 40 DAS		SCMR 60 DAS		SCMR 80DAS		HI	
variation	DF	NS	WS	NS	WS	NS	WS	NS	WS
Replication	1	0.19	13.48	6.39	0.11	0.19	20.92	193.42	3.44
Genotype	29	6.73*	42.12*	16.63*	7.08*	13.38	16.58	104.71*	74.03*
Error	29	3.49	19.66	8.05	10.09	9.95	16.49	51.8	61.25

***, **:** significant and highly significant difference at ($P \leq 0.05$) and ($P \leq 0.01$) probability level respectively, DF = Degree of Freedom, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index, LAI = Leaf Area Index

Table 4.13: ANOVA for physiological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Source of variation	DF	SCMR 40DAS	SCMR 60DAS	SCMR 80DAS	HI (%)
Replication	1	8.42	2.41	12.53	72.62
Condition (C)	1	428.24**	204.36**	3.61*	293.79**
Genotype (G)	29	32.03**	14.27*	17.28*	107.63**
G x C	29	16.81*	9.44	12.69	71.10
Error	58	11.46	8.99	13.14	57.67

***, **:** significant and highly significant difference at ($P \leq 0.05$) and ($P \leq 0.01$) probability level respectively, DF = Degree of Freedom, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index

Highly significant (P≤0.01) variations were observed for all physiological traits measured except SCMR at 80DAS which showed non-significant (P≥0.05) difference. Mean square for genotypes was highly significant (P≤0.01) for SCMR at 40 DAS and harvest index, all traits measured showed significant (P≤0.05) difference. Mean squares for Genotype x Condition (G x C) showed significant (P≤0.05) difference for SCMR at 40 DAS and non-significant (P>0.05) difference for other traits recorded. (Table 4.13)

4.6 Mean Performance for Non-Stress and Water-Stress Conditions at Samaru 2019.

The mean performance for the morphological traits measured among the seven (7) parents, twenty-one (21) crosses and two (2) checks evaluated under non-stress and water stress conditions is presented in Table 4.14 and that of the combined analysis in Table 4.15. The genotypes showed considerable variation for the different traits measured.

Days to 50% flowering has a mean of 39 days for both non-stress and water-stress conditions. Among the 7 parents, RS006F_4B_1-50 (P_2) and ICG 12989 (P_4) flowered earliest 38 days both conditions, respectively, while ICGV-IS-07841 (P_3) flowered late (42 days) under non-stress condition and SAMNUT 23(P_5) and ICG 3312(P_7) flowered late (41days) under water-stress conditions, respectively. RS006F_4B_1-50 x ICG 5195 flowered earliest 36 days under non-stress condition while ICGV-IS-07813 x ICG 3312, RS006F_4B_1-50 x SAMNUT 23 and RS006F_4B_1-50 x ICG 3312 and ICGV-IS-07841 x ICG 5195 flowered earliest (38 days) under water stress condition. RS006F_4B_1-50 x ICG 12989, ICGV-IS-07841 x ICG 12989 and SAMNUT 23 x ICG 5195 flowered late (42 days) under non-stress condition while ICGV-IS-07813 x ICGV-IS-07841 and SAMNUT 23 x ICG 3312 flowered late (42 days) under water stress condition.

Table 4.14: Mean performances for Morphological Traits of Diallel Parents and Progenies Evaluated under Non-Stress and Water-Stress Conditions at Samaru 2019

Genotypes	DFF		PHT (cm)		SWT (g)		100 SWT (g)		PDY (g/plant)		NPP	
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813 (P1)	39	39	61.3	48.8	3.7	1.3	23.4	28.8	7.1	2.7	16	9
RS006F4B1-50 (P2)	38	40	52.5	32.7	5.5	0.3	27.7	12.5	4.4	0.8	18	3
ICGV-IS-07841 (P3)	42	39	47.3	33.3	4.5	1.7	40.0	16.6	12.5	2.2	8	7
ICG 12989 (P4)	38	38	37.5	40.4	3.7	2.7	21.0	18.2	12.7	4.4	20	11
SAMNUT 23 (P5)	39	41	73.8	39.8	4.6	3.0	25.1	25.0	7.9	5.2	15	14
ICG 5195 (P6)	39	39	38.0	37.2	4.3	3.4	26.1	15.2	10.1	5.4	16	20
ICG 3312 (P7)	41	41	59.9	42.6	11.7	2.8	29.6	78.4	8.3	2.7	23	17
ICGV-IS-07813 x RS006F4B1-50	41	39	35.9	39.6	2.4	1.5	21.0	53.7	10.5	1.8	14	5
ICGV-IS-07813 x ICGV-IS-07841	39	42	36.3	79.7	7.7	1.4	50.9	19.6	3.1	3.9	13	8
ICGV-IS-07813 x ICG 12989	38	41	47.6	57.0	8.2	2.5	27.0	16.2	7.4	4.2	23	11
ICGV-IS-07813 x SAMNUT 23	40	39	34.0	52.8	2.0	2.8	24.2	24.7	10.3	2.9	11	12
ICGV-IS-07813 x ICG 5195	40	40	47.1	47.7	7.5	2.3	26.5	30.5	9.4	4.8	17	6
ICGV-IS-07813 x ICG 3312	40	38	35.7	60.3	5.3	2.7	20.8	13.3	10.2	5.3	23	14
RS006F4B1-50 x ICGV-IS-07841	40	40	64.4	41.8	1.2	1.5	15.2	18.2	8.6	3.4	8	10
RS006F4B1-50 x ICG 12989	42	41	101.6	56.8	3.3	10	22.3	22.0	3.6	2.0	16	6
RS006F4B1-50 x SAMNUT 23	38	38	53.5	33.1	5.3	3.5	26.8	15.4	8.6	4.8	15	13
RS006F4B1-50 x ICG 5195	36	39	56.3	40.9	5.1	2.1	17.3	23.0	17.6	6.6	26	12
RS006F4B1-50 x ICG 3312	38	38	64.4	39.9	5.2	20	24.2	51.7	7.3	3.7	15	6
ICGV-IS-07841 x ICG 12989	42	39	55.4	41.2	9.0	2.3	149.2	23.3	6.5	3.6	13	5
ICGV-IS-07841 x SAMNUT 23	41	40	46.8	40.5	5.2	4.1	42.3	120.3	6.4	6.1	11	11
ICGV-IS-07841 x ICG 5195	38	38	51.6	44.2	12.4	2.6	27.1	17.3	9.4	5.8	29	16
ICGV-IS-07841 x ICG 3312	39	40	59.0	55.7	4.8	3.8	38.3	21.3	5.5	5.4	11	13
ICG 12989 x SAMNUT 23	40	39	52.9	52.7	4.1	2.8	20.0	14.7	7.1	4.1	14	13
ICG 12989 x ICG 5195	39	41	48.9	47.0	5.8	2.5	134.9	20.0	7.7	3.9	20	10
ICG 12989 x 1CG 3312	40	39	49.9	44.8	3.5	1.9	18.5	16.8	3.6	3.7	14	7
SAMNUT 23 x ICG 5195	42	41	41.0	36.2	4.8	0.9	18.9	15.3	7.4	2.1	13	9
SAMNUT 23 x ICG 3312	39	42	44.6	36.7	2.2	2.1	21.1	17.7	8.8	4.0	11	8
ICG 5195 x ICG 3312	39	39	36.8	48.7	5.3	3.6	23.6	18.4	16.8	5.6	20	16
SAMNUT 24	39	39	56.3	39.6	6.4	4.3	21.5	23.1	10.8	7.6	26	15
SAMNUT 25	38	39	45.5	38.5	1.4	10.0	14.0	31.6	11.6	2.6	11	20
Mean	**39**	**39**	**51.2**	**45.0**	**5.2**	**2.62**	**33.3**	**27.4**	**8.27**	**4.2**	**16**	**10.8**
C.V (%)	**5.1**	**4.8**	**23.5**	**28.4**	**57.1**	**72.4**	**19.8**	**14.0**	**38.9**	**22.9**	**20.6**	**26.5**
L S D	**4.1**	**3.9**	**24.6**	**26.2**	**6.0**	**3.9**	**88.3**	**63.9**	**6.59**	**6.3**	**13.1**	**10.3**

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, NSP = Number of Seeds per plant, SWT = Seed Weight, PDY= Pod yield, CV = Coefficient of Variation

Table 4.15: Mean Performance for Morphological traits of Groundnut Genotypes Evaluated under Combined Analysis at Samaru 2019

Genotype	DFF	PHT(cm)	NPP	SWT (g)	100 SWT (g)	Pod Yield(g/plant)
ICGV-IS-07813 (P_1)	39	55.1	12	2.5	26.1	4.9
RS006F4B1-50 (P_2)	40	34.3	8	1.4	16.8	2.6
ICGV-IS-07841 (P_3)	39	34.8	10	4.7	33.8	7.3
ICG 12989 (P_4)	38	44	17	5.4	22.6	8.5
SAMNUT 23 (P_5)	40	36.9	12	2.5	24.6	4.5
ICG 5195 (P_6)	39	42.1	18	5.4	20.9	7.7
ICG 3312 (P_7)	41	39.2	20	4.0	49.6	6.8
ICGV-IS-07813 x RS006F_4B_1-50	38	46.1	12	3.5	40.7	6.6
ICGV-IS-07813 x ICGV-IS-07841	41	72	8	1.3	17.4	2.5
ICGV-IS-07813 x ICG 12989	42	79.3	13	2.9	19.3	5.6
ICGV-IS-07813 x SAMNUT 23	38	53.1	13	4.1	25.8	7.2
ICGV-IS-07813 x ICG 5195	38	52	16	3.7	23.9	6.1
ICGV-IS-07813 x ICG 3312	38	62.3	14	4.0	18.7	7.5
RS006F_4B_1-50 x ICGV-IS-07841	41	44.5	9	3.0	29.1	6.0
RS006F_4B_1-50 x ICG 12989	42	56.1	5	5.0	85.6	2.8
RS006F_4B_1-50 x SAMNUT 23	39	39.9	12	4.3	28.9	6.7
RS006F_4B_1-50 x ICG 5195	38	46.2	20	7.3	25.1	10.6
RS006F_4B_1-50 x ICG 3312	39	49.4	8	3.4	45	5.5
ICGV-IS-07841 x ICG 12989	39	39.3	16	3.0	22.1	5.0
ICGV-IS-07841 x SAMNUT 23	40	46.7	12	4.1	70.1	6.2
ICGV-IS-07841 x ICG 5195	38	46.5	18	4.2	76.1	7.6
ICGV-IS-07841 x ICG 3312	40	52.8	13	3.6	19.9	5.4
ICG 12989 x SAMNUT 23	39	63.2	14	3.7	19.9	5.6
ICG 12989 x ICG 5195	41	44	11	3.6	19.5	5.8
ICG 12989 x 1CG 3312	39	44.7	9	2.0	18.9	3.7
SAMNUT 23 x ICG 5195	40	37.1	12	2.6	20.7	4.7
SAMNUT 23 x ICG 3312	40.5	36.7	20	7.6	24	6.4
ICG 5195 x ICG 3312	40	54.3	20	7.6	24	11.2
SAMNUT 24	39	48	20	5.3	22.3	9.2
SAMNUT 25	39	42	15	5.7	22.8	7.2
Mean	**39**	**48.1**	**13.3**	**3.9**	**30.4**	**6.2**
C. V	**5.1**	**25.7**	**32.9**	**23.2**	**12.2**	**5.3**
LSD	**2.9**	**17.4**	**8.1**	**3.5**	**5.9**	**4.4**

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight

Plant height has an overall mean of 51.2 cm and 45.0 cm under non-stress and water-stress conditions, respectively. Under non-stress condition, plant height ranged from 38.0 cm for ICG 5195 (P_6) to 73.8cm for SAMNUT 23(P_5) among the parents while it ranged from 34.0 cm for ICGV-IS-0813 x SAMNUT 23 to 101.6 cm for RS006F_4B_1-50 x ICG 12989 among the progenies. Under water-stress condition, it ranged from 32.7 cm for RS006F_4B_1-50 (P_2) to 48.8 cm for ICGV-IS-07813 (P_1) among the parents and from 33.1 cm for RS006F_4B_1-50 x SAMNUT 23 to 79.7 cm for ICGV-IS-0813 x ICGV-IS-07841among the progenies.

Seed weight had an average of 5.2 g and 2.6g under non-stress and water-stress conditions, respectively and it ranged from 3.7 g for ICGV-IS-07813 (P_1) and ICG 12989 (P_4) to 11.7 g for ICG 3312 (P_7) and 0.3 g in RS006F_4B_1-50 (P_2) to 3.4g for ICG 12989 among the parents under non-stress and water-stress conditions, respectively. Under non-stress, it ranged from and 1.2g for RS006F_4B_1-50 x ICGV-IS-07841 to 12.4g for ICGV-IS-07813 x ICG 5195 while under water-stress condition, it ranged from 0.9g for SAMNUT 23 x ICG 5195 to 3.5 g for RS006F_4B_1-50 x SAMNUT 23. However, the check SAMNUT 25 had highest seed weight 10 g under water stress condition.

One hundred seed weight has a mean of 33.3 g and it ranged from 21.0 g for ICG 12989 to 29.6 g in ICG 3312 among the parents under non-stress condition. Under water-stress condition, it has an overall mean of 27.4 g and the parents ranged from 12.5 g for RS006F_4B_1-50 to 78.4 g for ICG 3312. Under water-stress condition, the progenies; ICGV-IS-07813 x ICG 3312 recorded the lowest value of 13.3 g for 100 seed weight and the highest value of 120.3 g was recorded for ICGV-IS-07841 x SAMNUT 23. For non-stress condition, progenies RS006F_4B_1-50 x ICGV-IS-

07841 recorded the lowest value 15.2g and ICGV-IS-07841 x ICG 12989 149.2g recorded the highest value for hundred-seed weight.

The overall mean for pod yield were 8.3g and 4.2g/plant under non-stress and water-stress respectively. Under non-stress, pod yield ranged from 3.9 g/plant for SAMNUT 23 to 12.7 g/plant for ICG 12989 among the parents while among the progenies, pod yield ranged from 3.1 g/plant for ICGV-IS-07813 x ICGV-IS-07841 to 17.6g/plant for RS006F_4B_1-50 x ICG 5195. Under water-stress pod yield ranged from 0.8 g/plant for RS006F_4B_1-50 to 5.4g/plant for ICG 5195 among the parents and 1.8g/plant for ICGV-IS-07813 x RS006F_4B_1-50 to 6.6g/plant for RS006F_4B_1-50 x ICG 5195 among the progenies. Number of pods per plant has an overall mean of 16 pods per plant and 11 pods per plant under non-stress and water-stress respectively. Under non-stress condition, the genotypes with the most Number of pods were ICG 12989 23pods, ICG 3312 23 pods and RS006F_4B_1-50 x ICG 5195 29pods while the genotypes with the least number of pods are; SAMNUT 23 11pods and RS006F_4B_1-50 x ICG 12989 5pods.The genotypes with the most Number of pods per plant under water-stress condition are ICG 5195 20 pods among the parents, ICGV-IS-07841 x ICG 5195 16pods and ICG 5195 x ICG 3312 16pods among the progenies while RS006F_4B_1-50 2 pods among the parents and ICGV-IS-07813 x RS006F_4B_1-50 (5pods) among the progenies recorded the least number of pods (Table 4.14).

The mean performance for the morphological traits of the groundnut genotypes evaluated under combined analysis is given in Table 4.15. The genotypes showed considerable variation for the different traits. For the morphological traits, days to 50% to flowering had an overall mean of 39days. Among the seven parents used in this study, ICGV-IS-ICG 12989 flowered early 38 days) while parent ICG 3312 flowered late 41 days. The progenies, ICGV-IS-07813 x ICG 3312,

ICGV-IS-07813 x ICG 5195 and RS006F_4B_1-50 x ICG 5195 flowered earliest 38 days while ICGV-IS-07813 x ICG 12989 and RS006F_4B_1-50 x ICG 12989 flowered late 42 days. Plant height recorded an overall mean of 48.1cm. Among the parents, it ranged from 34.3 cm for RS006F_4B_1-50 to 55.1cm for ICGV-IS-07841. Among the progenies, plant height ranged from 36.7cm for SAMNUT23 x ICG 3312 to 79.3cm for ICGV-IS-07813 x ICG 12989.

The mean for number of pods per plants recorded was 13pods. The genotypes with the most number of pods per plant are ICG 3312 20 pods among the parents and SAMNUT23 x ICG 3312 20 pods, RS006F_4B_1-50 x ICG 5195 20 pods and ICG 5195 x ICG 3312 20 pods while RS006F_4B_1-50 8 pods and RS006F_4B_1-50 x ICG 12989 5 pods recorded the least value for number of pods per plant.

Seed weight had a mean of 3.9g and it ranged from 1.4g for RS006F_4B_1-50 to 5.4g for ICG 12989 and ICG 5195 among the parents while it ranged from 1.3g for ICGV-IS-07813 x ICGV-IS-07841 to 7.6 g for SAMNUT 23 x ICG 3312 and ICG 5195 x ICG 3312 among the progenies.

The mean for 100 seed weight was recorded to be 30.4g. Among the parents, one hundred seed weight ranged from 16.8g for RS006F_4B_1-50 to 49.6g for ICG 3312 under combined analysis. Among the progenies, ICGV-IS-07813 x ICGV-IS-07841recorded the lowest value of 17.4g for 100 seed weight and RS006F_4B_1-50 x ICG 12989 recorded the highest value of 85.6g.

Pod yield recorded a mean of 8.3 g/plant. It ranged from 2.6g/plant for RS006F_4B_1-50 to 8.5 g/plant for ICG 12989 among the seven parents, the progenies with the lowest *per se performance* is ICGV-IS-07813 x ICGV-IS-07841 2.5 g/plant while ICG 5195 x ICG 3312 had the highest *per se performance* 11.2 g/plant (Table 4.15).

Mean performance for the physiological traits of seven (7) parents, twenty-one (21) progenies and two (2) checks of groundnut evaluated under non-stress and water-stress conditions is presented in Table 4.16. Under non-stress condition, SCMR at 40 DAS had an overall mean of 42.8 and it ranged from 40.3 for SAMNUT 23 to 44.2 for RS006F_4B_1-50 among the parents and the progenies ICGV-IS-07841 x ICG 12989 36.1 had the lowest SCMR 40 DAS while SAMNUT 23 x ICG 3312 44.8 had the highest SCMR at 40 DAS.

Under water-stress SCMR at 40DAS had an overall mean 46.6 and it ranged from 48.00 for ICG 5195 to 52.3 for RS006F_4B_1-50 among the parents and the progenies RS006F_4B_1-50 x SAMNUT 23 36.8 recorded the lowest SCMR 40 DAS while SAMNUT 23 x ICG 5195 recorded the highest value of 55.3 for SCMR 40DAS.

SCMR at 60 DAS has an overall mean of 41.8 and 39.2 and it ranged from 39.5 for ICG 12989 and 34.0 for ICG 3312 to 47.8 for ICG 3312 and 40.7 for SAMNUT 23 under non-stress and water-stress conditions, respectively. The progenies; ICGV-IS-07841 x ICG 3312 47.7 and SAMNUT 23 x ICG 5195 42.4 recorded the highest values while ICGV-IS-07813 x SAMNUT 23 36.4 and SAMNUT 23 x ICG 3312 36.1 recorded the lowest values of SCMR at 60 DAS under non-stress and water-stress conditions, respectively.

For SCMR at 80 DAS, the genotypes had an overall mean of 38.4 and 38.1, the parents ranged from 36.5 for ICG 12989 to 42.2 for ICGV-IS-07841 and 33.6 for RS006F_4B_1-50

Table 4.16: Mean performances for physiological traits of diallel parents and progenies evaluated under non-stress and water-stress conditions at Samaru 2019

Genotypes	SCMR 40DAS		SCMR 60DAS		SCMR80DAS		HI (%)	
	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813 (P_1)	43.5	49.8	41.8	39.3	38.8	37.2	15.8	9.5
RS006F4B1-50 (P_2)	44.2	52.3	45	36.6	37.4	33.6	17.7	3.9
ICGV-IS-07841 (P_3)	43.3	52.2	45.5	39.5	42.2	37	12.4	13.9
ICG 12989 (P_4)	44.3	48.2	39.5	37.2	36.5	38	16.9	14.5
SAMNUT 23 (P_5)	40.3	50.2	42.1	40.7	37.2	39.6	14.2	13.9
ICG 5195 (P_6)	43.4	48	40.3	38.8	37.3	39.8	15.7	19
ICG 3312 (P_7)	43.5	49.3	47.8	34	40.3	39.6	29.3	13
ICGV-IS-07813 x RS006F4B1-50	44.8	43	39.6	40.8	36.1	37.5	9.6	16.5
ICGV-IS-07813 x ICGV-IS-07841	43.9	39.5	41	41	31.2	37	41.3	6.8
ICGV-IS-07813 x ICG 12989	42.7	38.4	44.6	40.1	41	39.2	25.1	13.4
ICGV-IS-07813 x SAMNUT 23	42.5	42.8	36.4	39.3	38.6	34.8	10.3	12.6
ICGV-IS-07813 x ICG 5195	40.9	49.6	38.3	39.2	39.9	36.8	22.3	9.7
ICGV-IS-07813 x ICG 3312	42.1	46.4	40.4	40.6	40.2	36.2	13.7	14.4
RS006F4B1-50 x ICGV-IS-07841	43	50.8	40.1	41.4	38	41.3	9.6	7.9
RS006F4B1-50 x ICG 12989	41.1	43.5	43.3	40.8	39.1	40.2	13.4	7.8
RS006F4B1-50 x SAMNUT 23	43.8	36.8	42.2	37.7	38.7	31.9	21.5	22.8
RS006F4B1-50 x ICG 5195	44.3	46.9	41.3	38.2	34.1	43.2	23.9	10.3
RS006F4B1-50 x ICG 3312	42.7	48.9	43.1	40.5	36.4	40.1	17.5	9.3
ICGV-IS-07841 x ICG 12989	36.1	48.1	45.2	39	41.8	40.6	8	11.9
ICGV-IS-07841 x SAMNUT 23	39.5	47.1	38.4	39.7	41.1	37	17.2	23.6
ICGV-IS-07841 x ICG 5195	44.5	46.1	44.7	38.7	38.2	37.9	31.1	19.7
ICGV-IS-07841 x ICG 3312	42.9	39.1	47.7	38.4	38.8	40.3	14.6	16.3
ICG 12989 x SAMNUT 23	43.2	40.1	36.1	39.3	36.6	38.3	22.8	13.2
ICG 12989 x ICG 5195	42.3	45.8	42.3	43	39.3	40.2	18.9	21.7
ICG 12989 x 1CG 3312	41.9	43.8	39.3	39.7	32.9	40.8	14.9	13.1
SAMNUT 23 x ICG 5195	42	55.3	43	42.4	40.1	35.3	16.9	10.5
SAMNUT 23 x ICG 3312	44.8	51.2	42.5	36.1	42.2	35.9	9.6	12.6
ICG 5195 x ICG 3312	43.6	46.8	41.5	39.8	39	43.7	16.4	20.3
SAMNUT 24	43.8	51.1	41.3	38.1	38.8	37	20.2	25.6
SAMNUT 25	44.7	45.6	41.3	37.4	40.4	31.8	11.8	30.8
Mean	**42.8**	**46.6**	**41.8**	**39.2**	**38.4**	**38.1**	**17.7**	**14.6**
C.V	**4.4**	**9.5**	**6.8**	**8.1**	**8.2**	**10.7**	**40.5**	**13.5**
L S D	**3.8**	**9.1**	**5.8**	**6.5**	**6.5**	**8.3**	**14.7**	**16**

SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index, LAI= Leaf Area Index

Table 4.17: Mean performance for physiological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Genotype	SCMR 40DAS	SCMR 60DAS	SCMR 80DAS	HI (%)
ICGV-IS-07813 (P_1)	46.7	40.6	38.0	12.7
RS006F4B1-50 (P_2)	48.6	38.1	34.9	6.7
ICGV-IS-07841 (P_3)	48.0	40.2	34.1	27.6
ICG 12989 (P_4)	45.5	40.9	39.5	19.8
SAMNUT 23 (P_5)	46.4	38.6	39.1	12.1
ICG 5195 (P_6)	44.5	38.5	39.9	20.7
ICG 3312 (P_7)	45.7	37.2	39.9	13.4
ICGV-IS-07813 x RS006F_4B_1-50	43.6	42.9	37.4	17.1
ICGV-IS-07813 x ICGV-IS-07841	41.2	40.5	37.5	8.2
ICGV-IS-07813 x ICG 12989	39.7	41.7	39.1	13.4
ICGV-IS-07813 x SAMNUT 23	43.3	40.7	36.8	17.1
ICGV-IS-07813 x ICG 5195	46.9	40.2	35.4	16.8
ICGV-IS-07813 x ICG 3312	44.6	41.8	36.3	15.9
RS006F_4B_1-50 x ICGV-IS-07841	47.1	43.5	41.8	10.1
RS006F_4B_1-50 x ICG 12989	39.8	43.0	41.0	7.9
RS006F_4B_1-50 x SAMNUT 23	38.1	38.0	36.5	20.0
RS006F_4B_1-50 x ICG 5195	45.7	41.4	40.7	20.7
RS006F_4B_1-50 x ICG 3312	45.9	44.1	39.4	12.0
ICGV-IS-07841 x ICG 12989	46.2	39.2	38.6	14.4
ICGV-IS-07841 x SAMNUT 23	45.2	37.9	36.8	23.2
ICGV-IS-07841 x ICG 5195	44.2	40.5	38.6	19.3
ICGV-IS-07841 x ICG 3312	40.5	38.9	36.6	15.6
ICG 12989 x SAMNUT 23	40.2	40.7	37.7	13.7
ICG 12989 x ICG 5195	43.9	43.0	40.1	19.3
ICG 12989 x 1CG 3312	44.3	41.1	41.5	11.3
SAMNUT 23 x ICG 5195	49.4	41.3	36.3	13.1
SAMNUT 23 x ICG 3312	47.35	38.8	37.4	24.8
ICG 5195 x ICG 3312	45.1	43.8	42.0	24.8
SAMNUT 24	47.5	39.7	37.9	22.9
SAMNUT 25	45.1	39.3	36.1	21.3
Mean	**44.7**	**40.5**	**38.2**	**16.2**
C. V (%)	**7.6**	**7.4**	**9.5**	**46.9**
LSD	**4.8**	**4.2**	**5.1**	**10.7**

SCMR = SPAD chlorophyll meter reading, DAS= days after sowing, HI = Harvest Index

to 39.8 for ICG 5195 under non-stress and water-stress conditions, respectively. The progenies, ICGV-IS-07813 x ICGV-IS-07841 31.2 and RS006F_4B_1-50 x SAMNUT 23 31.9 recorded the lowest values while SAMNUT 23 x ICG 3312 42.2 and ICG 12989 x ICG 3312 40.8 recorded the highest values of SCMR at 80 DAS under non-stress and water-stress respectively.

Results for harvest INDEX revealed that the overall mean were 17.7% and 14.6%; the parents ICG 3312 and ICG 5195 recorded the highest values 29.3% and 19.0%) while ICGV-IS-07841 and RS006F_4B_1-50 recorded the least values 12.4% and 3.9% harvest index under non-stress and water-stress conditions, respectively. Among the progenies, harvest index ranged from 8.0% for ICGV-IS-07841 x ICG 12989 to 41.3% for ICGV-IS-07813 x ICGV-IS-07841 under non-stress condition while progenies ICGV-IS-07813 x ICGV-IS-07841 recorded the least value 6.8% and ICGV-IS-07841 x SAMNUT 23 recorded the highest value 23.6% under water-stress condition. The two checks SAMNUT 24 and SAMNUT 25 recorded higher values of harvest index under water-stress condition (Table 4.16).

Under combined analysis, SCMR 40 DAS had a mean of 44.7 and it ranged from 44.5 for ICG 5195 to 48.6 for RS006F_4B_1-50 among the parents. The progenies; SAMNUT 23 x ICG 5195 had the highest SCMR at 40 DAS 49.4 while RS006F_4B_1-50 x SAMNUT 23 had the lowest value of 38.1 for SCMR 40 DAS.

SCMR at 60 DAS recorded an overall mean of 40.5 and it ranged from 37.2 for ICG 3312 to 40.9 for ICG 12989. The progenies; ICGV-IS-07841 x SAMNUT 23 and recorded the lowest values of 37.9 for SCMR at 60DAS while RS006F4B1-50 x ICG 3312 recorded the highest values 44.1. For SCMR at 80 DAS, the genotypes had an overall mean of 38.2 under combine analysis. Among the parents, ICGV-IS-07841 recorded the lowest value (34.1) while ICG 5195

and ICG 3312 recorded the highest value 39.9. The progenies, ICGV-IS-07813 x ICG 5195 recorded the lowest value 35.4 while ICG 5195 x ICG 3312 42.0 recorded the highest values of SCMR at 80 DAS.

Results for Harvest index revealed that the overall mean recorded was 16.2%. RS006F_4B_1-50 and ICGV-IS-07841 recorded the least and highest values 6.7% and 27.6% among the parents, respectively. Among the progenies, harvest index ranged from 7.9% for RS006F_4B_1-50 x ICG 12989 to 24.8% for SAMNUT 23 x ICG 3312 and ICG 5195 x ICG 3312 (Table 4.17).

4.7 Genetic Variability Parameters and Broad Sense Heritability for Morphological Traits

Genetic variability parameters and broad sense heritability of morphological traits evaluated under non-stress and water stress at Samaru are presented in Table 4.18. For the morphological traits, the GCV and PCV were low for days to 50% flowering 1.11% and 1.16% and 3.78% and 3.19% under both conditions, respectively. Generally, PCV was higher than GCV for all traits measured under the two conditions. High 61.96%, 60.00% and 91.19% broad-sense heritability estimates were recorded for plant height, pod yield and 100 seed weight under non-stress condition. Moderate 41.10% and 31.87%, 37.53% and 36.85% broad-sense heritability estimates were recorded for number of pods per plant, seed weight under non-stress and water-stress conditions, respectively. Moderate 46.23% broad-sense heritability was also recorded for 100 seed weight under water-stress condition, while low 12.14% heritability was recorded for pod yield under water-stress condition. Days to 50% flowering recorded low 8.16% and 13.37% broad-sense heritability values under non-stress and water-stress conditions, respectively (Table 4.18).

Table 4.18: Variance component and heritability estimates for morphological traits of groundnut genotypes evaluated under non-stress and water-stress conditions at Samaru 2019

Traits	Component of Variance						GCV (%)		PCV (%)		H_b (%)	
	σ_e^2		σ_g^2		σ_p^2							
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
Days to 50% flowering	2.01	1.79	0.19	0.21	2.20	1.58	1.11	1.16	3.78	3.19	8.16	13.37
Plant height	72.6	81.81	118.25	17.3	190.85	99.10	21.25	9.25	27.00	22.13	61.96	17.45
Number of pods/plant	20.51	12.62	14.31	5.90	34.82	18.53	23.97	22.46	37.39	39.79	41.10	31.87
Seed Weight	4.36	1.79	2.62	1.05	6.99	2.84	31.28	39.1	51.06	64.41	37.53	36.85
Pod yield	5.19	4.74	7.76	0.66	12.95	5.40	33.68	19.18	43.51	55.04	60.00	12.14
100-Seed weight	933.02	488.6	9.24	15.09	942.27	503.69	9.13	14.16	92.21	81.83	91.19	46.23

σ_e^2 =Error variance, σ_g^2 = Genotypic variance, σ_p^2 = Phenotypic variance, GCV= Genotypic Coefficient of Variation, PCV= Phenotypic coefficient of variation, h_b = Broad-sense heritability

Table 4.19: Variance component and heritability estimates for morphological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Traits	Component of Variance				GCV (%)	PCV (%)	H_b (%)
	σ_e^2	σ_{gc}^2	σ_g^2	σ_p^2			
Days to 50% flowering	1.90	1.22	0.73	1.82	2.17	3.43	40.21
Plant height	77.2	1.61	82.85	102.95	18.93	21.11	80.47
Number of pods/plant	16.57	2.45	6.36	11.72	18.95	25.74	54.21
Pod yield	4.97	3.42	2.52	5.47	25.42	37.46	46.05
Seed weight	3.08	3.56	4.43	6.98	54.00	67.79	63.45
100-Seed weight	4.92	3.57	0.02	3.04	0.46	5.74	0.64

σ_e^2 = Error variance, σ_g^2 = Genotypic variance, σ_{gc}^2 = Genotype x Condition Variance, σ_p^2 = Phenotypic variance, GCV= Genotypic Coefficient of Variation, PCV= Phenotypic Coefficient of Variation, h_b = Broad-sense Heritability

Genetic variability and broad sense heritability estimates for the morphological traits of groundnut genotypes evaluated under combined analysis are presented in Table 4.19. The genotypic variance ranged from 0.02 for 100 seed weight to 82.85 for plant height, the genotype x condition (G x C) variance ranged from 1.22 for days to 50% flowering to 3.57 for 100 seed weight and the phenotypic variance ranged from 1.82 for days to 50% flowering to 102.95 for plant height. The GCV were high 54.00% and 25.42% for seed weight and pod yield, moderate 18.93%, 18.95% for plant height and number of pods per plant. The PCV were high 67.79%, 37.46%, 25.74% and 21.11% for seed weight, pod yield, number of pods per plant and plant height. The PCV were low 3.43%, 5.74% for days to 50% flowering and 100 seed weight, respectively. Broad sense heritability estimates were high 80.47% and 63.45% for plant height and seed weight and moderate for all other traits studied except for 100 seed weight which was low 0.64% (Table 4.19).

Variance components for physiological traits evaluated under non-stress and water stress at Samaru are presented in Table 4.20. The genotypic variance ranged from 1.62 for SCMR at 40 DAS under non-stress condition and 0.04 for SCMR at 80 DAS under water-stress to 26.46 for harvest index under non-stress condition and 11.23 for SCMR at 40 DAS under water-stress condition. The phenotypic variance ranged from 3.36 for SCMR at 40 DAS under non-stress condition and 3.54 for SCMR at 60 DAS under water-stress condition to 52.35and 37.01 for harvest index under non-stress and water-stress conditions, respectively. The estimates of GCV were highest for harvest index 28.98% and 17.29% under non-stress and water-stress conditions followed for SCMR at 40 DAS under non-stress condition.

Table 4.20: Variance component and heritability estimates for physiological traits of groundnut genotypes evaluated under non-stress and water-stress conditions at Samaru 2019

Traits	Component of Variance						GCV (%)		PCV (%)		H_b (%)	
	σ_e^2		σ_g^2		σ_p^2							
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
SCMR at 40DAS	1.74	9.83	1.62	11.23	3.36	21.06	2.98	7.2	4.29	9.86	48.19	53.33
SCMR at 60DAS	4.03	5.04	4.29	1.51	8.32	3.54	4.95	3.13	6.89	4.8	51.59	42.54
SCMR at 80DAS	4.98	8.25	1.71	0.04	6.69	8.29	3.41	0.55	6.74	7.57	25.62	0.53
Harvest index	25.9	30.625	26.46	6.39	52.35	37.01	28.98	17.29	40.77	41.62	50.53	17.26

σ_g^2 = Genotypic variance, σ_p^2 = Phenotypic variance, GCV= Genotypic Coefficient of Variation, PCV= Phenotypic Coefficient of Variation, h_b = Broad-sense heritability, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing

Table 4.21: Variance component and heritability estimates for physiological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Traits	Component of Variance				GCV (%)	PCV (%)	H_b (%)
	σ_e^2	σ_{gc}^2	σ_g^2	σ_p^2			
SCMR at 40DAS	5.79	2.91	3.81	6.7	4.37	5.8	56.76
SCMR 60DAS	4.54	2.08	1.21	3.38	2.71	4.54	35.7
SCMR 80DAS	6.61	1.92	1.15	3.76	2.8	5.07	30.52
Harvest Index	28.26	2.52	9.13	17.46	18.67	25.82	52.32

SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, σ_g^2 = Genotypic variance, σ_{gc}^2 = Genotype x Condition Variance, σ_p^2 = Phenotypic variance, GCV= Genotypic Coefficient of Variation, PCV= Phenotypic Coefficient of Variation, h_b = Broad-sense Heritability

Estimates of PCV were highest 40.77% and 41.62% for Harvest Index under non-stress and water-stress conditions, respectively followed for SCMR at 40 DAS under non-stress condition. The GCV were lowest 2.98% for SCMR at 40 DAS and PCV were lowest 4.29% for SCMR 40 DAS under non stress while GCV were lowest 0.55% for SCMR at 80 DAS and PCV were lowest 4.80% for SCMR at 60 DAS under water stress. Broad sense heritability for physiological traits ranged from ranged from 25.62% for SCMR at 80 DAS to 51.59% for SCMR at 60 DAS under no-stress condition while it ranged from 17.26% for harvest index to 53.33% for SCMR at 40 DAS under water-stress condition. Moderate 48.19% and 53.33%, 51.59% and 42.54% broad-sense heritability estimates were recorded for SCMR at 40 DAS, SCMR 60 DAS under non-stress and water-stress conditions, respectively. Moderate 50.53% broad-sense heritability was also recorded for harvest index under non-stress condition. Low values 17.26% and 0.53% were recorded for harvest index and SCMR at 80 DAS under water-stress condition.

Genetic variability and heritability estimates for physiological traits of groundnut genotypes evaluated under combined analysis are presented in Table 4.21. The genotypic variance ranged from 1.15 for SCMR at 80 DAS to 9.13 for harvest index. The genotype x condition (G x C) variance ranged from 1.92 for SCMR at 80 DAS to 2.91 for SCMR at 40 DAS. The phenotypic variance ranged from 3.38 for SCMR at 60 DAS to 17.46 for harvest index. The GCV were moderate 18.67% for harvest index and low for all other traits recorded. The PCV was high 25.82% for harvest index. The PCV were low for all other traits recorded. Broad sense heritability estimates were moderate 30.52%-56.76% for all the traits studied. (Table 4.19).

4.8 Combining Ability

4.8.1 Combining ability variances for morphological traits

The mean squares for combining ability for morphological traits of groundnut evaluated under non-stress and water-stress conditions at Samaru are presented in Table 4.22. The mean squares due to General Combining Ability (GCA) under non-stress condition were highly significant ($P \leq 0.01$) for plant height. Number of pods per plant and seed weight showed significant ($P \leq 0.05$) difference while days to 50% flowering and pod yield did not record a significant ($P > 0.05$) variation. Under water-stress, mean squares due to general combining ability (GCA) showed a highly significant ($P \leq 0.01$) difference for plant height and pod yield while other traits recorded showed a significant difference ($P \leq 0.05$). The mean squares due to specific combining ability (SCA) were highly significant ($P \leq 0.01$) for plant height, number of pods per plant and seed weight while other traits recorded showed significant differences ($P \leq 0.05$).

Table 4.23 presents the combining ability for morphological traits across the water conditions. The mean squares due to general combining ability (GCA) were highly significant ($P \leq 0.01$) for plant height and number of pods per plant and non-significant ($P > 0.05$) for other traits recorded. The mean squares due to specific combining ability (SCA) were highly significant ($P \leq 0.01$) for plant height and pod yield, significant ($P \leq 0.05$) for number of pods per plant and seed weight. Non-significant ($P \leq 0.05$) difference was observed for days to 50% flowering. The mean squares due to GCA x condition interaction showed a significant ($P \leq 0.05$) difference for pod yield and seed weight, other traits recorded a non-significant ($P > 0.05$) difference. The mean squares due to SCA x condition interaction showed a significant ($P \leq 0.05$) difference for number of pods per plant and non-significant ($P > 0.05$) for other traits recorded.

Table 4.22: ANOVA for morphological traits of groundnut genotypes evaluated under non-stress and water-stress condition at Samaru in 2019

Source of variation	DF	DFF		PHT		NPP		Pod yield		SWT	
		NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
GCA	6	3.06	0.35*	641.17**	325.83**	118.76*	31.46*	18.31	7.60**	15.85*	2.79*
SCA	21	4.82	4.13*	405.71**	208.41**	53.23	32.66*	27.48**	2.74**	14.30*	1.34*
Error	29	2.01	1.79	72.6	81.81	20.51	12.62	5.18	4.74	4.36	1.79

GCA= General Combining Ability, SCA= Specific Combining Ability, DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight

Table 4.23: ANOVA for morphological traits of groundnut genotypes evaluated under combined analysis at Samaru in 2019

Source of Variation	DF	DFF	PHT	NPP	Pod yield	SWT
GCA	6	0.91	927.91**	101.67**	9.74	7.26
SCA	21	6.57	455.25**	54.92*	18.66**	9.08*
GCA x Condition	6	2.49	39.08	48.55	16.17*	11.38*
SCA x Condition	21	2.38	158.87	30.97*	11.57	6.56
Error	58	1.90	77.20	16.57	4.96	3.08

GCA= General Combining Ability, SCA= Specific Combining Ability, DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight

4.8.2 Combining ability variance for physiological traits

The mean squares for combining ability for physiological traits of groundnut evaluated under non-stress and water-stress conditions at Samaru are presented in Table 4.24. The mean squares due to GCA under non-stress condition were highly significant (P≤0.01) for SCMR 40 DAS, SCMR 60 DAS and harvest index, while SCMR 80 DAS was significant at (P≤0.05). The mean squares due to SCA were highly significant (P≤0.01) for harvest index while other traits recorded showed significant differences at (P≤0.05).Under water-stress, mean squares due to (GCA) were highly significant (P≤0.01) for SCMR 40 DAS while other traits recorded showed a significant difference (P≤0.05). The mean square due to (SCA) of all physiological traits showed significant difference (P≤0.05).

For combined analysis presented in Table 4.25, the mean squares due to GCA were highly significant (P≤0.01) for SCMR at 40 DAS and significant (P≤0.05) difference for other traits recorded except SCMR at 80 DAS which was non-significant (P>0.05). The mean squares due to SCA were highly significant (P≤0.01) for SCMR at 40 DAS and harvest index and significant (P≤0.05) for other traits recorded except SCMR 80 DAS which was not significant (P>0.05). The mean squares due to GCA x Condition and SCA x Condition interaction were highly significant (P≤0.01) for SCMR 40 DAS and harvest index and significant (P≤0.05) for other traits recorded except SCMR 80 DAS which was non- significant (P>0.05).

Table 4.24: ANOVA for morphological traits of groundnut genotypes evaluated under non-stress and water-stress condition at Samaru in 2019

SOV	DF	SCMR 40 DAS		SCMR 60 DAS		SCMR 80 DAS		HI	
		NS	WS	NS	WS	NS	WS	NS	WS
GCA	6	7.14**	94.12**	25.06**	8.81*	7.06*	17.49*	58.81**	85.04*
SCA	21	7.20*	28.85*	15.20*	7.14*	16.08*	13.28*	131.03**	44.82*
Error	29	1.74	9.83	4.03	5.04	4.98	8.25	25.90	30.62

SOV= Source of variation, GCA= General Combining Ability, SCA= Specific Combining Ability, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index

Table 4.25: ANOVA for physiological traits of groundnut genotypes evaluated under combined Analysis at Samaru in 2019

SOV	DF	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	HI
GCA	6	61.54**	18.53*	17.7	55.58*
SCA	21	25.62**	13.75*	17.24	124.26**
GCA x Condition	6	39.72**	15.34*	6.85	88.28*
SCA x Condition	21	10.44**	8.59*	12.12	51.59**
Error	58	5.79	5.79	6.61	28.26

SOV= Source of variation, GCA= General Combining Ability, SCA= Specific Combining Ability, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index

4.8.3 Combining ability variance and narrow-sense heritability estimates for morphological traits

Components of GCA variance, SCA variance, GCA/SCA variance ratios and narrow-sense heritability (h_n) for morphological traits of groundnut genotypes evaluated under non-stress and water-stress conditions are presented in Table 4.26. Under non-stress condition, magnitudes of SCA variances were higher than GCA variances for all morphological traits. GCA variances were positive except for 50% flowering under non-stress (-0.20%) and water-stress conditions, number of pods per plant under water-stress condition and pod yield under non-stress condition. The ratios of GCA to SCA variance for all the traits were less than unity, positive GCA/SCA ratios for all the traits.

Under water-stress condition, the magnitudes of SCA variances were greater than GCA variances for all traits. The ratios of GCA to the SCA variance for all the morphological traits were less than unity, while positive GCA/SCA ratios were recorded for all the morphological traits. The narrow sense heritability estimates are presented were low for all traits under non-stress condition and water-stress condition. combined analysis as presented in Table 4.27 revealed that ratios of GCA to the SCA variance for all the traits were less than unity, positive GCA/SCA ratios for all traits. The magnitudes of GCA variances were lower than SCA variances for all the morphological traits except plant height. The narrow-sense heritability estimates were positive for all traits and were moderate for days to 50% flowering (46.15%), plant height (52.52%), seed weight (35.94%) and pod yield (42.11%) while it was low for number of pods per plant (15.91%).

Table 4.26: GCA, SCA variance and narrow-sense heritability of morphological traits of groundnut genotypes evaluated under non-stress and water-stress condition at Samaru 2019

Traits	σ_e^2		σ_{GCA}^2		σ_{SCA}^2		$\sigma_{GCA}^2 : \sigma_{SCA}^2$		h_n (%)	
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
Days to 50% flowering	1.01	0.90	-0.2	-0.42	2.81	2.34	0.56	0.14	-	-
Plant height	36.30	40.91	26.16	13.05	333.11	126.6	0.76	0.76	12.41	13.48
Number of pods/plant	10.26	6.31	7.28	-0.13	32.72	20.04	0.82	0.66	25.31	-
Pod yield	2.59	2.37	-1.02	0.10	22.3	2.00	0.57	0.69	-	4.19
Seed weight	2.18	0.90	0.17	0.11	9.94	0.05	0.69	0.75	2.76	18.26

σ_e^2 = Error variability, σ_{GCA}^2 = General Combining Ability variance, σ_{SCA}^2 = Specific Combining Ability variance, $\sigma_{GCA}^2 : \sigma_{SCA}^2$ = GCA:SCA ratio, h_n =Narrow-sense heritability

Table 4.27: GCA, SCA variance and narrow-sense heritability of morphological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Traits	σ_e^2	σ_{GCA}^2	σ_{SCA}^2	σ_{GCAXC}^2	σ_{SCAXC}^2	$\sigma_{GCA}^2 : \sigma_{SCA}^2$	h_n %
Days to 50% flowering	0.95	2.82	4.67	0.11	0.48	0.60	46.15
Plant height	38.60	85.85	78.05	-119.79	81.67	1.10	52.52
Number of pods/plant	8.29	5.19	38.35	17.58	14.4	0.14	15.91
Pod yield	2.48	6.79	13.70	4.60	6.61	0.50	42.11
Seed weight	1.54	5.35	16.00	4.82	3.48	0.33	35.94

σ_{GCA}^2 = General Combining Ability variance, σ_{SCA}^2 = Specific Combining Ability variance, $\sigma_{GCA}^2 : \sigma_{SCA}^2$ = GCA:SCA ratio, h_n = Narrow-sense heritability

4.8.4 Combining ability and narrow-sense heritability estimates for physiological traits

Components for GCA variance, SCA variance, GCA/SCA variance ratios and narrow-sense heritability (h_n) for physiological traits measured under non-stress and water-stress (Table 4.28). Under non-stress condition, magnitudes of SCA variances were higher than GCA variances for all physiological traits. GCA variances were negative for all the traits except for SCMR at 60DAS under non-stress (1.10). The ratios of GCA to SCA variance for all the traits were less than unity, positive GCA/SCA ratios for all the traits. Under water-stress condition, the magnitudes of SCA variances were greater than GCA variances for all traits. The ratios of GCA to the SCA variance for all the morphological traits were less than unity, positive GCA/SCA ratios were recorded for all the physiological traits. The narrow sense heritability estimates were negative for all the traits except SCMR at 60DAS and under non-stress condition (14.25%), but positive for all traits under water-stress condition.

Under combined analysis, Table 4.29 revealed the ratios of GCA to the SCA variance for all the traits were less than unity positive GCA/SCA ratios for all traits, positive GCA/SCA ratios for all the traits. The narrow-sense heritability estimates were positive for all traits and were low for days to all traits except harvest index which was moderate 37.88%.

Table 4.28: GCA, SCA variance and narrow-sense heritability of physiological traits of groundnut genotypes evaluated under non-stress and water-stress condition at Samaru 2019

Traits	σ_e^2		σ_{GCA}^2		σ_{SCA}^2		$\sigma_{GCA}^2 : \sigma_{SCA}^2$		h_n (%)	
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
SCMR at 40 DAS	0.87	4.92	-0.01	7.25	5.46	19.02	0.66	0.87	-	37.73
SCMR at 60 DAS	2.02	2.52	1.10	0.19	11.17	2.10	0.77	0.71	14.25	7.44
SCMR at 80 DAS	2.49	4.13	-1.00	0.47	11.10	5.03	0.47	0.72	-	9.27
Harvest Index	12.95	15.31	-8.02	4.47	105.13	14.20	0.47	0.79	-	23.25

σ_{GCA}^2= General Combining Ability variance, σ_{SCA}^2= Specific Combining Ability variance, $\sigma_{GCA}^2 : \sigma_{SCA}^2$= GCA:SCA ratio, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, h_n = Narrow-sense heritability

Table 4.29: GCA, SCA variance and narrow-sense heritability of physiological traits of groundnut genotypes evaluated under combined analysis at Samaru 2019

Traits	σ_e^2	σ_{GCA}^2	σ_{SCA}^2	σ_{GCAXC}^2	σ_{SCAXC}^2	$\sigma_{GCA}^2 : \sigma_{SCA}^2$	h_n %
SCMR at 40 DAS	2.90	3.99	19.83	29.28	4.65	0.20	23.76
SCMR at 60 DAS	2.90	0.53	7.96	6.75	2.8	0.07	7.17
SCMR at 80 DAS	3.31	4.50	10.63	-5.27	5.51	0.42	15.99
Harvest Index	14.13	20.81	40.00	36.69	23.33	0.52	37.88

σ_{GCA}^2= variance due to General Combining Ability, σ_{SCA}^2= Variance due to Specific Combining Ability, $\sigma_{GCA}^2 : \sigma_{SCA}^2$= GCA: SCA ratio, SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, h_n = Narrow-sense heritability, σ_{GCAXC}^2= Variance due to GCA x Condition and σ_{SCAXC}^2= Variance due to SCA x Condition

4.9 Combining Ability Effects

4.9.1 General combining ability effects for morphological traits

The estimates of general combining ability effects under non-stress and water-stress conditions are presented in Table 4.30. Under non-stress condition, ICG 12989 recorded significant ($P \leq 0.05$) positive GCA effects for days to 50% flowering (0.36) while highly significant ($P \leq 0.01$) negative GCA effects were recorded for ICGV-IS-07813 (-0.07) and a significant ($P \leq 0.05$) negative GCA effect for ICG 5195 (-0.57) for days to 50% flowering.

Highly significant ($P \leq 0.01$) positive GCA effects were recorded for $RS006F_4B_1$-50 (10.26) for plant height while very low and highly significant ($P \leq 0.01$) negative GCA effects were recorded for ICGV-IS-07813 (-8.42) and significant ($P \leq 0.05$) negative GCA effect were recorded for ICG 3312 (-0.92) for plant height.

Number of pods per plant recorded a positive significant ($P \leq 0.05$) GCA effect for ICG 5195 and a significant ($P \leq 0.05$) negative GCA were recorded for ICGV-IS-07841 (-3.58) and SAMNUT 23 (-3.08) for number of pods per plant. Significant ($P \leq 0.05$) positive GCA effects were recorded for seed weight for ICGV-IS-07841 (1.11). Significant ($P \leq 0.05$) positive GCA effects were recorded for pod yield for ICG 5195.

Under water-stress condition, highly significant ($P \leq 0.01$) negative GCA effects were recorded for ICG 12989 (-0.01) and SAMNUT 23 (-0.22) for days to 50% flowering. Highly significant ($P \leq 0.01$) negative GCA effects were recorded for ICG 5195 (-4.20), significant ($P \leq 0.05$) negative GCA effects was recorded for ICGV-IS-07813 (-6.35) for plant height while significant ($P \leq 0.01$) positive GCA effects were recorded for $RS006F_4B_1$-50 (7.22) for plant height.

Table 4.30: General combining ability effect estimates for some morphological traits of groundnut genotypes evaluated under non-stress and water-stress condition in Samaru 2019

Genotypes	DFF		PHT (cm)		NPP		SWT (g)		PWT (g/plant)	
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813(P_1)	-0.07**	-0.08	-8.42**	-6.35*	0.99	0.87	-0.03	-0.2	0.14	-0.21
RS006F4B1-50(P_2)	-0.57	0.2	10.26**	7.22*	0.2	-2.13	-1.27	-0.43*	-0.38	-0.90*
ICGV-IS-07841(P_3)	0.5	-0.08	0.57	0.87	-3.58*	-1.92	1.11*	-0.49	0.49	-0.85
ICG 12989(P_4)	0.36*	-0.01**	5.29	-2.34	0.2	0.80*	0.09	0.33	-0.92	0.52
SAMNUT 23(P_5)	0.29	-0.22**	-1.47	-1.23	-3.08*	0.65	-1.24	0.58*	-1.48*	0.65
ICG 5195(P_6)	-0.57*	-0.13	-5.31	-4.20**	4.42*	0.8	1.19	0.11	1.78*	0.06**
ICG 3312(P_7)	0.07	0.06	-0.92*	1.35	0.85	0.94*	0.15	0.33	0.36	0.72
SE ±	0.44	0.43	2.64	2.84	1.40	1.09	0.65	0.31	0.71	0.42

DFF= Days to 50% flowering, PLT = plant height, NPP= Number of pods per plant, SWT = Seed Weight, PWT= pod weight

Table 4.31: General combining ability effect estimates for some morphological traits of groundnut genotypes evaluated under combined analysis in Samaru 2019

Genotypes	DFF	PHT	NPP	SWT	Pod yield
ICGV-IS-07813(P_1)	-0.08	-7.38**	0.93	-2.82	-0.03
RS006F_4B_1-50(P_2)	-0.18	8.74**	-0.96	-0.85	-0.64
ICGV-IS-07841(P_3)	0.21**	0.72	-2.75**	0.31**	-0.18**
ICG 12989(P_4)	0.17	3.82	0.50	0.21	-0.20
SAMNUT 23(P_5)	0.03*	-1.35	-1.21	-0.33**	-0.41*
ICG 5195(P_6)	-0.22**	-4.75*	2.61*	0.54	0.92*
ICG 3312(P_7)	0.07*	0.21	0.89	0.24	0.54*
SE ±	0.24	0.96	1.08	0.52	0.62

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight, S.E= Standard Error

Number of pods per plant recorded a positive significant (P≤0.05) GCA effect for ICG 12989 (0.80) and ICG 3312 (0.94). Significant (P≤0.05) positive GCA effects were recorded for pod yield for ICG 5195 (0.06).

Result of the combined analysis is presented in Table 4.31. Highly significant (P≤0.01) negative GCA effects were recorded for ICG 5195 (-0.22), significant (P≤0.05) positive GCA effect was recorded for SAMNUT 23 (0.03) while ICGV-IS-07841 (0.21) recorded a highly significant (P≤0.01) positive GCA effects for days to 50% flowering. Highly significant (P≤0.01) positive GCA effects were recorded for RS006F_4B_1-50 (8.74), highly significant (P≤0.01) negative GCA effects was recorded for ICGV-IS-07813 (-7.38) for plant height while significant (P≤0.01) negative GCA effects were recorded for ICG 5195 (-4.75) for plant height. Number of pods per plant recorded a positive significant (P≤0.05) GCA effect for ICG 5195 (2.61) while ICGV-IS-07841 (-2.75) recorded a highly significant (P≤0.01) negative GCA effects for number of pods per plants. ICGV-IS-07841 (-0.18) recorded a highly significant (P≤0.01) negative GCA effects for pod yield. Significant (P≤0.05) negative GCA effects were recorded for seed weight for SAMNUT 23 (-0.33) while ICGV-IS-07841 recorded a significant (P≤0.05) positive GCA effects (0.31) for seed weight. Significant (P≤0.05) positive GCA effects were recorded for pod yield for ICG 5195 (0.92) and ICG 3312 (0.54) while SAMNUT 23 (-0.41) recorded significant (P≤0.05) negative GCA effects for pod yield

4.9.2 General combining ability effects for physiological traits

The estimates of general combining ability effects for physiological traits for groundnut genotypes evaluated under non-stress and water-stress conditions are presented in Table 4.32. Under non-stress condition, ICG 12989 recorded significant (P≤0.05) negative GCA effects for

SCMR 40 DAS. For SCMR 60 DAS, ICGV-IS-07841 and ICG 3312 recorded a significant (P≤0.05) positive GCA effect (1.51) and (1.47) respectively. ICGV-IS-07813 and SAMNUT 23 recorded a significant (P≤0.05) negative GCA effects (-1.42) and (-1.60). Non-significant difference was recorded for SCMR 80 DAS. However, ICG 5195 recorded the lowest negative GCA effect (-0.02) for SCMR 80 DAS. Highly significant (P≤0.01) negative GCA effects were recorded for harvest index for RS006F_4B_1-50 (-1.76) while SAMNUT 23 (-1.86) and ICG 3312 (-1.37) recorded significant (P≤0.05) GCA effect for harvest index.

Under water-stress condition, ICG-IS-07813 (3.78) and ICG 5195 (2.72) recorded highly significant (P≤0.01) positive GCA effects for SCMR 40 DAS while SAMNUT 23 (-2.44) recorded a significant (P≤0.05) negative GCA effect for SCMR 40 DAS. Non-significant difference was recorded for SCMR 60 DAS and SCMR 80 DAS. However, ICG 12989 and ICGV-IS-07813 recorded the lowest negative GCA effect (-0.09) and (-0.37) for SCMR 60 DAS and SCMR 80 DAS respectively. Significant (P≤0.05) positive GCA effects were recorded for harvest index for SAMNUT 23 (3.52), ICG 5195 (1.01) and ICG 3312 (0.38) for harvest index.

Combined analysis as presented in Table 4.33 showed that ICG-IS-07813 (2.04) recorded highly significant (P≤0.01) positive GCA effects for SCMR 40 DAS while SAMNUT 23 (-2.44) recorded a significant (P≤0.05) negative GCA effect for SCMR 40 DAS. For SCMR 60 DAS, ICGV-IS-07841 recorded a significant (P≤0.05) positive GCA effects (1.09) and (1.47) while ICGV-IS-07813 (-1.31) recorded a significant (P≤0.05) negative GCA effects. RS006F_4B_1-50 (-1.47) recorded a highly significant (P≤0.01) negative GCA effects for SCMR 80 DAS. Significant (P≤0.05) negative GCA effects were recorded for harvest index by ICGV-IS-07841 (-0.65) and ICG 3312 (-0.49) for harvest index.

Table 4.32: General combining ability effect estimates for some physiological traits of groundnut genotypes evaluated under non-stress and water-stress condition in Samaru 2019

Genotypes	SCMR 40 DAS		SCMR 60 DAS		SCMR 80 DAS		HI (%)	
	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813(P_1)	0.30	3.78**	-1.42*	-1.19	-0.32	-0.37	1.8	-1.23
RS006F_4B_1-50(P_2)	0.81	-1.68	0.37	0.44	-1.17	-1.77	-1.76**	-2.72
ICGV-IS-07841(P_3)	-0.73	-0.75	1.51*	0.67	0.47*	0.48	1.22	2.52
ICG 12989(P_4)	-0.94*	-1.88	-0.24	-0.09	-0.13	0.82	-0.81	1.55
SAMNUT 23(P_5)	-0.31	-2.44*	-1.60*	0.7	0.91	-0.7	-1.86*	3.52*
ICG 5195(P_6)	0.39*	2.72**	-0.09	0.26*	-0.02	0.23	2.79	1.01*
ICG 3312(P_7)	0.47	0.25	1.47*	-2.16	0.26	1.31	-1.37*	0.38*
SE ±	0.41	0.97	0.63	0.70	0.71	0.90	1.59	1.38

SCMR = SPAD chlorophyll meter reading, DAS=Days after sowing, HI = Harvest Index and S.E= standard error

Table 4.33: General combining ability effect estimates for some physiological traits of groundnut genotypes evaluated under combined analysis in Samaru 2019

Genotypes	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	HI
ICGV-IS-07813(P_1)	2.04**	-1.31*	-0.34	0.28
RS006F_4B_1-50(P_2)	-0.44	0.40	-1.47**	-2.24
ICGV-IS-07841(P_3)	-0.74	1.09*	0.48	-0.65*
ICG 12989(P_4)	-1.41*	-0.16	0.35	0.37
SAMNUT 23(P_5)	-1.37*	-0.45	0.10	0.83
ICG 5195(P_6)	1.56*	0.09	0.10	1.90
ICG 3312(P_7)	0.36	0.34	0.78	-0.49*
S.E ±	0.97	0.60	0.40	1.45

SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, HI = Harvest Index, S.E=Standard Error

4.9.3 Specific combining ability effects for morphological traits

The estimates of specific combining ability effects under non-stress and water-stress condition are presented in Table 4.34. Under non-stress condition, positive significant (P≤0.05) SCA effects were recorded for days to 50% flowering for RS006F_4B_1-50 x ICG 12989 (2.93) and SAMNUT 23 x ICG 5195 (2.50). For plant height at maturity, positive and highly significant (P≤0.01) SCA effects was recorded RS006F_4B_1-50 x ICG 12989 (35.11) while highly (P≤0.01) significant and negative SCA effects were recorded for ICG 12989 x SAMNUT 23 (-33.09) and a significant (P≤0.05) negative SCA effects were recorded for ICGV-IS-07813 x RS006F_4B_1-50 (-16.93) and SAMNUT 23 x ICG 3312 (-29.75). For number of pods per plant, the cross ICGV-IS-07841 x ICG 5195 recorded positive and highly (P≤0.01) significant SCA effects (12.65).

Highly significant (P≤0.01) positive SCA effects for pod yield was obtained for ICGV-IS-07841x SAMNUT 23 (5.17) while negative and highly significant SCA effects were recorded for RS006F_4B_1-50 x ICG 12989 (-5.27). Positive and highly (P≤0.01) significant SCA effects were recorded for ICGV-IS-07841 x ICG 5195 (4.85) for seed weight while a significant (P≤0.05) negative SCA effect was recorded for RS006F_4B_1-50 x ICGV-IS-07841 (-3.95). For pod yield, a highly significant (P≤0.01) positive SCA effect was recorded for ICGV-IS-07813 x ICG 12989 (5.17) and ICGV-IS-07841 x ICG 5195 (7.07) while a highly significant (P≤0.01) negative SCA effects for RS006F_4B_1-50 x ICGV-IS-07841 (-5.27) and ICG 5195 x 1CG 3312 (-4.46). A significant (P≤0.05) positive SCA effects were recorded for RS006F_4B_1-50 x SAMNUT 23 (3.85) while a significant (P≤0.05) negative SCA effect was recorded for ICGV-IS-07841 x ICG 12989 (-4.23). Under water-stress condition, positive significant (P≤0.05) SCA effects were recorded for days to 50% flowering for RS006F_4B_1-50 x ICGV-IS-07841 (2.37).

Table 4.34: Specific combining ability effect estimates for some morphological traits of groundnut genotypes evaluated under non-stress and water-stress conditions in Samaru 2019

Genotypes	Crosses	DFF		PHT		NPP		SWT		Pod yield	
		NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813 x RS006F4B1-50	P_1P_2	1.86	-0.13	-16.93*	-13.76	-3.20	-6.58*	-1.56	-1.41	-3.62	-1.99
ICGV-IS-07813 x ICGV-IS-07841	P_1P_3	-1.21	-0.35	-6.85	-6.81	0.08	-2.80	1.31	0.00	3.61	-0.69
ICGV-IS-07813 x ICG 12989	P_1P_4	-2.07	-1.42*	-0.22	-1.23	6.30	-1.51	2.83	0.17	5.17**	0.18*
ICGV-IS-07813 x SAMNUT 23	P_1P_5	0.00	1.80	-7.11	1.74	-2.92	1.63	-1.99	0.28	-3.07	0.81
ICGV-IS-07813 x ICG 5195	P_1P_6	1.36	-1.06	9.83	-2.12*	-3.92	7.49**	1.08	1.32	-0.13	1.65
ICGV-IS-07813 x ICG 3312	P_1P_7	1.36	1.86	-33.09**	-13.90	7.64	7.93	1.43	0.92	0.93	1.72
RS006F4B1-50 x ICGV-IS-07841	P_2P_3	0.29	2.37*	2.58	25.97**	-4.13	1.20	-3.95*	-0.03	-5.27**	-0.35
RS006F4B1-50 x ICG 12989	P_2P_4	2.93*	1.30	35.11**	1.80	-0.42	1.49	-0.77	0.20	0.44	0.33
RS006F4B1-50 x SAMNUT 23	P_2P_5	-1.00	-0.99	-6.28	1.22	1.87	3.13	2.55	0.31	3.85*	0.55
RS006F4B1-50 x ICG 5195	P_2P_6	-2.14	0.15	0.36	-0.91	5.87	-3.01	-1.66	0.45	-0.31	-0.16
RS006F4B1-50 x ICG 3312	P_2P_7	-0.64	-0.86	23.08	26.52*	-4.14	5.93	-1.66	0.44	-1.09	0.43
ICGV-IS-07841 x ICG 12989	P_3P_4	1.86	1.58	-1.41	7.95	-7.13	-3.72	2.50	-1.24	-4.23*	-1.62
ICGV-IS-07841 x SAMNUT 23	P_3P_5	0.43	-1.70	-3.29	-12.18	1.65	3.42	0.03	1.07	1.28	1.05
ICGV-IS-07841 x ICG 5195	P_3P_6	-1.71	-1.06*	5.34	-1.41	12.65	2.28**	4.85	0.35**	7.07**	0.49*
ICGV-IS-07841 x ICG 3312	P_3P_7	-2.07	-2.14	13.19	-2.38	-1.43	-7.36	1.31	-0.31*	-1.17	1.27*
ICG 12989 x SAMNUT 23	P_4P_5	-0.43	0.72	-1.91	-6.25	1.37	1.30	0.00	0.85	0.54	0.98
ICG 12989 x ICG 5195	P_4P_6	-0.57	-2.13	-2.08	0.42	-0.63	3.56	-0.73	-0.02*	0.28	1.32*
ICG 12989 x 1CG 3312	P_4P_7	2.29	0.93	18.56	15.54	-6.64	-0.64	-0.26	1.56	-2.33	1.60
SAMNUT 23 x ICG 5195	P_5P_6	2.50*	1.08	-3.16	6.84	-4.35	-2.30	-0.40	-0.36*	-0.86	-0.71*
SAMNUT 23 x ICG 3312	P_5P_7	0.21	0.21	-29.75*	-10.53	-7.93	-6.29	-3.74	-0.65	-5.34	-0.47
ICG 5195 x ICG 3312	P_6P_7	-0.14	1.57	-5.64	-5.00	7.07	-1.14	2.04	0.81	2.86	1.24
SE ±		1.51	1.46	7.67	9.72	9.82	3.73	2.21	1.07	4.99	1.42

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight, S.E= Standard Error

Table 4.35: Specific combining ability effect estimates for some morphological traits of groundnut genotypes evaluated under combined analysis in Samaru 2019

Genotypes	Crosses	DFF	PHT	NPP	SWT	Pod yield
ICGV-IS-07813 x RS006F4B1-50	P_1P_2	0.86	-15.35**	-4.89	-1.49	-2.81
ICGV-IS-07813 x ICGV-IS-07841	P_1P_3	-0.78	-6.83	1.36	0.65	1.46
ICGV-IS-07813 x ICG 12989	P_1P_4	-1.74*	-0.72	2.39	1.50	2.68
ICGV-IS-07813 x SAMNUT 23	P_1P_5	0.90	-2.68	-0.64	-0.85	-1.13
ICGV-IS-07813 x ICG 5195	P_1P_6	0.15	5.97	1.79	1.20	0.76
ICGV-IS-07813 x ICG 3312	P_1P_7	1.61	-23.50**	7.79	1.18	1.33
RS006F4B1-50 x ICGV-IS-07841	P_2P_3	1.33	14.28**	-1.46	-1.99	-2.81
RS006F4B1-50 x ICG 12989	P_2P_4	2.11**	18.45**	0.54	-0.29	0.38
RS006F4B1-50 x SAMNUT 23	P_2P_5	-0.99	-2.53	2.50	1.43	2.20
RS006F4B1-50 x ICG 5195	P_2P_6	-0.99	-0.27	1.43	0.19	-0.23
RS006F4B1-50 x ICG 3312	P_2P_7	-0.75	24.80**	0.89	-0.61	-0.33
ICGV-IS-07841 x ICG 12989	P_3P_4	1.72*	3.27	-5.43*	0.63	-2.93
ICGV-IS-07841 x SAMNUT 23	P_3P_5	-0.64	-7.73	2.54	0.55	1.16
ICGV-IS-07841 x ICG 5195	P_3P_6	-1.39*	-1.97	7.46**	2.60*	3.78*
ICGV-IS-07841 x ICG 3312	P_3P_7	-2.11	5.41	-4.39	0.50	-1.22
ICG 12989 x SAMNUT 23	P_4P_5	0.15	-4.08	0.04	0.42	0.76
ICG 12989 x ICG 5195	P_4P_6	-1.35	-0.83	1.46	0.38	0.80
ICG 12989 x 1CG 3312	P_4P_7	1.61	17.05*	-3.64	0.65	0.80
SAMNUT 23 x ICG 5195	P_5P_6	1.79*	1.84	-3.32	-0.38	-0.78
SAMNUT 23 x ICG 3312	P_5P_7	0.21	-20.14*	-7.11	-2.19	-2.91
ICG 5195 x ICG 3312	P_6P_7	-0.71	-5.32	2.96	1.43	2.05
SE ±		0.69	5.66	2.93	1.35	1.79

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight, S.E= Standard Error

For plant height, a highly significant (P≤0.01) positive SCA effects were recorded for RS006F_4B_1-50 x ICGV-IS-07841 (25.97) and a significant (P≤0.05) positive SCA effects were recorded for RS006F_4B_1-50 x ICG 3312 (26.52). For number of pods per plant, positive highly (P≤0.01) significant SCA effects were recorded for ICGV-IS-07813 x ICG 5195 (7.49) while ICGV-IS-07813 x RS006F_4B_1-50 recorded negative (P≤0.05) significant SCA effects (-6.58). Seed weight and pod yield recorded a significant (P≤0.05) negative and positive SCA effects for ICG 12989 x 5195 (-0.02 and 1.32) while negative significant (P≤0.05) SCA effects were recorded for SAMNUT 23 x ICG 5195 (-0.36 and -0.71) and ICGV-IS-07841 x ICG 3312 (-0.31 and -1.27).

For combined analysis (Table 4.35), days to 50% flowering recorded a positive significant (P≤0.01) SCA effects were for RS006F_4B_1-50 x ICG 12989 (2.11), a significant (P<0.05) positive SCA effects for ICGV-IS-07841 x ICG 12989 (1.72) and SAMNUT 23 x ICG 5195 (1.79) while a significant (P≤0.05) negative SCA effect was recorded for ICGV-IS-07813 x ICG 12989 (-1.74). For plant height, positive and highly (P≤0.01) significant SCA effects were recorded for RS006F_4B_1-50 x ICGV-IS-07841 (14.28), RS006F_4B_1-50 x ICG 12989 (18.45) and RS006F_4B_1-50 x ICG 3312 (24.80) while highly (P≤0.01) significant and negative SCA effects were recorded for ICGV-IS-07813 x RS006F_4B_1-50 (-15.35) and ICGV-IS-07813 x ICG 3312 (-23.50). A significant (P<0.05) positive SCA effects for ICG 12989 x ICG 3312 (17.05) while a significant (P≤0.05) negative SCA effect was recorded for SAMNUT 23 x ICG 3312 (-20.14) for plant height. For number of pods per plant, positive and highly (P≤0.01) significant SCA effects (7.46) was recorded for ICGV-IS-07841 x ICG 5195 (7.46) while a significant (P≤0.05) negative

SCA effects were recorded for ICGV-IS-07841 x ICG 3312 (-5.43). Seed weight recorded significant (P≤0.05) positive SCA effect for ICGV-IS-07841 x ICG 5195 (2.60). Pod yield Significant recorded significant (P≤0.05) positive SCA effect for ICGV-IS-07841 x ICG 5195 (3.78).

4.9.4 Specific combining ability effects for physiological traits

Specific Combining Ability Effect Estimates for some physiological traits of groundnut genotypes evaluated under non-stress and water-stress condition in Samaru are presented in Table 4.36. Under non-stress, negative highly (P≤0.01) significant SCA effects were recorded for ICGV-IS-07841 x ICG 12989 (-4.83) for SCMR at 40 DAS while a significant (P≤0.05) negative SCA effect was recorded for ICG 12989 x ICG 3312 (-3.78). For SCMR at 60 DAS, a positive highly (P≤0.01) significant SCA effects was recorded by ICGV-IS-07813 x ICG 12989 (4.55) while a highly (P≤0.01) significant negative SCA effects were recorded for ICG 12989 x SAMNUT 23(-3.81), also a significant (P≤0.05) negative SCA effect was recorded for RS006F_4B_1-50 x ICGV-IS-07841 (-3.52). Negative highly (P≤0.01) significant SCA effects were recorded for ICGV-IS-07813 x ICGV-IS-07841 (-7.26) for SCMR at 80 DAS. Under water-stress condition, negative highly (P≤0.01) significant SCA effects were recorded for ICG 12989 x ICG 3312 (11.18) while a significant (P≤0.05) negative SCA effect was recorded by ICGV-IS-07841 x SAMNUT 23 (-6.26) for SCMR at 40DAS. For SCMR at 60DAS, a negative highly (P≤0.01) significant SCA effects were recorded for ICG 5195 x ICG 3312 (-5.33). Negative significant (P≤0.05) SCA effects were recorded for ICGV-IS-07841 x SAMNUT 23 (-6.04) for SCMR at 80DAS. For harvest index, a positive significant (P≤0.05) SCA effects was recorded for ICGV-IS-07841 x SAMNUT 23 (8.04).

Table 4.36: Specific combining ability effect estimates for some physiological traits of groundnut genotypes evaluated under non-stress and water-stress conditions in Samaru 2019

Genotypes	Crosses	SCMR 40 DAS		SCMR 60 DAS		SCMR 80 DAS		HI	
		NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07813 x RS006F_4B_1-50	P_1P_2	1.07	3.99	-1.07	-1.85	-0.67	-2.46	-8.40	-5.92
ICGV-IS-07813 x ICGV-IS-07841	P_1P_3	1.71	2.88	-0.84	0.83	-7.26**	1.28	20.33**	3.88
ICGV-IS-07813 x ICG 12989	P_1P_4	0.74	0.09	4.55**	-0.70	3.14	-0.63	6.16	0.37
ICGV-IS-07813 x SAMNUT 23	P_1P_5	-0.09	2.65	-2.26	1.97	-0.32	2.42	-7.54	-2.14
ICGV-IS-07813 x ICG 5195	P_1P_6	-2.41	-4.71	-1.95	0.53	1.98	1.74	-0.22	5.49
ICGV-IS-07813 x ICG 3312	P_1P_7	-1.60	3.03	-4.36	-5.71	0.78	0.72	1.07	1.84
RS006F_4B_1-50 x ICGV-IS-07841	P_2P_3	0.36	-4.36	-3.52*	0.72	0.41	0.06	-7.75	-1.68
RS006F_4B_1-50 x ICG 12989	P_2P_4	-1.42	4.33	1.49	0.50	2.13	1.90	-2.01	0.84
RS006F_4B_1-50 x SAMNUT 23	P_2P_5	0.66	0.65	1.71	-1.04	0.7	-0.89	7.22	-1.98
RS006F_4B_1-50 x ICG 5195	P_2P_6	0.46	2.29	-0.71	-0.75	-3.04	0.10	4.97	-2.4
RS006F_4B_1-50 x ICG 3312	P_2P_7	-1.16	1.48	-3.08	1.07	-2.37	-4.29	-0.59	-5.24
ICGV-IS-07841 x ICG 12989	P_3P_4	-4.83**	-0.09	2.23	1.05	3.17	0.70	-10.39	-5.01
ICGV-IS-07841 x SAMNUT 23	P_3P_5	-2.10	-6.26*	-3.24	-2.9	1.41	-6.04*	-0.13	8.04*
ICGV-IS-07841 x ICG 5195	P_3P_6	2.20	-1.36	1.56	-1.98	-0.51	4.32	9.12*	-2.00
ICGV-IS-07841 x ICG 3312	P_3P_7	-1.63	-2.97	2.18	0.50	-3.16	-2.10	4.87	-1.47
ICG 12989 x SAMNUT 23	P_4P_5	1.85	5.2	-3.81**	-0.16	-2.52	-1.37	7.58	4.77
ICG 12989 x ICG 5195	P_4P_6	0.28	-0.98	0.95	-0.73	1.14	-1.35	-1.04	3.39
ICG 12989 x 1CG 3312	P_4P_7	-3.78*	-11.18**	-1.86	0.10	-4.01	-0.76	-1.46	5.53
SAMNUT 23 x ICG 5195	P_5P_6	-0.68	-0.77	3.01	2.86	0.88	2.45	-1.99	3.41
SAMNUT 23 x ICG 3312	P_5P_7	3.77	1.04	-2.67	1.86	5.7	0.45	-5.16	3.03
ICG 5195 x ICG 3312	P_6P_7	0.04	-1.65	-0.31	-5.33**	1.42	-0.48	4.89	2.78
SE ±		1.41	3.31	2.15	2.40	2.43	2.63	5.41	4.73

SCMR = SPAD chlorophyll meter reading, HI = Harvest Index, S.E=Standard Error

Table 4.37: Specific combining ability effect estimates for some physiological traits of groundnut genotypes evaluated under combined analysis in Samaru 2019

Genotypes	Crosses	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	HI
ICGV-IS-07813 x RS006F_4B_1-50	P_1P_2	2.53	-1.46	-1.57	-7.16*
ICGV-IS-07813 x ICGV-IS-07841	P_1P_3	2.30	0.00	-4.27**	12.10**
ICGV-IS-07813 x ICG 12989	P_1P_4	0.42	1.93	1.26	3.26
ICGV-IS-07813 x SAMNUT 23	P_1P_5	1.28	-0.14	1.05	-4.84
ICGV-IS-07813 x ICG 5195	P_1P_6	-3.56*	-0.71	1.86	2.63
ICGV-IS-07813 x ICG 3312	P_1P_7	0.72	-5.04*	0.75	1.45
RS006F4B1-50 x ICGV-IS-07841	P_2P_3	-2.00	-1.40	0.24	-4.72
RS006F4B1-50 x ICG 12989	P_2P_4	-2.87	1.00	2.02	-0.58
RS006F4B1-50 x SAMNUT 23	P_2P_5	0.66	0.34	-0.10	2.62
RS006F4B1-50 x ICG 5195	P_2P_6	1.38	-0.73	-1.47	1.28
RS006F4B1-50 x ICG 3312	P_2P_7	0.16	-1.00	-3.33	-2.92
ICGV-IS-07841 x ICG 12989	P_3P_4	-2.46	1.64	1.94	-7.70**
ICGV-IS-07841 x SAMNUT 23	P_3P_5	-4.18*	-3.07*	-2.32	3.96
ICGV-IS-07841 x ICG 5195	P_3P_6	0.42	0.21	1.90	3.56
ICGV-IS-07841 x ICG 3312	P_3P_7	-2.30	1.34	-2.63	1.70
ICG 12989 x SAMNUT 23	P_4P_5	3.53*	-1.99	-1.94	6.17*
ICG 12989 x ICG 5195	P_4P_6	-0.35	0.11	-0.11	1.17
ICG 12989 x 1CG 3312	P_4P_7	-7.48**	-0.88	-2.38	2.03
SAMNUT 23 x ICG 5195	P_5P_6	-0.72	2.94*	1.66	0.71
SAMNUT 23 x ICG 3312	P_5P_7	2.41	-0.41	3.08	-1.07
ICG 5195 x ICG 3312	P_6P_7	-0.80	-2.82	0.47	3.83
SE ±		1.70	1.32	1.56	3.79

SCMR = SPAD chlorophyll meter reading, HI = Harvest Index, S.E=Standard Error

Under combined analysis, positive significant (P≤0.05) SCA effects were recorded for SCMR at 40DAS by ICG 12989 x SAMNUT 23 (3.53), while a significant (P≤0.05) negative SCA effect were recorded for ICGV-IS-07813 x ICG 5195 (-3.56) and ICGV-IS-07841 x SAMNUT 23 (-4.18). In addition, negative and highly (P≤0.01) significant SCA effects were recorded for ICG 12989 x ICG 3312 (-7.48). For SCMR 60 DAS, a significant (P≤0.05) positive SCA effects was recorded for SAMNUT 23 x ICG 5195 (2.94) while a significant (P≤0.05) negative SCA effects were recorded for ICGV-IS-07813 x ICG 3312 (-5.04) and ICGV-IS-07841 x SAMNUT 23 (-3.07). Highly significant (P≤0.01) negative SCA effects were recorded by ICGV-IS-07813 x ICGV-IS-07841 (-4.27) for SCMR 80 DAS. For harvest index, a positive and highly (P≤0.01) significant SCA effects was recorded by ICGV-IS-07813 x ICGV-IS-07841 (12.10) while negative highly significant SCA effects were recorded by ICGV-IS-07841 x ICG 12989 (-7.70). Also, a significant (P≤0.05) positive SCA effect was recorded for ICG 12989 x SAMNUT 23 (6.17) while a significant (P≤0.05) negative SCA effects were recorded for ICGV-IS-07813 x RS006F_4B_1-50 (-7.16) (Table 4.37).

4.10 Relationship between Pod Yield with Morphological and Physiological Traits

The relationship between pod yield and other morphological traits evaluated under non-stress and water-stress are presented in Table 4.38. Under non-stress condition, number of pods per plant and seed weight had a strong positive and highly significant relationship (r = 0.67, P≤0.01; and r = 0.80, P≤0.01) with pod yield (g/plant). Seed weight had a strong positive and highly significant relationship (r = 0.50, P≤0.01) with number of pods per plant. Number of pods per plant had a moderate negative and highly significant relationship (r = -0.42, P≤0.01) was observed with days to 50% flowering. Plant height recorded a weak negative and non-significant

relationship (r = -0.07, P>0.05 and r = -0.07, P>0.05) with pod yield and seed weight. Under water-stress condition, number of pods per plant had a strong positive and highly significant relationship (r = 0.71, P≤0.01and r =0.65, P≤0.01) with pod yield (g/plant) and seed weight while moderate negative significant relationship (r = -0.34, P≤0.05) was observed with plant height. Days to 50% flowering recorded a moderate negative and non- significant relationship with number of pods per plant, pod yield and seed weight (r = -0.18, P>0.05, r= -0.14, P>0.05 and r = -0.12, P>0.05). Seed weight had a strong positive and highly significant relationship (r =0.93, P≤0.01) with pod yield (g/plant). For physiological traits Table 4.39, under non-stress condition, SCMR at 40 DAS recorded a moderate negative significant relationship with SCMR 80 DAS (r = -0.23, P≤0.05) while a moderate and highly significant relationship (r = 0.30, P≤0.05) was observed with harvest index. SCMR 80 DAS observed a moderate negative and highly significant relationship (r = -0.35, P≤0.01) with harvest index. Pod yield recorded a moderate positive and significant relationship (r = 0.24, P≤0.05 and r = 0.25, P≤0.05) with SCMR at 40 DAS and SCMR 60 DAS respectively while a high positive and highly significant relationship (r = 0.79, P≤0.01) was observed for harvest index.

Under water-stress condition, pod yield (g/plant) had a strong positive and highly significant relationship (r = 0.83, P≤0.01) with harvest index (HI). HI observed a weak negative and non-significant relationship (r = -0.05, P>0.05) with SCMR at 40 DAS while a weak positive and non-significant relationship (r = 0.06, P>0.05 and r = 0.06, P>0.05) was observed with SCMR 80 DAS and pod yield. SCMR 60 DAS observed a moderate negative and highly significant relationship (r = -0.35, P≤0.01) with HI while a weak positive and highly significant relationship (r = 0.31, P≤0.01) was observed with SCMR 80 DAS. Pod yield recorded a moderate positive and significant relationship (r = 0.45, P≤0.05) with SCMR at 60 DAS.

Table 4.38: Correlation estimates between pod yield and morphological traits evaluated under non-stress and water-stress conditions at Samaru 2019

Traits		NON-STRESS					Traits	WATER-STRESS				
		1	2	3	4	5		1	2	3	4	5
DFF	1	1.00					1	1.00	0.1	-0.18	-0.14	-0.12
PHT	2	0.24*	1.00				2		1.00	0.01	-0.07	-0.06
NPP	3	-0.42**	-0.16	1.00			3			1.00	0.71**	0.65**
PYD	4	-0.21	-0.07	0.67**	1.00		4				1.00	0.93**
SWT	5	0.01	-0.07	0.50**	0.80**	1.00	5					1.00

DFF= Days to 50% flowering, PHT = plant height, NPP= Number of pods per plant, SWT = Seed Weight and PYD= Pod yield

Table 4.39: Correlation estimates between pod yield and physiological Traits evaluated under non-stress and water-stress conditions at Samaru 2019

Traits	NON-STRESS						Traits	WATER-STRESS					
		1	2	3	4	5	6		1	2	3	4	5	6
SCMR at 40 DAS	1	1.00						1	1.00	0.04	0.06	0.02	0.06	-0.05
SCMR at 60 DAS	2	-0.03	1.00					2		1.00	0.31**	-0.04	0.45**	-0.07
SCMR at 80 DAS	3	-0.23*	0.27*	1.00				3			1.00	0.12	-0.07	-0.24*
NPP	4	0.31**	0.21	-0.15	1.00			4				1.00	0.71**	0.59**
PDYLD	5	0.24*	0.25*	-0.09	0.67	1.00		5					1.00	0.83**
HI	6	0.30**	-0.01	-0.35**	0.48**	0.79**	1.00	6						1.00

SCMR = SPAD chlorophyll meter reading, DAS= Days after sowing, NPP= Number of pods per plant PDYLD= Pod yield and HI = Harvest Index

CHAPTER FIVE

5.0 DISCUSSION

EXPERIMENT I

Understanding drought stress resistance in groundnut would help pinpointing important traits for efficient screening of germplasm to facilitate future breeding for genetic improvement. Previous studies related to drought research in groundnut have applied mainly screening under stress for yield and some agronomic traits and in areas where groundnut is not commonly grown in Nigeria. The originality of this study lie in the fact that it integrated approach of combining some agro-morphological and physiological traits to efficiently identify useful genotypes and traits of interest targeted for implementing breeding programs for drought tolerance in Nigeria especially under water stress condition. The amount of genetic improvement that can be achieved in a given set of genotypes depends on the amount of genetic variability that is present within the population (Falconer and Mackay, 1996).

In this study, significant differences observed among the genotypes for all of the traits measured under the two water conditions (non-stress and water stress), indicated the presence of appreciable variability which suggests that progress can be made through selection. The significant effect of genotypes, water conditions and the Genotype x water condition interaction for the various traits indicated that the expressions of the genotypes across the two growing water conditions were not static and non-responsive. This finding was in accordance with those of Porch *et al.*, (2009), Rezene *et al.* (2011) and Asfaw and Blair (2014) who found the similar result in common bean. The study revealed wide variation in the drought tolerance among the 107 groundnut genotypes examined.

Understanding physiological changes to improve photosynthetic efficiency in groundnut is one of the key components in the present physiological research (Long *et al*., 2006). The results on reduced chlorophyll content under drought effect in this study support the reduction in chlorophyll content observed in drought stressed *Catharanthus roseus* (Jaleel *et al*., 2008) and *Helianthus annus* (Reddy *et al*., 2004). The genotypic difference for chlorophyll content observed under water-stress condition could be attributed to the difference in their water use efficiency (Nguyen *et al*., 1997). Therefore, the genotypes showing high SPAD values under water-stress condition might show higher water use efficiency through a substantial reduction in stomatal conductance without affecting carbon assimilation rate. The lower SPAD values under water-stress condition effect in certain genotypes might be due to the production of reactive oxygen species that lead to impaired pigment biosynthetic pathways, degradation of chloroplast membrane or increased lipid peroxidation (Jaleel *et al*., 2009), and finally reduced net photosynthesis (Grzesiak *et al*., 2006).

The higher leaf chlorophyll content observed in the non-stressed condition in this study was a result of availability of moisture in the soil throughout the entire life cycle of the crop, which favors the vegetative growth and induced the plants to grow taller and produce more chlorophyll. Chaves *et al*., (2009) reported that drought stress reduces leaf chlorophyll content. However, a small chlorophyll increase (4%) has been observed under drought as well (Asfaw *et al*., 2012).

Earlier researchers have recognized the significance of LAI in photosynthesis and yield determination Jaleel *et al*., (2009). The reduction in LAI under water-stress effect observed in this study might be due to reduced PSII activity that results in rapid declines in cell division and cell size or cell death (Pandey and Shukla, 2015). Results of this study support the conclusion of

Fukai and Cooper (1995) that drought conditions can cause severe leaf rolling and reduce leaf expansion, which may potentially lower stomatal conductance and transpiration rate thereby affecting yield reduction. Genotypic variability for leaf area might be due to varied root length, transpiration rate and dehydration tolerance among the genotypes (Grzesiak *et al*., 2006). The genotypes showing higher LAI under drought treatments might acquire an ability to maintain leaf water potential through osmotic regulation and epicuticular wax load (Nguyen *et al*., 1997). Genotypes in different clusters have dissimilar attributes compared to each other.

PCA performed on the studied traits showed that the first component (PC1) positively related to all the traits measured except LAI which was negative. The second component (PC2) showed higher loadings for LAI, SCMR at 80 DAS and days to 50% flowering. PC3 positive corresponds to days to 50% flowering, SCMR at 60 and 80 DAS and LAI while, SCMR at 40 DAS and number of pods per plant were negatively related.

Under water stress, PCA performed on the studied characters analyzed showed that the first component (PC1) positively related to all the traits measured except LAI which measured negative. The second component (PC2) showed higher loadings for LAI, days to 50% flowering and SCMR at 60DAS. The third component (PC3) positively related to days to 50% flowering and SCMR at 40DAS while, SCMR at 60 and 80DAS, LAI and number of pods per plant were negatively related. Thus, the six studied traits were able to discriminate the 107 investigated genotypes, into distinct groups.

Cluster analysis also explains the nature and level of genetic diversity among the genotypes. The level of genetic diversity was high based on the pattern of the convergence and divergence of the

genotypes. Cluster II consist of most of the drought tolerant genotypes although some were all found in cluster I and III under water-stress condition.

EXPERIMENT II

Plant breeding research with self-pollinating individuals have been traditionally performed with single crosses between any two (2) parents, followed by development of segregating populations. This method generally results in reasonable amount of genetic variability needed for selection and attaining homozygosity. In this study; a 7 x 7 diallel mating design Model II was used to develop segregating populations which were evaluated using randomized complete block design with 2 replications. The results of this evaluation revealed a significant difference among the genotypes for both morphological and physiological traits measured under the two water conditions at individual and combined analysis. This indicates the presence of appreciable variability in them which is a pre-requisite for any crop improvement program.

The significant differences observed for water conditions for all traits measured under the two conditions except SCMR at 40 DAS, SCMR at 60 DAS and LAI under non-stress condition indicates that the conditions in the two water conditions were not similar in many respects and that is why the genotypes did not perform in same like manner. Similar results were reported by Mhike *et al*., (2011) who found out those environmental differentials could be an indication that the environments were unique. The genotype × condition interactions were significant for all traits thus, indicating that suitable hybrids could be developed for specific environments. This was in agreement with the findings of Showemimo *et al.* (2000) who reported performance or expression of genes controlling maize characters to be strongly influenced by environmental variation.

Combined analysis of variance showed highly significant (P≤0.01) difference among the seven parents, twenty-one (21) progenies and two (2) checks for all the traits recorded, indicating that genetic variation exists for these traits and, thus, that heritability could be estimated. The interaction effects of G x C were significant for (P≤0.05) pod yield and HI. In theory, pod yield is a complex trait in which multiple genes are involved, and high G x E interaction is expected (Wright *et al*., 1996). Based on low co-efficient of variation and high *F*-ratio from the analysis of variance, the best assessment time for SCMR was determined to be 60DAS.

The mean performances of the parents and progenies for the traits studied under non-stress and water-stress at individual and across conditions show similar trend. The wide variability observed for pod weight implied that there is ample opportunity for selection for improvement of this important economic character. Most of the crosses produced more pods per plant as compared to the parents. This showed that genes controlling pod yield in the parents contributed favourably in the crosses. It also showed that the parents that differ in their genetic background combined well and produce promising crosses. Similar findings were reported by Jogloy *et al.* (2011) and Shamsideen (2016). Generally, pod yield varied appreciably among the progenies in each condition and across conditions. Under non-stress condition, the top ranking hybrid for pod yield was P_2 x P_6 which out-yielded the checks by (36%-63%). Under water-stress condition, the top ranking hybrid for grain yield was P_2 x P_6 and it under-yielded the check by 43%. Across the conditions, the top-ranking hybrids for pod yield were P_5 x P_6 and P_5 x P_7 and it out-yielded the check by 11%.

Overall, the pod yield was reduced by 60% under water-stress conditions, as a result of reduced plant height and number of pods per plant and increased days to 50% flowering. Similar results were reported by Betran *et al*., (2003a) who reported yield reductions of 13% to 50% under severe drought stress, respectively, in one site and of 5 to 48% in another site during the same season. Banziger *et al*., (2006) also reported yield reductions under drought stress at flowering of 30-65% and under drought stress at grain filling of 50% in maize.

Effectiveness of selecting and assessing the potential worth of a genotype depends on the magnitude of genetic variability in a particular character. It is therefore necessary to study variability with respect to quantitative characters from components of variation. An assessment of heritable and non-heritable components of the total variability observed is indispensable in adopting suitable breeding procedure. The heritable portion of the observed variation can be ascertained by estimating the heritability. In this study, the PCV was greater than GCV for all studied traits in the genotypes under the both conditions. These results indicated that the environment had an important role in the expression of these traits. Therefore, there is enough scope for selection based on these traits and the diverse genotypes can provide materials for a sound breeding program. These results are in a harmony with those obtained by Shakoor *et al*. (2007), Hefny (2011) and Nagabhushan *et al*. (2011). Similar results have been reported by Bello *et al*., (2012). High values of GCV and PCV were also obtained for plant height, number of pods per plant, pod yield, seed weight and HI under non-stress and water-stress indicates the presence of high variability for these traits and provides ample scope for selection of superior and desired genotypes which is in conformity with the findings of Abhirami *et al.* (2005) and Pradeepa (2007). On the other hand, very low values of PCV and GCV were recorded for SCMR

40DAS, SCMR 60DAS, days to 50% flowering and hundred-seed weight under the three conditions revealed that the variability among the genotypes was very low for these traits.

The most important function of heritability in genetic study of quantitative characters is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Al-Tabbal and Al-Fraihat, 2012). The high broad-sense heritability obtained for some of these traits (seed weight, pod yield, plant height and hundred seed weight) revealed that variations were transmitted to the progeny and indicated potential for developing high yielding varieties through selection of desirable plants in succeeding generations. These results were in agreement with those of Aminu and Izge (2012).

The broad sense heritability of SCMR at 40DAS and days to 50% flowering increased with increasing drought stress, whereas, that of number of pods per plant, seed weight, hundred seed weight, SCMR at 60 and 80DAS and harvest index decreased with increasing drought stress. An increase in error variance under water stress condition has been reported to cause decrease in heritability estimates (Hulmel *et al*., 2005), which was similar to the results obtained in this study. Decreased heritability for these traits under stress conditions were reported earlier by Bolanos and Edmeades (1996). The decreased heritability for traits under stress indicates the need for selection of genotypes under specific environmental conditions for rapid genetic improvement. Heritability for plant height and pod yield was moderate GCV in relation to the mean were low under non-stress condition, suggesting that these traits cannot be improved substantially. These finding agrees with the work of Gravois and Milligan (1992).

Investigation of the influence of different genetic systems can facilitate a better understanding of the nature of gene interactions that could influence drought tolerance (Guo *et al*., 2017). The significance of mean squares of GCA for most of the traits (even though some parents had positive values and other had negative values) reported in this study under the different conditions suggested the prevalence of additive variance for these traits. The significant SCA mean squares detected in this study under the two conditions suggested that dominance variance was important for these traits. These results are in general agreement with those reported by Aminu and Izge (2013) and Badu-Apraku *et al*., (2013). The fact that both additive and non-additive gene actions were important in genetic control of most traits studied under the different conditions means that there is tremendous amount of variability in the genetic materials evaluated, confirming the results of Aminu and Izge (2013), Bello and Olaoye (2009) and Olaoye *et al.,* (2005). Even though, additive and non-additive gene actions were responsible in the genetic control of most traits, the comparative variance due to GCA and SCA revealed the predominance of non-additive gene action for majority of the traits. This corroborate with the findings of Mohammed (2009) and Meseka *et al*. (2006).

Significant effects ($P \leq 0.05$) between both GCA and SCA x water conditions, for pod yield and some traits indicate that the assessment of water-stress and non-stress progenies favor identification of variability among genotypes. This variability may be related to additive (gi) and/or non-additive (sij) genetic effects. However, the significant interaction (SCA) progenies x water condition reduce the relationship between phenotype and its genotype, restricting the validity of inferences about the behavior, from the viewpoint of breeding and inheritance of quantitative traits (Li *et al*., 2000). In work with Eucalyptus clones by Vellini *et* al. (2008)

subjected to different water conditions, significant differences were found among both clones and water conditions for most morphological and physiological traits.

The ratio of GCA to SCA variance also portrays the importance and the predominance of non-additive genetic effects because the SCA variance was higher than the GCA variance and all of the ratios were less than unity, confirming the results of Aminu and Izge (2013), Majid *et al*. (2010). However, the results contradict the view reported by Sharma *et al*. (2004) who found the preponderance of additive genetic effects in the control of most traits in maize. The expression of the traits being controlled by non-additive genes in this study has an implication in breeding in that good parent cannot be identified using these traits; instead good specific combiners are the ones that can be selected for. The genotypes used in this study can therefore be exploited under drought conditions through targeting the SCA effects.

Heritability estimates in broad sense and narrow sense for physiological traits followed a similar trend to those for morphological traits related to drought resistance. However, narrow sense heritability estimates for physiological traits were somewhat higher than those for morphological traits related to drought resistance implying that the use of physiological traits as surrogate traits for pod yield in this population may be effective. Therefore, better improvement for these traits would be expected especially where they reveal higher narrow sense heritability.

The ratio of GCA to SCA variance also portrays the importance and the predominance of non-additive genetic effects because the SCA variance was higher than the GCA variance and most of the ratios were less than unity, confirming the results of Aminu and Izge (2013) and Majid *et al*. (2010). However, the results contradict the report by Sharma *et al*. (2004) who found the preponderance of additive genetic effects in the control of most traits in maize. The expression of

the traits being controlled by non-additive genes in this study has an implication in breeding in that good parent cannot be identified using these traits; instead good specific combiners are the ones that can be selected for. The genotypes used in this study can therefore be exploited under drought conditions through targeting the SCA effects.

The GCA effects of parents under non-stress and water-stress conditions exhibited variation both in direction and magnitude. The combining ability effects revealed that different parents were general combiners for different traits under different conditions. In this study negative GCA effects were desirable for traits such as days to 50% flowering, plant height while in the case of other characters like pod yield, number of pods per plant, seed weight, 100-seed weight, SCMR at 40, 60 and 80DAS and HI positive GCA effects are most desirable. The parent P_6 (ICG 5195) showed consistency in its performance exhibiting good GCA effects for pod yield under the two conditions and combined analysis. This genotype was also a good general combiner for other traits including days to 50% flowering, plant height and number of pods per plant was consistent in its GCA effects under the two conditions and combined analysis, again proving to be a good general combiner for pod yield and other traits under water-stress condition. Early flowering are needed for crop early harvest, while shorter heights are required for lodging resistance. Hence, it is the best general combiner.

On the other hand, the negative significant GCA effect observed for P_1(ICGV-IS-07813), P_4 (ICG 12989) and P_5 (SAMNUT 25) for days to 50% flowering and plant height under water-stress condition makes them the best general combiner for these traits while the significant positive GCA effect observed in P_4, P_5 and P_7 as the best general combiner for number of pods per plant, seed weight, SCMR at 40 and 60 DAS and HI under water stress and combined

analysis . These genotypes could be considered as good combiners for yield and most of the yield attributing traits under different conditions. These parents could therefore be utilized for pure line selection or pedigree selection, or an elite breeding population by allowing thorough mixing among them to achieve novel genetic recombination and the resultant populations could then be subjected to recurrent selection. These populations could invariably serve as a source of new desirable hybrids.

The effect of the specific combining ability is interpreted as the deviation of a cross compared to what would be expected based on the GCA of their parents (Griffing, 1956).When the values are positive and negative; there is evidence of bidirectional dominance. Therefore, there are genes that enhance the expression of the traits and others, equally dominant, that reduce it. Hybrids (P_1 x P_4) and (P_3 x P_6) were good specific combiners as indicated by significant positive SCA effects for pod yield under the three conditions. Other traits with significant SCA effect for (P_1 x P_4) were days to 50% flowering, number of pods per plant and seed weight under combined condition, (P_3 x P_6) for number of pods per plant and seed weight under non-stress condition. Hybrids with significant positive SCA effects for pod yield are (P_3 x P_7, P_1 x P_4, P_3 x P_7, P_4 x P_6) under water-stress and P_3 x P_6 under combined condition. However, (P_1 x P_4 and P_1 x P_6) observed a negative significant SCA effects for days to 50% flowering and plant height under water-stress while (P_1 x P_4, P_1 x P_2 and P_1 x P_7) under combined condition. Negativity of these traits is important, implying that these hybrids could mature earlier and could escape drought. Similar results were reported by Aminu and Izge (2013). For physiological traits, significant positive SCA effect observed for P_3 x P_5 for HI under water-stress condition, P_1 x P_3 and P_4 x P_5 under combined condition; P_4 x P_5 and P_5 x P_6 for SCMR at 40 and 60 DAS. This suggests that

these hybrid combinations may exhibit favorable factors that enable continued plant growth and development, even in adverse conditions of water availability.

Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters; it resolves the complex relationship between characters into simple form of association (Channayaa, 2009). When correlation exists between any two characters, a selection for one character will lead to corresponding change in the other correlated character. The relationship between pod yield and physiological traits related to drought tolerance were from non-significant ($P>0.05$) to highly significant ($P\leq0.01$), positive and negative. Under non-stress condition, moderate positive significant ($P\leq0.05$) relationship was observed between SCMR at 60 DAS and pod yield; this means that knowing the value of SCMR at 60 DAS gives little information for predicting pod yield in groundnut under non-stress condition. HI and number of pods per plant had a strong positive and highly significant ($P\leq0.01$) relationship with pod yield; this means that knowing HI and number of pods/plant gives a greater accuracy prediction of pod yield. This study supports the earlier study conducted by Jogloy *et al*. (2011) on strong and positive relationship between HI and number of pods/plant with pod yield. Under water-stress, SCMR at 60 DAS had a moderate positive significant ($P\leq0.05$) with pod yield. This means that, understanding the values of SCMR at 60 DAS in groundnut gives some important information about pod yield under water-stress condition. HI and number of pods per plant had a strong positive and highly significant ($P\leq0.01$) relationship with pod yield. Understanding the values of HI and number of pods per plant gives accuracy information on pod yield in groundnut. This study supports the previous study which obtained significant relationship between SCMR at pod yield (Boontang *et al*., 2010). Positive and highly significant

relationship between SCMR at 60 DAS, which is an indirect measure of chlorophyll density and pod yield under water stress condition, means groundnut genotypes with high SCMR could maintain higher photosynthetic capacity, added with thicker leaves which influence carbon exchange rate and chlorophyll content and therefore leads to high pod yield. The higher significant correlation between SCMR 60 DAS with number of pods per plant and pod yield under water-stress condition compared to non-stress condition, means SCMR can be used in breeding programs. Strong positive and highly significant relationship between HI and number of pods per plant and pod yield implies that genotypes with high HI and number of pods per plant under water-stress had high pod yield. Such results imply that, HI is the relative distribution of photosynthesis products between commercial sinks and other existing sinks in the plant. Therefore this can be used in breeding program as a selection criterion in drought tolerance breeding programs Philipo *et al*. (2016).

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Plant breeding research with self-pollinating individuals have been traditionally performed with single crosses between any two (2) parents, followed by development of segregating populations. This method generally results in reasonable amount of genetic variability needed for selection and attaining homozygosity. In this study; one hundred and seven (107) genotypes were screened in a randomized complete block design (RCBD) experiment under non-stress and water-stress conditions during 2018 dry season. Seven (7) genotypes (ICGV-IS-07813, RS006F_4B_1-20, ICGV-IS-07841, ICG 12989, SAMNUT 23, ICG 5195 and ICG 3312) were selected based on PCA ranking and a 7 x 7 Diallel Mating Design Model II was used to develop segregating population. The 21 F_1s, 7 parents and 2 checks were evaluated in the screen house of the Department of Plant Science, Institute for Agricultural Research (IAR) Samaru, Ahmadu Bello University Zaria, during the 2018/2019 dry season. The experiment was laid out in a randomized complete block design with two replications. Data were collected on some morphological and physiological traits along with *drought* tolerant indices. Data were analyzed using SAS (2002) following RCBD and Diallel design model II.

Significant genetic variations were observed for most of the morphological and physiological traits studied under non-stress, water-stress conditions and combined analysis indicated the presence of appreciable variability among the genotypes which is a pre-requisite for any crop improvement program. The results of this study also showed progenies that were tolerant to

drought with superior morphological and physiological traits such as good pod yield and SCMR at 60 DAS.

The entry mean broad-sense heritability estimates were high to moderate for most studied characters. This gave an indication of the importance of additive gene effects governing these characters and selection for genetic improvement would be worthwhile. Broad sense heritability was high for plant height and seed weight under combined analysis. This revealed that variation were transmitted to the progeny and indicated potential for developing drought tolerant varieties with improved morphological features, through selection of desirable progenies in succeeding generations.

Generally, pod yield varied appreciably among progenies in each condition and across conditions. Under non-stress, the top ranking hybrid for pod yield was P_2 x P_6 and out-yielded the checks by (36%-63%). Under water-stress, the top ranking hybrid for pod yield was P_2 x P_6 and it under-yielded the check by 43%. Across the conditions, the top-ranking hybrids for pod yield were P_5 x P_6 and P_5 x P_7 and it out-yielded the check by 11%. Overall, the pod yield was reduced by 60% under water-stress conditions, of which the average yield would have been in the same environment under non-stress condition.

In this study, SCMR at 60 DAS, number of pods per plant and HI were found to be positively and significantly correlated to pod yield under both water conditions.

6.2 Conclusions

It is concluded from this study that the success of hybridization in a breeding program depends on the choice of distant parental lines. Based on the PCA ranking, sixty-two (62) genotypes were considered to be drought tolerant and forty-four (44) were considered drought susceptible.

Most of the traits are controlled by both additive and non-additive gene action. Narrow sense heritability estimates were much lower than broad sense heritability estimates and they were expected to be under estimated because of high-intra plant variation in the F_2 population.

For effective selection of genotypes tolerant to drought, and association of drought tolerant traits with pod yield due to the effect of morphological and physiological traits is very important. Therefore, SCMR at 60 DAS and HI could be used as an indirect selection for pod yield under drought stress condition.

6.3 Recommendations

Crosses that involve parents selected from the clusters characterized by maximum genetic distance are expected to result in maximum genetic recombination and variation in subsequent generations. Therefore, hybridization between genotypes selected from clusters I and IV under stress condition will provide the maximum genetic recombination and variation for drought tolerance.

It is further recommended that ICGV-IS-07813 x ICG 5195 and ICG 12989 x ICG 5195 should be further advanced by pedigree method or single seed descent to develop superior groundnut genotypes that are drought tolerant.

Advanced screening protocol for drought and the study of root architecture should be used in identifying superior genotypes. The genotypes identified should be further evaluated in drought prone areas of Nigeria to ascertain their stability. Such breeding effort may lead to the development of morphologically and physiologically superior groundnuts that are drought tolerant.

To fully exploit drought tolerance discovered in these genotypes, identification of DNA markers would be useful in the transfer of the tolerant genes to commercially useful backgrounds.. As there were high inter-correlation among physiological traits and pod yield, evaluation of SCMR at 60 DAS alone is sufficient for cultivar development because it will be more simple, economical and less time-consuming.

On the other hand, selection for SCMR at 80 DAS, 100 seed weight, HI and days to 50% flowering may be difficult in early segregating generation and evaluation should be carried out in more advanced generations.

REFERENCES

A.B.U. (Ahmadu Bello University), (2018). Zaria at a glance, 25th September, 2018. www.abu.edu.ng/info/zaria.php.

Abhirami, S., Vanniarajan, C. and Arumugachamy, S. (2005). Genetic variability studies in maize (*Zea mays*) germplasm. *Plant* Archives, 5(1); 105-108. Acquaah, G. (2007). Principles of Plant Genetics and Breeding. Blackwell Publishers Ltd. Pp.128.

Acquaah, G. (2007). Principles of Plant Genetics and Breeding. Blackwell Publishers Ltd. Pp.128.

Acquaah, G. (2007). *Principles of plant genetics and breeding*. Oxford, UK: Blackwell publishing Ltd, 146-151.

Ajeigbe, HA, Waliyar F, Echekwu C. A, Ayuba K., Motagi, B.N., Eniayeju D. and Inuwa A. (2014). A Farmer's Guide to Groundnut Production in Nigeria. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 36 pp.

Akram, M.(2011). Growth and yield components of wheat under water-stress of different growth stages. *Bangladesh Journal of Agricultural Research*. 36: 455-468.

Albert, A. (2014). Analysis of genetic diversity of some groundnut (*Arachis hypogeae* L.) genotypes using principal component analysis. A thesis submitted to the School of Postgraduate Studies, inpartial fulfilment of the requirements for the award of Degree of Master of Science in Plant Breeding. Ahmadu Bello University Zaria, Nigeria.

Alicja, K.W. (2013). The use of cluster analysis in the classification of similarities in variables associated with agricultural greenhouse gases emissions in OECD countries. *Poland Journal of Countryside and Agriculture,* 1(158): 59-66.

Allen, L. H. Jr., Boote, K. J., and Hammond, L. C. (1976): Peanut stomatal diffusive resistance affected by soil water and solar radiation. *Proceedings Soil and Crop Science Society of Florida.*, 35: 42–46.

Almeselmani, M., Saud, A., Harere, F., Al-Nasan M., Ammar, M.A, Kanbar, O.Z. and Al-Nassef, H. (2012). Physiological traits associated with drought tolerance of Syrian durum wheat varieties under rainfed condition. *Indian Journal of Plant Physiology*, 17(2): 166-169.

Al-Tabbal, J. A. and Al-Fraihat, A. H. (2012). Genetic variation, heritability, phenotypic and genotypic correlation studies for yield and yield components in promising barley genotypes. *Journal Agricultural Science*, 4(3): 193-210.

Al-yassin, A., Grando, S., Kafawin, O., Tell, A. and Ceccarelli, S. (2005). Heritability estimates in contrasting environments as influenced by the adaptation level of barley germplasm. *Annals of Applied biology*, 00: 1-10.

Aminu, D. and Izge, A. U. (2013). Gene action and heterosis for yield and yield traits in maize (*Zea mays* L.), under drought conditions in Northern guinea and Sudan savannas of Borno State, Nigeria. *Peak Journal of Agricultural Sciences*, 1(1): 17-23.

Aminu, D. and Izge, A.U. (2012). Heritability and correlation estimates in maize (*Zea mays* L.) under drought conditions in Northern Guinea and Sudan Savannas of Nigeria. *World Journal of Agricultural Sciences*, 8(6): 598-602.

Anand, I. J. and Murrty, B. R. (1968). Genetic divergence and hybrid performance in linseed. *Indonesian Journal of Plant Breeding*. 28: 178-185.

Aremu, M.O., Olaofe, O. and Akintayo, E.T. (2007). Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelatin properties. *Journal of Food Technology*, 5(2): 109-115.

Arya, S.S., Chauhan, S. and Akshata, R.S.(2015). Peanuts as functional food: A review. *Journal of Food Science and Technology*, 53(1): 1-30.

Asfaw, A. and Blair, M.W.(2014). Quantification of drought tolerance in Ethiopian common bean varieties. *Journal of Agricultural Science*, 5: 124-139.

Asibuo, J.Y., Akromah, R., Adu-Dapaah H.K and Safa-Kantanka, O.(2008). Evaluation of nutritional quality of groundnut (*Arachis hypogaea* L.) from Ghana. *African Journal of Food, Agriculture Nutrition and Development*, 8(2): 133-150.

Atasie, V.,N., Akinhanmi, T.F. and Ojiodu, C.C. (2009). Proximate analysis and physic-chemical properties of groundnut (*Arachis hypogaea* L.). *Pakistan Journal of Nutrition*, 8: 194-197.

Atif, I.A., Awadalla, A.A., Mutasim, M.K., Atif, E.I. and Abdellatif, M.O. (2012). Combining ability and heterosis for yield and yield components in maize (*Zea mays* L.). *Austalian Journal of Basic and Applied Sciences*, 6(10): 36-41.

Badu-Apraku, B., Oyekunle, M., Akinwale, R. O. and Aderounmu, M. (2013). Combining ability and genetic diversity of extra-early white maize inbreds under stress and non-stress environments. *Crop Science*, 53: 9-26.

Baker, R.J., (1978). Issues in Diallel Analysis. *Journal of Crop Science*, 18: 533-536.

Bansal, U.K., Satija, D.R., and Gupta, V.P. (1991). Combining ability for yield in inter and intragrowth habit crosses in groundnut. *Tropical Agriculture*, 68: 71-73.

Banziger, M., Setimela, P.S., Hodson, D. and Vivek, B. (2006). Breeding for improved abiotic stress tolerance in Africa in maize adapted to Southern Africa. *Journal of Agricultural Water Management*, 80: 212-214.

Basbag, S., Ekinci, R. and Gencer, O. (2007). Combining ability and heterosis for earliness characters in line × tester population of *Gossypium hirsutum* L. *Hereditas*, 144: 185-190.

Bello, O. B., Ige, S. A., Azeez, M. A., Afolabi, M. S., Abdulmaliq, S. Y. and Mahamood, J. (2012). Heritability and genetic advance for grain yield and its component characters in Maize (*Zea Mays* L.). *International Journal of Plant Research*, 2(5): 138-145.

Bello, O.B. and Olaoye, G. (2009). Combining ability for maize grain yield and other agronomic characters in a typical Southern Guinea Savanna ecology of Nigeria. *African Journal of Biotechnology*, 8(11): 2518-2522.

Bennett, J. M., Sexton, P. J. and Boote, K. J.(1990). A root tube-pegging pan apparatus: preliminary observations and effects of soil water in the pegging zone. *Peanut Science*, 17: 68–72.

Betran, F. J., Beck, D., Banziger, M and Edmeades, G. O. (2003). Genetic analysis of inbred and hybrid grain yield under stress and non-stress environments in tropical maize. *Journal of Crop Science*, 43: 807-817.

Bhagsari, A.S., Brown, R.H. and Schepers, J.S. (1976). Effect of Moisture Stress on Photosynthesis and Some Related Physiological Characteristics in Peanuts, *Journal of Crop Science*, 16: 712–715.

Bolanos, J. and Edmeades, G. O. (1996). The importance of anthesis-silking interval in breeding for drought tolerance in tropical maize. *Field Crops Research*, 48: 65-80.

Boontang, S., Girdthai, T., Jogloy, S., Akkasaeng C., Vorasoot, N., Patanothai, A., and Tantisuwichwong, N. (2010). Responses of released cultivars of peanut to terminal drought for traits related to drought. *Asian Journal of Plant Sciences*, 9: 423-431.

Boontang, S., Songsri, P., Jogloy, S., Akkasaeng, C., Vorasoot, N., Tantisuwichwong, N. and Patanothai, A.(2010). Evaluation of peanut cultivars commonly grown in Thailand under water limited conditions. *Asian Journal of Plant Sciences*, 9(6): 320-328.

Boote, K. J. and Ketring, D. L. (1990): Peanut. In: Stewart, B. A., Nielson, D. R. (eds.), *Irrigation of Agricultural Crops*. ASA-CSSA-SSSA, Madison.

Boote, K.J. and Ketring, D.L. (1990). Peanut. In: Stewart B.A. And Nielson D.R. (Eds), Irrigation of Agricultural Crops. Asa- Groundnut - A Global Perspective. *International Crops Research* CSSA-SSSA, Madison. 7: 35-42.

Channayya, H. (2009) Traits in Groundnut (*Arachis hypogaea* L.). Thesis submitted to the University of Agricultural Sciences, Dharwad in partial fulfilment of the requirements for the degree of Master of Science (Agricultural) In Genetics and Plant Breeding. 7(11): 1408-1420.

Chaudhary, R.R. (2001). Genetic variability and heritability in sugarcane. *Nepal Agricultural Research Journal,* 4 and 5: 56-59.

Chaves, M.M., Flexas, C. and Pinheiro, C.(2009). Photosynthesis under drought and salt stress:regulation mechanisms from whole plant to cell. *Annual Journal of Botany,* 100: 551-560.

Christie, B.R. and Shattuck V.I. (1992). The Diallel Cross: Design, Analysis, and Use for Plant Breeders. In: *Plant Breeding Reviews,* 9: 9-36.

Cohen, J., Cohen P., West S.G., and Aiken L.s., (2003). Applied Multiple Regression/Correlation Analysis for Behavioural Sciences, Third Ed. Lawrence Erlbaum Associates, Inc., 100(19): 104-109.

Cohen, L., Manion, L. and Morrison, K. (2000). Research methods in education (5^{th} Edition). London: Routledge Falmer, 8: 1-6.

Coulibaly, A. M. (2013). genetic analysis of earliness and drought tolerance in groundnut (*Arachis hypogaea* L.) in niger. A thesis submitted to the University of Ghana, Legon in partial fulfilment of the requirement for the award of PhD Plant Breeding degree.

Dabholkar, A.R. (1992). *Elements of Biometrical Genetics*. Concept Publishing Company. New Delhi, India, pp: 138-140.

Devaiah, M. K., Hemanth K. N., Vasanthaiah, Ramesh Katam A. A., Sheikh Basha M. and Karamthotsivasankar N. (2011). Impact of Drought Stress on Peanut (*Arachis hypogaea* L.) Productivity and Food Safety, Plants and Environment, Dr. Hemanth Vasanthaiah (Ed.),ISBN:978-953-307-779-6,InTech,Availablefrom: http://www.intechopen.com/books/plants-and-environment/impact-of-drought-stress on peanut-(*Arachis hypogaea* L.)-productivity-and-food-safety.

Edema N.E.(2014) Effects of Climate Change Critical Factors on the Seedling Growth and Development of Maize (*Zea mays* L.).*Naeem et al.; IJPSS, 6(1): 1-9, 2015; Article no.IJPSS.2015.0917*. *American Journal of Experimental Agr*iculture, 4(12): 1649-1657.

El-Tayeb, M.A., El-Enany, A.E. and Ahmed, N.L.(2006). Salicylic acid-induced adaptive response to copper stress in sunflower (*Helianthus annus* L.). *International Journal of Botany*, 2: 372-379.

Fageria, N.K., Moreira, A. and Coelho, A. M. (2011). Yield and Yield Components of Upland Rice as Influenced by Nitrogen sources. *Journal of Plant Nutrition*, 34: 361–370.

Falconer, D.S. and Mackay, T.F.C. (1996). *Introduction to Quantitative Genetics*, Ed 4. Longmans Green, Harlow, Essex, UK. 167(4): 1529-1536.

FAO (2008). Food and Agricultural Organization of the United Nation, FAO Statistical Database http://faostat.fao.org

FAO (2018). Food and Agricultural Organization of the United Nation, FAO Statistical Database. http://faostat.fao.org.

Fedrick, H.L.(2013) in Proteomic and Metabolomic Approaches to Biomarker Discovery: *Chapter 19- Multivariate Analysis for Metabolomics and Proteomics Data*. Pp 299-311.

Fukai, S. and Cooper, M. (1995). Development of drought resistant cultivars using physio-morphological traits in rice. Field crops research, 40, 67-86. http://dx.doi.org/10.1016/0378-4290(94)00096-U.

Gomez, K.A. and Gomez A.A. (1984). Statistical procedures for agricultural research. 2nd edition. John Wiley and Sons, New York. 2(3): 124-128.

Gowda, A. and Hegde, B.R. (1986). Moisture Stress and Hormonal Influence on The Flowering behavior And Yield Of Groundnut, *Journal of Plant Physiology*, 66: 835–837.

Gowda, A. and Hegde, B. R. (1986): Moisture stress and hormonal influence on the flowering behavior and yield of groundnut (*Arachis hypogaea* L.). *Madras Journl of Agriculture*, 73: 82–86.

Gravois, K.A. and Milligan, S,B. (1992). Genetic relationship between fibre and sugarcane yield components. *Crop Science*, 32(1): 62-67.

Gregory, W. C., Krapovickas, A. and Gregory, M. P. (1980). Structure, variation, evolution and classification in *Arachis*. Pp 409-411. In: *Advances in Legume Sciences*. Royal Botanic Gardens, London, pp. 469-481.

Griffing, B. (1956) Concept of general and specific combining ability in relation to diallel crossing system.Australian *Journal of Biology*, 9: 463–493.

Grzesiak, M.T., Grzesiak S. and Skoczowski, A. (2006). Change of leaf water potential and gas exchange parameters during and after drought in triticale and maize genotypes differing in drought tolerance. *Photosynthetica*, 44: 561-568.

Guo, Y., Chen, X., Zhao, S., Zhu, C. and Chang, X. (2017). Identification of drought-responsive miRNAs and physiological characterization of tea plant (*Camellia sinensis* L.) under drought stress. *BMC Plant Biology*, 17: 211-218.

Hair, J. F., Jr., Anderson, R. E., Tatham, R. L. and Black, W. C.(1995). *Multivariate Data Analysis*, 3rd edition, Macmillan Publishing Company, New York. https://en.wikipedia.org/wiki/Ward%27s_

Hallauer, A.R., and Miranda-Filho, J.B. (1988). Quantitative Genetics in Maize Breeding. Second edition. Iowa State University Press, Ames, Iowa. pp. 663.

Hallauer, A.R., Carena, M.J., and Miranda-Filho, J.B. (2010). Quantitative Genetics in Maize Breeding: Handbook of Plant Breeding. Springer, New York. pp. 663.

Hamidou, F., Halilou, O., and Vadez, V. (2013). Assessment of groundnut under combined heat and drought stress. *Journal of Agronomy and Crop Science*, 199(1): 1-11.

Hasan, M. A, Ahmed, J. U, Hossain, T., Mian, M. A. K., Haque, M.M. (2013). Evaluation of the physiological quality of wheat seed as influenced by high parent plant growth temperature. *Journal of Crop Science and Biotechnology*, 16: 69-74.

Hefny, M. (2011). Genetic parameter and path analysis of yield and its components in corn inbred lines (*Zea mays* L.) at different sowing dates. *Asian Journal of Crop Science*, 3(3): 106-117.

Holbrook, C.C. and Stalker, T. (2003). Peanut breeding and genetic resources. Plant Breed Revision;22:297–356. http://dx.doi.org/10.1002/9780470650202.ch6. (*Arachis hypogaea* L.) most susceptible to environmental stress. *Tropical Agriculture (Trinidad),* 68: 296–300.

Hulmel, M.B., E. Heumez, P. Pluchard, D. Beghin, C. Depatureaux, A. Giraud and Le Gouis, J. (2005). Indirect versus direct selection of winter wheat for low-input or high-input levels. *Crop Science*, 45: 1427-1431.

ICRISAT (2017). Annual Report. International Crop Research Insti tute for Semi-arid Tropics, Patancheru, India.

Isleib, T.G., Wynne, J.C., Elkan, G.H. & Schneeweis, T.J. (1980). Quantitative genetic aspects of nitrogen fixation in peanuts (*Arachis hypogaea* L.). *Peanut Science*, 7: 101-105.

Jajarmi V. (2002). Effect of water stress on germination indices in seven wheat cultivar. *World Academy of Science and Engineering Technology*, 49: 105-106.

Jaleel, C.A., Gopi, R. and Panneerselvam, R. (2008). Differential responses in water use efficiency in two varieties of *Cantharanthus roseus* under drought stress. *Comptes Rendus Biologies*, 331: 42-47.

Jaleel, C.A., Manivannan, P., Wahid, A., Farooq, M., Somasundaram, R. and Panneerselvam, R. (2009). Drought stress in plants: A review on morphological characteristics and pigments composition. *Internal Journal of Agriculture and Biology*, 11(1): 100-105.

Janamatti, V.S., Sashidharv, R., Prasad, I.G. and Sastry, K.S.K. (1986). Effect of cycles of moisture stress on flowering pattern, flower production, gynophore length and their relationship to pod yield in bunch types of groundnut, *Journal of Agricultural Research*, 1(2): 136–142.

Jankulovska, M., Ivanovska, S., Marjanovic-Jeromela, A., Bolaric, S., Jankuloski, L.J., Dimov, Z., Bosev, D. and Kuzmanovska, B. (2014). Multivariate Analysis of Quantitative Traits that can Effectively Classify Rapeseed Germplasm. *Genetika*, 46(2): 545-559.

Jogloy, C. Jaisil, P., Akkasaeng, C. and Jogloy, S. (2011). Heritability and correlation for maturity and pod yield in peanut. *Journal of Applied Sciences Research*, 7(2): 134-140.

Jogloy, S.; Patanothai, A., Toomsan, S. and Isleib, T.G. (1996). Breeding peanut to fit into Thai cropping systems. Procedure of the Peanut Collaborative Research Support Program-International Research Symposium and Workshop, Two Jima Quality Inn, Arlington, Virginia, USA, 25-31 March,: pp 353-362.

Joshi, B.K., Mudwari, A., Bhatta, M.R. and Ferrara, G.O.(2004). Genetic diversity in Nepalese wheat cultivars based on agromorphological traits and coefficients of parentage. *Nepalese Agricultural Research Journal*, 5: 7-17.

Kalariya, K.A., Singh, A.I., Chakraborty, K., Zala, P.V. and Patel, C.B. (2013). Photosynthesis characteristics of groundnut (*Arachis hypogaea* L.). *Indian Journal of Plant Physiology*, 18(2): 157-163.

Karim, A.N.M.S., Ahmed, S., Akhi, A.H., Talukder, M.Z.A. and Mujahidi, T.A.(2018). Combining ability and heterosis study in maize (*Zea mays* L.) hybrids at different environments in Bangladesh. *Bangladesh Journal of Agricultural Research,* 43(1): 125-134.

Kochert, G., Stalker, H. T., Gimenes, M., Galgaro, L., Lopes, C. R. and Moore, K. (1996). RFLP and cytogenetic evidence on the origin and evolution of allotetraploid domesticated peanut *Arachis hypogaea* (Leguminosae). *American Journal of Botany*, 83: 1282–1291.

Kumari, M. and Misra, B. (2011). Application of cluster analysis in agriculture A Review Article, *International Journal of Computer Applications*, 36 (4): 43-47.

Ladodo, A., Hussaaini, M.A.and Muhammed, S.G.(2015). Evaluation of tillage practices on weed control and yield of groundnut (*Arachis hypogaea* L.) in Sudan savanna Agroecology of Nigeria. *American Journal of Experimental Agriculture*, 6(6): 361-371

Lauriano, J.A., Lidon, F.C., Carvalho, C.A., Campos, P.S. and Matos, M.D.C. (2000). Drought Effects On Membrane Lipids And Photosynthetic Activity In different Peanut cultivars, *Photosynthetica (Prague)*, 38: 7-12.

Li, C., Berninger, F., Koskela, J., Sonninen, E. (2000) Drought responses of Eucalyptus microtheca provenances depend on seasonality of rainfall in their place of origin. *Australian Journal of Plant Physiology*, 27: 231–238.

Lokesh, K.M., Chandra, S. and Saket, K. (2017). Cluster analysis to form similarity for major selected crops in Rajasthan, India. *International Journal of Current Microbiology and Applied Sciences*, 6(4): 2673-2682.

Long, S.P., Zhu, X.G., Naidu, S.L. and Ort, D.R. (2006). Can improvement in photosynthesis increase crop yields? *Journal of Cell and Environmental Biology*, 29(3): 315-330.

Maji, A.T. and Shaibu, A.A.(2012). Application of principal component analysis for rice germplasm characterization and evaluation. *Journal of Plant Breeding and Crop Science*, 4(6): 87-93.

Majid, S., Rajab, C., Eslam, M. and Farokh, D. (2010). Estimation of combining ability and gene action in maize using line x tester method under three irrigation regimes. *Journal of Research in Agricultural Science*, 6: 19-28.

Makinde, S.C.O. and Ariyo, O.J. (2010). Multivariate analysis of genetic divergence in twenty-two genotypes of groundnut (*Arachis hypogaea* L.). *Journal of Plant Breeding and Crop Science*, 2(7): 192-204.

Mamta, T. and Bharat, M. (2011). Application of cluster analysisin agriculture- A review article. *International Journal of Computer Applications*, 36(4): 43-47.

Martinez-Calvo, J., Gisbert, A.D., Alamar, M.C., Hernandorena, R., Romero, C., Llacer, G. and Badenes, M.L. (2008). Study of a germplasm collection of loquat (Eriobotrya japonica Lindl.) by multivariate analysis. *Genetic Resources and Crop Evolution*, 55(5): 695-703.

Meisner, C. A. and Karnok, K. J. (1992): Peanut root response to drought stress. *Journal of Agronomy*, 84: 159–165.

Meseka, S.K., Menkir, A., Ibrahim, A.E.S. and Ajala, S. (2006). Genetic analysis of performance of maize inbred lines selected for tolerance to drought under low soil nitrogen. *Maydica*, 51: 487–495.

Mhike, X., Lungu, D.M. and Vivek, B. (2011). Combining ability studies amongst AREX and CIMMYT maize (*Zea mays* L.) inbred lines under stress and non-stress conditions. *African Journal of Agricultural Research*, 6(8): 1952-1957.

Mohammed, M.I. (2009). Line x tester analysis across locations and years in Sudanese x exotic lines of forage sorghum. *Journal of Plant Breeding and Crop Science*, 9: 311 – 319.

Moreshat, S., Bridges, D.C., NeSmith, D.S. and Huang, B. (1996). Effects of water stress on competitive interaction of peanut and sicklepod. *Journal of Agronomy*, 88: 636–644.

Mostafa, K., Mohammad, H.F. and Mohammad, M. (2011). Genetic diversity of wheat (*Triticum aestivum* L.) genotypes based on cluster and principal component analyses for breeding strategies. *Australian Journal of Crop Science*, 5(1): 17-24.

Mshelmbula, B.P., Jummai, B.F., Mallum, S.M. and Zacharia, R. (2017). Studies on four cultivars of groundnut grown in Mubi, Adamawa State Nigeria. Journal of Technology Research, 12(1): 1-4.

Mutsaers, H.J.W., Weber, G.K., Walker, P. and Fisher, N.M. (1997). A field guide for on-farm experimentation. liTA!CTA/ISNAR.

Naeem, M.K., Ahmad, M., Kamran, M., Nawaz Shah, M.K. and Iqbal, M.S. (2015). Physiological responses of wheat (*Triticum aestivum* L.) to drought stress. *Internal Journal of Plant and Soil Science*, 6(1): 1-9.

Nagabhushan, N. M., Mallikarjuna, C., Haradari, M. S., Shashibhaskar and Prahalada, G. D. (2011). Genetic variability and correlation studies for yield and related characters in single cross hybrids of maize (*Zea mays* L.). *Current Biotica*, 5(2): 157-163.

Nageswara Rao, R.C. Williams J.H. and Singh M. (1989). Genotypic sensitivity to drought and yield potential of peanut. *Journal of Agronomy*, 81: 887-893.

Nageswara Rao, R.C., Talwar, H.S and Wright, G.C. (2001). Rapid assessment of SLA and leaf nitrogen in peanut using chlorophyll meter. *Crop Science*, 186: 175-182.

Nageswara Rao, R.C., Udayakumar, M., Farquhar, G.D., Talwar, H.S. and Prasad T.G. (1995). Variation in carbon isotope discrimination and its relationship to specific leaf area and ribulose-1,5-bisphosphate carboxylase content in groundnut genotypes. *Australian Journal of Plant Physiology*, 22: 545-551.

Nageswara Rao, R.C.. Sardar Singh, M.V.K., Sivakumar, .K.L, Sivakumar, K.L. and Williams.(1985). Effect of Water Deficit at Different Growth Phases Of Peanut. Ii. Yield responses, *Journal of Agronomy*, 77: 782-786.

Narasimhulu, R., Kenchanagoudar, P.V. and Gowda, M.V.C. (2012). Study of genetic variability and correlations in selected groundnut genotypes. *International Journal of Applied Biology and Pharmaceutical Technology*, pp 355-358.

Nemati, A., Sedghi, M., Sharifi, R.S. and Seiedi. (2009). Investigation of correlation between traits and path analysis of corn (*Zea mays* L.) grain yield at the climate of Ardabil region (Northwest Iran). *Notulae Botanicae Horti Agrobotanici Cluj- Napoca*, 37: 194-198.

Nguyen, H.T., Babu, R.C. and Blum, A. (1997). Breeding for drought resistance in rice: physiology and molecular genetics considerations. *Crop Science*, 37: 1426-1434.

Nigam, S.N., Chandra S., Srievi, K.R., Manohar, B., Reddy, A.G.S., Nageswara Rao, R., Wright, G.C., Reddy, P.V., Deshmukh, M.P., Mathur, R.K., Basu, M.S., Vasundhara S., Varman P.V. and Nagda A.K. (2005). Efficiency of physiological trait-based and empirical selection approaches for drought tolerance in groundnut. *Annals of Applied Biology*, 146: 433-439.

Pan, X.Y, Wang, Y.F., Wang, G.X., Cao, Q.D., Wang, J.(2002). Relationship between growth redundancy and size inequality in spring wheat populations mulched with clear plastic film. *Acta Phytoecology Sinica*, 26: 177-184.

Pandey, V. and Shukla, A.(2015). Acclimation and tolerance strategies of rice under drought stress. Available online at www.sciencedirect.com. 22(4): 147-161.

Pasupuleti, J., Singh, S.M., Rathore, A, and Nigam, S.N. (2015). Inheritance of SPAD chlorophyll meter reading and specific leaf area in four crosses of groundnut (*Arachis hypogaea* L.). *Indian Journal of Genetics and Plant Breeding*, 75(3): 408

Pfeiffer, W.H., Trethowan, R.M., Van, G.M., Ortiz, M.I.and Rajaram, S. (2005).Breeding for abiotic stress tolerance in wheat in abiotic stresses: plant resistance through breeding and molecular approaches (eds. Ashraf, M. and P.J.C. Harris), The Haworth Press, New York, NY, USA, pp 401-489.

Philipo, M., Mollay, C. and Nchimbi-Msolla, S. (2016). Heritability and relationship between drought tolerance traits and yield in groundnuts (*Arachis hypogaea* L.) under different watering regimes. *Asian Journal of Agriculture and Biology*, 4(4): 120-125.

Pimratch, S., Jogloy, S., Vorasoot, N., Toomsan, B., Kesmala, T., Patanothoi, A. and Holbrook, C.C. (2008). Effect of drought stress on traits related to N_2 fixation in eleven peanut (*Arachis hypogaea* L.) genotypes differing in degree of resistance to drought. *Asian Journal of Plant Science*, 7(4): 43-52.

Porch, T.G., Ramirez, V.H., Santana, D. and Harmsen, E.W. (2009). Evaluation of common bean for drought tolerance in Juana Diaz, Puerto Rico. *Journal of Agronomy and Crop Science*, 195(5): 305-316.

Pradeepa, B.P. (2007). Genetic studies on quantitative and quality traits of three way cross hybrids and evaluation of germplasm in maize (*Zea mays* L.). *MSc. Thesis,* University of Agricultural Science, Dharwad, Karnataka (India). Pp 45-49.

Puangbut, D., Jogloy, S. and Vorasoot,N.(2017). Association of photosynthetic traits with water use efficiency and SPAD chlorophyll meter reading of Jerusalem artichoke under drought conditions. *Journal of Agricultural Water Management.* 188: 29-35.

Rao, I.M., Beebe, S., Polania, J., Ricaurte, J., Cajiao, C., Garcia, R. and Rivera, M. (2013). Cantepary bean be a model for improvement of drought resistance in common bean? *African Journal of Crop Science*, 21: 265–281.

Rao, R. C. N., Singh, S., Sivakumar, M.V.K., Srivastava, K. L. and Williams, J.H. (1985): Effect of water deficit at different growth phases of peanut. I. Yield responses. *Journal of Agronomy*, **77**: 782–786.

Reddy, A. J. and Rao, I. M. (1968). Influence of induced water stress on chlorophyll components of proximal and distal leaflets of groundnut plants. *Current Science*, 5: 118–121.

Reddy, T.Y., Reddy V.R. and Anbumozhi, V. (2003). Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioration. A critical review. *Plant growth Regulation*, 41: 75-88.

Rezene, Y., Gebeyehu, H. and Zelleke, H. (2011). Genetic variation for drought resistance in small red seeded common bean genotypes. *African Journal of Crop Science*, 19: 303-312.

Robinson, F.H., Comstock, R.E. and Harvey, P.H. (1949). Estimates of heritability and the degree of dominance in corn. *Agronomy Journal*, 41: 353-359.

Rong-hua, L.I., Pei-guo, G.U.O., Baum, M., Grando, S. and Ceccarelli. (2006). Evaluation of chlorophyll content and fluorescence parameters as indicators of drought tolerance in barley. *Agricultural Sciences in China*, 5(10): 751-757.

Rosielle, A.A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Science*, 21: 943-946.

Roychowdhury, R. and Tah, J. (2011). Evaluation of genetic parameters for agro-metrical characters in carnation genotypes. *African Journal of Crop Science*, 19(3): 183-188.

Rucker, K.S., Kevin, C.K., Holbrook, C.C. and Hook, J.E. (1995). Identification of Peanut Genotypes with Improved Drought Avoid- Ance Traits, *Peanut Science*, 22(1): 14–18.

Ruming, L. (2004). A genetic study of resistance to kernel infection by *Aspergillus flavus* in maize. A PhD dissertation submitted to graduate faculty of the Loisiana State University Agricultural and Mechanical College in partial fulfillment of the requirements for the dregree of Doctor of Philosophy in the Department of Agronomy and Environment management, pp 13-15.

SAS Institute, 2004. SAS/STAT 9.1 User's guide. SAS Inc. Cary., N. C. USA. Pp 53-60.

Sexton, P. J., Bennett, J. M. and Boote, K J. (1997): The effect of dry pegging zone soil on pod formation of Florunner peanut. *Peanut Science.*, 24: 19–24.

Shakoor, M. S., Akbar, M. and Hussain, A. (2007). Correlation and path coefficients studies of some morpho-physiological traits in maize double crosses. *Pakistan Journal of Agricultural* Science, 44(2): 213-216.

Shamsideen, J.M. (2016). Inheritance of Oil Content and Other Agronomic Traits in Groundnut Genotypes *(Arachis hypogaea* L.). A thesis submitted to the School of Postgraduate Studies, inpartial fulfilment of the requirements for the award of Degree of Master of Science in Plant Breeding. Ahmadu Bello University Zaria, Nigeria. Pp 43-60.

Sharafi, Y., Majidi, M.M. and Mirlohi, A.(2015). Multivariate analysis of genetic variation in winter rapeseed (*Brassica napus* L.) cultivars. *Journal of Agricultural Science Techniques*, 17: 1319-1331.

Sharief, A.E., El-Kalla, S.E., Gado, H.E. and Abo-Yousef, H.A.E. (2009). Heterosis in yellow maize. *Australian Journal of Crop Science*, 3: 146-154.

Sharma, P. S. and Sivakumar, M. V. K. (1991): Penetrometer soil resistance, pod number and yield of peanuts as influenced by drought stress. *Indian Journal of Plant Physiology*, 34: 147–152.

Sharma, S., Narwal, M.S., Kumar, R. and Dass, S. (2004). Line x tester analysis in maize (*Zea mays* L.). *Forage Research*, 30: 28-30.

Showemimo, F.A., Echekwu, C.A. and Yeye, M.Y. (2000). Genotype x environment interaction in sorghum trials and their implication for future variety evaluation in Sorghum growing areas of northern Nigeria. *The Plant Scientist*, 1: 24–31.

Singh, M. and Ceccarelli, S. (1995). Estimation of heritability using variety trials data from incomplete blocks. *Theoritical Applied Genetics*, 90: 142-145.

Singh, R.K. and Chaudhary, B.D. (1985). *Biometrical methods in quantitative genetic analysis*. Kalyani publishers, New Delhi, India. pp. 67-78, 69- 77, 205-207.

Sivakumar, M. V. K. and Sharma, P. S. (1986). Studies on water relations of groundnut. pp. 83–98. In: *Agrometeorology of Groundnut*. *Proceedings of International Symposium*. ICRISAT Shelan Centre, Niamey, Niger.

Sivasubramanian, S. and Menon, M. (1973). Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*, 60: 1139.

Skelton, B.J. and Shear, G.M. (1971). Calcium Translocation in the Peanut (*Arachis hypogae* L.). *Journal of Agronomy*, 63: 409–412.

Smartt J, (Eds.). 1994. The Groundnut crop: A Scientific Basis for Improvement. Chapman and Hall, London. 756.

Smith, L.I. (2002). A toturial on principal components analysis; http://www.cs.otago.ac.nz/cosc453/student_tutorials/principal_components.pdf.

Snedecor, G, W. and Cochran, W.G.(1994). Statistical methods (eighth edition). Caiculatta, India: Oxford and IBH Publishing Co. 58: 67-69.

Songsri, P., Joglloy, S., Kesmala, T., Vorasoot, N., Akkasaeng, C.P.A. and Holbrook, C. (2008). Heritability of drought resistant traits and correlation of drought resistance and agronomic traits in peanut. *Crop Science*, 48: 2245-2253.

Songsri, P., Jogloy, S., Holbrook, C.C., Kesmala T., Vorasoot, N., Akkasaeng, C. and Patanothai, A. (2009). Association of root, specific leaf area and SPAD chlorophyll meter reading to water use efficiency of peanut under different available soil water. *Agricultural Water Management*, 96: 790-798.

Stirling, C.M.; Black, C.R. and Ong, C.K. (1989). The response of groundnut (*Arachis hypogaea* L.) to timing of irrigation. II. 14C partitioning and plant water status. *Journal of Experimental Botany*, 40 (221): 1363–1373.

Sudhir, I., Kumar, G.M. and Vijay, K.K. (2010). Estimation of genetic diversity of new advanced breeding lines of groundnut (*Arachis hypogaeae* L.). *World Journal of Agricultural Science*, 6(5): 547-554.

Sunday, C.O.M. and Omolayo, J.A. (2010). Multivariate analysis of genetic divergence in twenty two groundnut (*Arachis hypogaea* L.). *Journal of Plant Breeding and Crop Science*, 2(7): 192-204.

Suther, D.M. and Patel, M.S. (1992): Yield and nutrient absorption by groundnut and iron availability in soil as influenced by lime and soil water. *Indian Journal of Soil Science*, 40: 594–596.

Swe, S.T. and Branch, W.D. (1986). Estimates of combining ability and heterosis among peanut cultivars. *Peanut Science,* 13: 70-74.

Tazeen, M., Nadia, K. and Farzana, N.N. (2009). Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in synthetic elite lines of wheat. *Journal of Food Agriculture and Environment*, 7(3 and 4): 278-282.

Thakur, S.B., Ghimire, S.K., Shrestha, S.M., Chaudhary, N.K. and Mishra, B. (2013). Variability in groundnut genotypes for tolerance to drought. *Nepal Journal of Science and Technology*, 14 (1): 41-50.

Upadhyaya, H.D., Nadaf, H.L., Mukri, G. and Singh, S. (2012). Variability and stability analysis for nutritional traits in the mini core collection of peanut. *Crop Science*, 52(1): 168

Upadhyaya, H.D., Reddy, L.J, Dwivedi, S.L., Gowda, C.L.L. and Singh, S. (2009). Phenotypic diversity in cold-tolerant peanut (*Arachis hypogaea* L.) germplasm. *Euphytica*, 165: 279-291.

Vellini, A.L.T.T., Paula, N.F., Alves, P.L.C., Pavani, C., Bonine, C.A.V. and Scarpinati, E.A. (2008) Respostas fisiológicas de diferentes clones de eucalipto sob diferentes regimes hídricos. *Revista Árvore, Viçosa*—MG, 32: 651–663.

Wright, G. C., Nageswara Rao, R. C. and Basu, M. S. (1996) A Physiological Approach to the Understanding of Genotype by Environment Interactions: A case study on improvement of drought adaptation in groundnut. p. 365–380. *In* M. Cooper and G. L. Hammer (eds.) *Plant adaptation and crop improvement.* CAB International, Wallingford, UK.

Zaharieva, M., Acevedo, E., Gaulin, E. and Monneveux, P. (2001). Drought and heat responses in wild wheat relative aegilops geniculate Roth: Potential interest for wheat improvement.*Crop Science*, 41(4): 16-21.

Zamurrad, M., Tariq, M., Shah, F.H., Subhani. A., Ijaz, M., Iqbal, M.S and Koukab M. (2013). Performance Based Evaluation of Groundnut Genotypes under Medium Rainfall Conditions of Chakwal. *Journal of Agriculture, Food and Applied Science*, 1: 9-12.

Zavala-Garcia, F., Bramel-Cox, P.J., Eastin, J.D., Witt, M.D. and Andrews, D.J. (1992). Increasing the efficiency of crop selection for unpredictable environments. *Crop Science*, 32: 51-57.

Zhao, B., Kondo, M. and Maeda, M. (2004). Water use efficiency and carbon isotope discrimination in two cultivars of upland rice during different development stages under three water regimes. *Plant and Soil*, 261: 61-74.

Zhu X, Chang G, He D, Zhao H. and Ma C. (2014). Evaluation of new onion varieties using cluster analysis and principal component analysis methods. *Gansu Journal of Agricultural Science,* 10: 25–8.

APPENDIX

Table 1: Mean performances for morphological traits of groundnut genotypes screened under non-stress and water stress conditions at Samaru 2018

GENOTYPES	DFF		NPPT		GENOTYPES	DFF		NPPT	
	NS	WS	NS	WS		NS	WS	NS	WS
12CS-010	38	39	4	3	ICGCV-IS-07889	37	36	4	2
12CS-102	36	40	2	1	ICG-IS-07803	36	40	11	5
ICG 02148	36	36	6	0	ICG-IS-07919	36	36	9	4
ICG 10346	36	38	7	4	ICG-IS-07947	36	36	4	1
ICG 11249	36	36	2	2	ICG-SM-07539	38	36	5	2
ICG 12189	36	36	13	4	ICG-SM-07541	36	40	19	6
ICG 1274	37	36	27	9	ICGV 07805	38	40	9	4
ICG 12989	37	41	7	1	ICGV-5M00010/P15/P2	36	36	6	1
ICG 12991	38	39	12	10	ICGV-5M00017/5/P1/P1	36	41	2	2
ICG 1519	37	39	5	3	ICGV-91283	37	40	1	0
ICG 15236	36	39	8	3	ICGV-IS-03323	36	40	1	0
ICG 1973	37	36	2	0	ICGV-IS-07803	36	36	8	0
ICG 2019	36	40	2	2	ICGV-IS-07809	37	36	1	0
ICG 2106	36	39	13	7	ICGV-IS-07812	36	36	5	2
ICG 231	37	40	7	2	ICGV-IS-07813	38	36	8	2
ICG 294	37	36	2	1	ICGV-IS-07815	36	36	8	5
ICG 297	36	41	5	2	ICGV-IS-07828	36	39	7	7
ICG 311	36	40	4	2	ICGV-IS-07829	38	39	4	2
ICG 3312	36	40	27	1	ICGV-IS-07841	38	39	12	7
ICG 3421	37	40	5	0	ICGV-IS-07842	37	40	8	0
ICG 3584	38	36	3	0	ICGV-IS-07843	38	40	2	1
ICG 4911	36	38	7	3	ICGV-IS-07845	38	40	3	0
ICG 5195	37	40	10	1	ICGV-IS-07849	36	36	5	1
ICG 5236	38	41	25	1	ICGV-IS-078513	37	36	6	4
ICG 6813	36	36	12	2	ICGV-IS-07853	38	36	25	5
ICG 7906	37	36	8	3	ICGV-IS-07855	36	36	9	4
ICG 9777	38	39	8	3	ICGV-IS-07859	36	36	7	3
ICG 9905	36	40	4	2	ICGV-IS-07883	37	36	3	4
ICGV-IS-07887	40	40	2	2	ICGX-5M-00017/5/P5/P2	37	36	7	4
ICGV-IS-07891	37	36	8	3	ICGX-5M-00018/5/4/P2	38	38	1	0
Mean	**36**	**38**	**5.00**	**4.00**	Mean	**36**	**38**	**5**	**4**
CV (%)	**0.05**	**0.10**	**16.50**	**39.00**	CV (%)	**0.05**	**0.10**	**16.50**	**39.00**

NS= Non-stress, WS= Water stress, DFF= Days to 50% flowering, NPPT= Number of pods per plants and CV= Coefficient of variation.

Table 1 Cont'd

GENOTYPES	DFF		NPPT		GENOTYPES	DFF		NPPT	
	NS	WS	NS	WS		NS	WS	NS	WS
ICGV-IS-07893	36	41	7	4	ICGX-IS-11057	36	39	7	4
ICGV-IS-07894	39	36	3	2	ICGX-IS-13011	36	39	10	1
ICGV-IS-07895	37	36	2	1	ICGX-IS-13988	38	40	5	0
ICGV-IS-07900	36	39	7	2	J.L 11	36	37	1	2
ICGV-IS-07902	36	39	11	3	RS006F3B1-22®	37	36	0	0
ICGV-IS-07904	37	36	1	4	RS006F4B1-17	37	36	6	1
ICGV-IS-13007	36	36	2	2	RS006F4B1-22	37	36	1	4
ICGV-IS-13050	36	41	4	1	RS006F4B1-31	36	41	1	2
ICGV-IS-13075	38	36	5	2	RS006F4B1-4(B)	36	38	8	3
ICGV-IS-13097	36	40	1	1	RS006F4B1-45(B)	36	38	3	2
ICGV-IS-13112	38	39	2	2	RS006F4B1-45 ®	36	36	3	0
ICGV-IS-13115	36	36	39	2	RS006F4B1-49	37	40	2	1
ICGV-IS-13865	37	37	2	2	RS006F4B1-50	36	36	3	2
ICGV-IS-13878	38	36	1	0	RS006F4B1-53(B)	38	38	3	3
ICGV-IS-13911	36	39	4	1	RS006F4B1-85	36	40	4	0
ICGV-IS-13938	38	36	1	1	RS006F4B1-B5	37	36	4	1
ICGV-IS-13978	36	36	24	23	RS006F4B-21	38	40	4	1
ICGV-IS-13982	38	39	5	2	RS006F4B-534	38	40	4	0
ICGV-IS-13986	38	36	5	1	RS066F3B1-57(B)	38	39	4	0
ICGV-IS-13989	38	36	5	1	SAMNUT 14	36	36	3	0
ICGV-IS-13990	37	36	5	4	SAMNUT 23	36	36	2	2
ICGV-IS-O7816	38	36	6	1	SAMNUT 24	36	39	5	1
ICGX 11003	36	36	4	4	SAMNUT 25	37	41	14	4
					SAMNUT 26	36	40	15	1
Mean	**36**	**38**	**5**	**4**	Mean	**36**	**38**	**5**	**4**
CV (%)	**0.05**	**0.1**	**16.50**	**38.9**	CV (%)	**0.05**	**0.1**	**16.5**	**38.9**

NS= Non-stress, WS= Water stress, DFF= Days to 50% flowering, NPPT= Number of pods per plants and CV= Coefficient of variation.

Table 2: Mean performances for morphological traits of groundnut genotypes screened under combined analysis at Samaru 2018

GENOTYPES	DFF	NPP	GENOTYPES	DFF	NPP
12CS-010	38	3	ICG 9905	38	3
12CS-102	38	2	ICGCV-IS-07889	36	3
ICG 02148	36	3	ICG-IS-07803	38	8
ICG 10346	37	5	ICG-IS-07919	36	7
ICG 11249	36	2	ICG-IS-07947	36	2
ICG 12189	36	8	ICG-SM-07539	37	4
ICG 1274	36	18	ICG-SM-07541	38	13
ICG 12989	39	4	ICGV 07805	39	6
ICG 12991	38	11	ICGV-5M00010/P15/P2	36	3
ICG 1519	38	4	ICGV-5M00017/5/P1/P1	39	2
ICG 15236	37	6	ICGV-91283	39	1
ICG 1973	36	1	ICGV-IS-03323	38	0
ICG 2019	38	2	ICGV-IS-07803	36	4
ICG 2106	37	10	ICGV-IS-07809	36	1
ICG 231	39	5	ICGV-IS-07812	36	4
ICG 294	36	2	ICGV-IS-07813	37	5
ICG 297	39	3	ICGV-IS-07815	36	7
ICG 311	38	3	ICGV-IS-07828	37	7
ICG 3312	38	14	ICGV-IS-07829	38	3
ICG 3421	38	3	ICGV-IS-07841	38	9
ICG 3584	37	1	ICGV-IS-07842	39	4
ICG 4911	37	5	ICGV-IS-07843	39	1
ICG 5195	38	6	ICGV-IS-07845	39	2
ICG 5236	40	13	ICGV-IS-07849	36	3
ICG 6813	36	7	ICGV-IS-078513	36	5
ICG 7906	36	5	ICGV-IS-07853	37	15
ICG 9777	38	6	ICGV-IS-07855	36	7
Mean	**37**	**4**	Mean	**37**	**4**
CV(%)	**0.08**	**22.87**	CV(%)	**0.08**	**22.87**

Days to 50% flowering, NPP= Number of pods per plant

Table 2 Cont'd

GENOTYPES	DFF	NPP	GENOTYPES	DFF	NPP
ICGV-IS-07859	36	5	ICGX-5M-00017/5/P5/P2	36	6
ICGV-IS-07883	36	3	ICGX-5M-00018/5/4/P2	38	1
ICGV-IS-07887	40	2	ICGX-IS-11057	37	5
ICGV-IS-07891	36	6	ICGX-IS-13011	37	5
ICGV-IS-07893	39	6	ICGX-IS-13988	39	2
ICGV-IS-07894	37	2	J.L 11	36	2
ICGV-IS-07895	36	2	RS006F3B1-22®	36	0
ICGV-IS-07900	37	5	RS006F4B1-17	36	4
ICGV-IS-07902	37	7	RS006F4B1-22	36	3
ICGV-IS-07904	36	3	RS006F4B1-31	39	2
ICGV-IS-13007	36	2	RS006F4B1-4(B)	37	6
ICGV-IS-13050	39	2	RS006F4B1-45(B)	37	3
ICGV-IS-13075	37	3	RS006F4B1-45®	36	2
ICGV-IS-13097	38	1	RS006F4B1-49	39	2
ICGV-IS-13112	38	2	RS006F4B1-50	36	2
ICGV-IS-13115	36	21	RS006F4B1-53(B)	38	3
ICGV-IS-13865	37	2	RS006F4B1-85	38	2
ICGV-IS-13878	37	1	RS006F4B1-B5	36	2
ICGV-IS-13911	37	2	RS006F4B-21	39	2
ICGV-IS-13938	37	1	RS006F4B-534	39	2
ICGV-IS-13978	36	13	RS066F3B1-57(B)	38	2
ICGV-IS-13982	38	3	SAMNUT 14	36	2
ICGV-IS-13986	37	3	SAMNUT 23	36	2
ICGV-IS-13989	37	3	SAMNUT 24	37	3
ICGV-IS-13990	36	5	SAMNUT 25	39	9
ICGV-IS-O7816	37	4	SAMNUT 26	38	8
ICGX 11003	36	4			
Mean	**37**	**4**	Mean	**37**	**4**
CV(%)	**0.08**	**22.87**	CV(%)	**0.08**	**22.87**

Days to 50% flowering, NPP= Number of pods per plant

Table 3: Mean performances for physiological traits of groundnut genotypes screened under combined analysis at Samaru 2018

GENOTYPES	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	LAI
12CS-010	41.06	40.76	36.13	0.07
12CS-102	45.16	40.42	41.66	0.06
ICG 02148	43.29	38.39	43.31	0.07
ICG 10346	37.11	40.35	34.97	0.07
ICG 11249	36.29	42.75	31.98	0.09
ICG 12189	47.04	48.94	48.66	0.08
ICG 1274	44.57	39.47	48.76	0.09
ICG 12989	45.43	44.09	40.81	0.06
ICG 12991	32.85	37.24	35.05	0.08
ICG 1519	48.46	41.88	43.60	0.09
ICG 15236	45.37	34.53	35.24	0.06
ICG 1973	40.83	38.05	36.66	0.08
ICG 2019	41.53	41.26	32.07	0.09
ICG 2106	42.13	48.91	45.25	0.09
ICG 231	48.05	44.75	44.73	0.09
ICG 294	42.91	40.56	38.01	0.09
ICG 297	45.07	39.94	32.03	0.09
ICG 311	46.27	43.41	40.39	0.09
ICG 3312	39.21	38.78	29.50	0.06
ICG 3421	30.91	43.18	28.76	0.09
ICG 3584	41.23	44.09	41.11	0.07
ICG 4911	30.56	42.90	42.42	0.09
ICG 5195	46.87	34.14	36.99	0.05
ICG 5236	47.85	42.18	34.55	0.09
ICG 6813	46.98	47.05	42.34	0.08
ICG 7906	43.29	46.07	44.94	0.09
ICG 9777	44.66	49.43	45.04	0.07
ICG 9905	41.06	43.27	45.70	0.08
ICGCV-IS-07889	46.15	37.61	40.52	0.09
ICG-IS-07803	48.46	39.54	47.94	0.05
ICG-IS-07919	50.85	42.96	47.74	0.06
Mean	**42.27**	**41.09**	**40.20**	**0.07**
CV (%)	**13.54**	**15.48**	**13.44**	**12.42**

SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

Table 3 Cont'd

GENOTYPES	SCMR 40DAS	SCMR 60DAS	SCMR 80DAS	LAI
ICG-IS-07947	33.19	45.73	45.82	0.07
ICG-SM-07539	38.57	47.60	40.41	0.09
ICG-SM-07541	44.32	45.69	43.12	0.08
ICGV 07805	49.72	46.27	43.45	0.08
ICGV-5M00010/P15/P2	37.93	43.39	36.28	0.09
ICGV-5M00017/5/P1/P1	44.93	43.91	47.46	0.07
ICGV-91283	42.94	33.39	33.99	0.09
ICGV-IS-03323	46.96	37.63	35.41	0.08
ICGV-IS-07803	45.38	46.45	45.61	0.09
ICGV-IS-07809	39.1	38.42	37.32	0.06
ICGV-IS-07812	41.23	43.13	32.07	0.09
ICGV-IS-07813	43.58	44.35	47.13	0.07
ICGV-IS-07815	45.49	45.55	52.86	0.07
ICGV-IS-07828	44.35	40.23	38.51	0.08
ICGV-IS-07829	44.71	37.25	39.82	0.07
ICGV-IS-07841	49.47	33.11	36.30	0.08
ICGV-IS-07842	45.45	43.32	49.03	0.09
ICGV-IS-07843	34.38	37.36	40.04	0.09
ICGV-IS-07845	44.03	38.72	44.95	0.08
ICGV-IS-07849	47.39	46.47	39.60	0.06
ICGV-IS-078513	47.68	44.04	41.78	0.05
ICGV-IS-07853	42.78	42.85	42.71	0.05
ICGV-IS-07855	39.07	35.71	30.97	0.05
ICGV-IS-07859	44.38	41.05	39.94	0.06
ICGV-IS-07883	43.07	40.43	36.54	0.07
ICGV-IS-07887	43.26	27.36	38.43	0.06
ICGV-IS-07891	45.52	34.04	43.14	0.07
ICGV-IS-07893	45.22	39.83	40.92	0.07
Mean	**42.27**	**41.09**	**40.2**	0.07
CV (%)	**13.54**	**15.48**	**13.44**	**12.42**

SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

Table 3 Cont'd

GENOTYPES	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	LAI
ICGV-IS-07894	43.73	39.67	35.21	0.08
ICGV-IS-07895	47.90	44.48	44.66	0.07
ICGV-IS-07900	36.65	42.35	41.06	0.09
ICGV-IS-07902	39.04	41.11	41.24	0.07
ICGV-IS-07904	38.49	41.8	41.64	0.06
ICGV-IS-13007	49.13	45.11	38.73	0.09
ICGV-IS-13050	38.72	47.26	36.60	0.07
ICGV-IS-13075	47.81	48.27	33.60	0.08
ICGV-IS-13097	32.40	42.99	36.75	0.08
ICGV-IS-13112	38.37	40.58	35.65	0.06
ICGV-IS-13115	44.44	45.10	41.13	0.05
ICGV-IS-13865	38.53	41.74	37.59	0.06
ICGV-IS-13878	41.92	41.49	43.79	0.09
ICGV-IS-13911	43.25	44.75	46.85	0.07
ICGV-IS-13938	44.73	46.02	39.44	0.09
ICGV-IS-13978	45.35	38.28	42.62	0.05
ICGV-IS-13982	41.17	43.39	41.95	0.09
ICGV-IS-13986	46.47	38.96	49.49	0.08
ICGV-IS-13989	35.77	32.15	34.85	0.06
ICGV-IS-13990	52.36	50.66	50.16	0.05
ICGV-IS-O7816	39.21	38.00	39.55	0.07
ICGX 11003	41.83	42.33	36.04	0.06
ICGX-5M-00017/5/P5/P2	39.56	38.65	29.64	0.09
Mean	**42.27**	**41.09**	**40.20**	**0.07**
CV (%)	**13.54**	**15.48**	**13.44**	**12.42**

SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

Table 3 Cont'd

GENOTYPES	SCMR 40 DAS	SCMR 60 DAS	SCMR 80 DAS	LAI
ICGX-5M-00018/5/4/P2	41.03	36.71	39.13	0.08
ICGX-IS-11057	42.50	39.63	42.85	0.07
ICGX-IS-13011	39.39	42.03	44.94	0.09
ICGX-IS-13988	36.31	43.12	40.54	0.06
J.L 11	43.05	41.89	40.27	0.09
RS006F3B1-22®	34.55	40.82	37.64	0.05
RS006F4B1-17	38.99	33.34	37.75	0.05
RS006F4B1-22	42.62	45.60	46.44	0.07
RS006F4B1-31	39.17	30.47	39.65	0.06
RS006F4B1-4(B)	39.33	39.27	41.54	0.07
RS006F4B1-45(B)	38.99	40.07	34.50	0.08
RS006F4B1-45®	30.45	31.99	27.36	0.05
RS006F4B1-49	34.84	39.38	37.80	0.09
RS006F4B1-50	42.41	40.43	39.05	0.07
RS006F4B1-53(B)	42.96	42.46	47.62	0.07
RS006F4B1-85	49.07	40.46	53.23	0.08
RS006F4B1-B5	41.66	39.10	36.94	0.07
RS006F4B-21	40.93	40.50	38.70	0.09
RS006F4B-534	35.84	35.39	31.03	0.09
RS066F3B1-57(B)	40.41	40.99	35.91	0.07
SAMNUT 14	41.65	43.09	43.03	0.09
SAMNUT 23	41.70	40.65	43.10	0.07
SAMNUT 24	43.42	29.87	34.06	0.08
SAMNUT 25	45.64	42.30	46.34	0.06
SAMNUT 26	44.07	41.49	43.59	0.08
Mean	**42.27**	**41.09**	**40.20**	**0.07**
CV	**13.54**	**15.48**	**13.44**	**12.42**

SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

Table 4: Mean performances for Physiological Traits of Groundnut Genotypes Screened under Non-Stress and Water Stress Conditions at Samaru 2018

GENOTYPES	SCMR 40 DAS		SCMR 60 DAS		SCMR 80 DAS		LAI	
	NS	WS	NS	WS	NS	WS	NS	WS
12CS-010	33.10	49.03	37.02	44.51	34.35	37.9	0.08	0.06
12CS-102	46.74	43.57	41.78	39.07	49.07	34.2	0.06	0.05
ICG 02148	40.82	45.75	35.93	40.85	42.16	44.5	0.07	0.05
ICG 10346	45.34	28.88	54.39	26.31	41.16	28.8	0.08	0.08
ICG 11249	31.59	40.99	43.47	42.03	26.74	37.2	0.07	0.06
ICG 12189	47.14	46.95	46.35	51.53	50.38	47	0.07	0.06
ICG 1274	38.92	50.22	33.25	45.69	50.98	46.6	0.09	0.05
ICG 12989	42.03	48.83	44.86	43.32	49.27	32.41	0.08	0.07
ICG 12991	37.11	28.58	32.45	42.03	36.25	33.84	0.08	0.05
ICG 1519	43.43	53.50	35.11	48.66	33.41	53.88	0.08	0.07
ICG 15236	43.08	47.66	25.61	43.45	26.79	43.72	0.07	0.07
ICG 1973	39.28	42.38	30.51	45.59	31.34	42.00	0.08	0.05
ICG 2019	35.81	47.24	36.33	46.19	35.96	28.23	0.09	0.08
ICG 2106	39.60	44.66	44.22	53.6	38.30	52.25	0.08	0.08
ICG 231	46.18	49.92	51.52	37.98	43.01	46.51	0.08	0.08
ICG 294	43.74	42.08	38.11	43.02	37.72	38.35	0.08	0.05
ICG 297	47.27	42.88	35.97	43.91	38.85	25.29	0.08	0.06
ICG 311	43.42	49.13	39.14	47.67	37.02	43.85	0.06	0.08
ICG 3312	35.84	42.58	41.17	36.4	27.84	31.28	0.07	0.05
ICG 3421	34.92	26.9	40.96	45.4	28.64	28.92	0.08	0.08
ICG 3584	32.44	50.02	39.62	48.56	38.74	43.53	0.08	0.05
ICG 4911	35.51	25.61	41.38	44.41	40.47	44.45	0.07	0.07
ICG 5195	52.26	41.49	40.39	27.89	48.27	25.70	0.07	0.08
ICG 5236	45.68	50.02	43.13	41.24	30.59	38.50	0.08	0.08
ICG 6813	44.24	49.72	43.67	50.44	35.25	49.40	0.07	0.09
ICG 7906	41.73	44.86	49.52	42.63	39.45	50.40	0.07	0.06
ICG 9777	36.82	52.50	47.73	51.13	39.47	50.60	0.07	0.05
ICG 9905	31.2	50.92	36.3	50.24	39.6	51.8	0.08	0.09
Mean	**40.99**	**43.56**	**39.35**	**42.83**	**39.42**	**41**	**0.08**	**0.07**
CV (%)	**19.63**	**2.02**	**22.75**	**2.026**	**19.16**	**2.82**	**15.9**	**2.02**

NS= Non-stress, WS= Water stress, SCMR= SPAD Chlorophyll Meter Reading and LAI= Leaf Area Index.

Table 4 Cont'd

GENOTYPES	SCMR 40 DAS		SCMR 60 DAS		SCMR 80 DAS		LAI	
	NS	WS	NS	WS	NS	WS	NS	WS
ICGCV-IS-07889	47.14	45.16	31.50	43.71	51.07	29.97	0.09	0.06
ICG-IS-07803	54.14	42.78	31.00	48.07	49.14	46.75	0.07	0.06
ICG-IS-07919	44.43	57.27	37.82	48.16	44.06	51.41	0.08	0.08
ICG-IS-07947	38.68	27.69	46.51	45	47.37	44.27	0.09	0.05
ICG-SM-07539	37.45	39.7	46.76	48.46	46.97	33.84	0.08	0.07
ICG-SM-07541	43.78	44.86	43.82	47.57	43.07	43.17	0.08	0.09
ICGV 07805	46.54	52.9	43.71	48.86	39.26	47.64	0.09	0.09
ICGV-5M00010/P15/P2	44.39	31.46	43.38	43.52	39.81	32.75	0.09	0.08
ICGV-5M00017/5/P1/P1	42.62	47.24	38.00	49.85	42.51	52.4	0.08	0.08
ICGV-91283	46.48	39.4	38.15	28.68	42.87	25.11	0.08	0.06
ICGV-IS-03323	51.55	42.38	46.12	29.27	45.41	25.41	0.09	0.05
ICGV-IS-07803	50.26	40.49	45.83	47.08	45.17	46.05	0.09	0.08
ICGV-IS-07809	34.34	43.87	32.00	44.8	31.96	42.68	0.09	0.07
ICGV-IS-07812	35.82	46.65	39.23	47.08	38.23	25.9	0.08	0.06
ICGV-IS-07813	48.25	38.91	46.28	42.53	52.58	41.69	0.08	0.06
ICGV-IS-07815	49.29	41.69	44.32	46.78	51.53	54.19	0.08	0.07
ICGV-IS-07828	42.75	45.95	40.91	39.56	43.18	33.84	0.07	0.07
ICGV-IS-07829	44.75	44.66	27.30	47.18	32.4	47.24	0.08	0.05
ICGV-IS-07841	49.82	49.13	35.74	30.56	40.65	31.96	0.07	0.07
ICGV-IS-07842	39.18	51.71	36.15	50.54	49.63	48.43	0.07	0.08
ICGV-IS-07843	43.95	24.81	35.53	39.26	48.42	31.66	0.08	0.08
ICGV-IS-07845	47.26	40.79	39.37	38.18	40.67	49.23	0.07	0.05
ICGV-IS-07849	42.47	52.3	43.63	49.35	34.05	45.16	0.07	0.09
ICGV-IS-078513	38.38	56.97	41.1	46.98	39.1	44.46	0.08	0.08
ICGV-IS-07853	33.26	52.3	32.93	52.81	29.54	55.88	0.09	0.05
ICGV-IS-07855	31.78	46.35	27.46	44.01	34.55	27.39	0.08	0.06
ICGV-IS-07859	37.56	51.21	34.00	48.07	35.31	44.56	0.08	0.07
ICGV-IS-07883	35.22	50.92	30.81	50.04	30.8	42.28	0.08	0.09
Mean	**40.99**	**43.56**	**39.45**	**42.83**	**39.42**	**40.99**	**0.08**	**0.07**
CV (%)	**19.63**	**2.02**	**22.8**	**2.026**	**19.16**	**2.82**	**15.9**	**2.02**

NS= Non-stress, WS= Water stress, SCMR= SPAD Chlorophyll Meter Reading and LAI= Leaf Area Index.

Table 4 Cont'd

GENOTYPES	SCMR 40 DAS		SCMR 60DAS		SCMR 80DAS		LAI	
	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-IS-07887	37.99	48.53	26.93	27.79	38.15	38.70	0.08	0.05
ICGV-IS-07891	44.19	46.85	41.27	26.80	47.27	39.00	0.09	0.06
ICGV-IS-07893	41.00	49.44	32.99	46.67	38.72	43.01	0.09	0.08
ICGV-IS-07894	42.20	45.26	33.46	45.89	28.14	42.32	0.08	0.09
ICGV-IS-07895	41.80	53.99	37.64	51.33	32.74	56.66	0.08	0.06
ICGV-IS-07900	39.75	33.55	40.90	43.81	37.15	45.00	0.06	0.06
ICGV-IS-07902	36.39	41.69	35.24	46.98	33.76	48.76	0.07	0.09
ICGV-IS-07904	37.38	39.6	35.93	47.67	41.29	42.53	0.08	0.07
ICGV-IS-13007	46.85	51.41	43.63	46.58	47.28	30.2	0.09	0.07
ICGV-IS-13050	44.38	33.05	41.71	52.81	44.71	28.5	0.09	0.05
ICGV-IS-13075	42.53	53.10	41.06	55.48	37.82	29.40	0.09	0.06
ICGV-IS-13097	35.02	29.78	42.87	43.12	34.39	39.10	0.09	0.09
ICGV-IS-13112	37.04	39.70	47.93	33.23	42.91	28.40	0.09	0.07
ICGV-IS-13115	42.34	46.55	40.94	49.25	35.12	47.10	0.09	0.04
ICGV-IS-13865	43.82	33.25	41.64	41.83	39.74	35.40	0.09	0.07
ICGV-IS-13878	38.09	45.75	38.08	44.9	48.78	38.80	0.09	0.07
ICGV-IS-13911	34.98	51.51	36.69	52.81	44.47	49.20	0.08	0.08
ICGV-IS-13938	41.13	48.33	41.61	50.44	39.87	39.00	0.08	0.06
ICGV-IS-13978	42.37	48.33	40.06	36.49	36.50	48.70	0.08	0.07
ICGV-IS-13982	43.13	39.20	42.48	44.31	42.41	41.50	0.07	0.06
ICGV-IS-13986	41.92	51.01	41.13	36.79	46.17	52.80	0.07	0.06
ICGV-IS-13989	47.13	24.42	41.95	22.35	46.67	23.00	0.09	0.09
ICGV-IS-13990	53.11	51.61	47.12	54.20	47.72	52.60	0.07	0.09
ICGV-IS-O7816	39.31	39.10	38.82	37.19	36.92	42.20	0.07	0.09
ICGX 11003	34.62	49.03	36.29	48.36	25.74	46.42	0.07	0.07
ICGX-5M-00017/5/P5/P2	36.43	42.68	36.46	40.85	26.24	33.10	0.07	0.08
ICGX-5M-00018/5/4/P2	33.03	49.03	30.88	42.53	33.49	44.85	0.09	0.08
Mean	**40.99**	**43.56**	**39.35**	**42.83**	**39.42**	**41**	**0.08**	**0.07**
CV (%)	**19.63**	**2.02**	**22.75**	**2.026**	**19.16**	**2.82**	**15.90**	**2.02**

NS= Non-stress, WS= Water stress, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing and LAI= Leaf Area Index.

Table 4. Cont'd

GENOTYPES	SCMR 40DAS		SCMR 60DAS		SCMR 80DAS		LAI	
	NS	WS	NS	WS	NS	WS	NS	WS
ICGX-IS-11057	35.11	49.89	35.15	44.12	33.71	52	0.09	0.08
ICGX-IS-13011	46.23	32.55	47.67	36.40	47.59	42.3	0.09	0.08
ICGX-IS-13988	42.25	30.37	42.82	43.42	34.34	46.8	0.08	0.05
J.L 11	44.51	41.59	39.38	44.41	37.76	42.8	0.07	0.06
RS006F3B1-22®	35.56	33.55	33.37	48.26	33	42.3	0.06	0.05
RS006F4B1-17	34.00	43.97	40.08	26.60	30.75	44.8	0.06	0.09
RS006F4B1-22	36.9	48.33	39.17	52.02	37.89	55.0	0.07	0.06
RS006F4B1-31	34.47	43.87	29.99	30.96	36.32	43.0	0.08	0.07
RS006F4B1-4(B)	30.03	48.63	27.31	51.23	28.69	54.4	0.05	0.05
RS006F4B1-45(B)	36.9	41.09	36.13	44.01	29.8	39.2	0.05	0.07
RS006F4B1-45 ®	37.48	23.42	37.98	26.01	30.99	23.7	0.07	0.04
RS006F4B1-49	34.15	35.53	35.25	43.52	34.7	40.9	0.08	0.05
RS006F4B1-50	39.96	44.86	39.32	41.54	37.3	40.8	0.08	0.08
RS006F4B1-53(B)	45.33	40.59	42.49	42.43	47.11	48.1	0.08	0.08
RS006F4B1-85	44.34	53.79	44.92	36	49.38	57.1	0.07	0.09
RS006F4B1-B5	41.53	41.78	42	36.2	41.91	32	0.07	0.06
RS006F4B-21	41.87	40.00	39.06	41.93	42.46	34.9	0.09	0.05
RS006F4B-534	44.08	27.59	42.5	28.29	35.77	26.3	0.09	0.06
RS066F3B1-57(B)	44.68	36.13	48.36	33.63	35.89	35.9	0.07	0.09
SAMNUT 14	38.33	44.96	47.81	38.37	44.37	41.7	0.07	0.06
SAMNUT 23	38.65	44.76	42.82	38.47	44.22	42.0	0.08	0.08
SAMNUT 24	40.59	46.25	34.03	25.71	43.12	25.0	0.07	0.05
SAMNUT 25	40.76	50.52	34.95	49.65	42.76	49.9	0.07	0.05
SAMNUT 26	43.19	44.96	43.72	39.26	43.52	43.7	0.06	0.08
Mean	**40.99**	**43.56**	**39.35**	**42.83**	**39.42**	**41**	**0.08**	**0.07**
CV (%)	**19.63**	**2.020**	**22.75**	**2.03**	**19.16**	**2.82**	**15.90**	**2.02**

NS= Non-stress, WS= Water stress, SCMR= SPAD Chlorophyll Meter Reading and LAI= Leaf Area Index.

Table 5: Principal component analysis for 107 groundnut genotypes screened under non-stress condition at Samaru 2018

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
SAMNUT 26	1.45	1.69	0.00	17.98	1
ICGV-IS-07812	3.32	3.18	3.41	15.13	2
ICG 3312	0.00	0.21	1.28	10.18	3
RS006F4B1-45(B)	3.73	0.91	0.00	9.92	4
ICGV-IS-07813	0.54	0.74	5.49	9.68	5
ICGV-IS-07904	1.54	1.98	0.52	9.62	6
ICG 297	0.68	1.32	0.22	8.68	7
ICGV-IS-07828	0.95	1.97	0.12	8.25	8
ICGX 11003	1.15	0.17	0.08	8.22	9
ICGV-IS-07842	2.36	0.09	3.15	8.03	10
ICGX-5M-00018/5/4/P2	0.79	0.01	1.32	7.71	11
RS006F4B1-4(B)	1.23	0.96	1.68	7.56	12
ICGV-IS-07902	0.45	0.22	0.28	7.49	13
ICGV-IS-13878	1.71	1.40	0.02	7.48	14
ICG 3584	0.08	0.02	1.20	7.06	15
ICGV-IS-07841	0.87	1.62	0.00	6.76	16
ICGV-IS-07887	6.32	0.00	1.38	6.73	17
RS006F4B1-85	1.16	0.15	0.35	6.47	18
ICG 311	0.02	0.57	1.78	6.30	19
ICGV-IS-07803	4.32	6.35	7.31	5.98	20
ICGV-IS-07894	0.50	0.06	1.31	5.94	21
ICG-IS-07803	7.41	0.83	0.02	5.86	22
ICG 5195	0.92	1.48	0.46	5.82	23
ICG 1973	0.69	1.68	0.32	5.73	24
ICG 12189	8.99	0.00	0.69	5.61	25
ICG 231	0.78	0.13	1.65	5.60	26
ICG-IS-07919	2.15	3.21	1.11	5.29	27
ICGX-IS-13988	1.11	1.03	0.01	5.17	28
ICGV-IS-07855	6.76	0.63	0.16	5.05	29
ICGV-IS-13007	3.32	0.09	1.28	4.69	30
ICGV-IS-O7816	0.17	1.53	0.27	4.64	31
ICGV-IS-13865	0.14	0.45	0.19	4.49	32
ICG 294	7.42	0.45	1.74	4.45	33
ICGV-IS-078513	0.00	0.71	1.67	4.41	34
ICGV-IS-13990	0.04	0.28	1.16	4.32	35

Table 5 Cont'd

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
RS006F4B1-49	8.09	0.01	0.12	4.26	36
ICGV-IS-07815	1.52	1.71	0.00	4.04	37
ICGX-5M-00017/5/P5/P2	4.79	0.01	1.14	3.91	38
SAMNUT 14	13.29	0.24	1.6	3.91	39
ICGV-IS-13075	5.24	0.62	0.44	3.87	40
ICG 1274	4.11	5.62	0.44	3.74	41
ICG 2019	2.15	0.17	0.00	3.48	42
ICGV-IS-07859	0.96	0.88	1.21	3.47	43
ICG 12991	0.11	0.05	1.69	3.28	44
ICGV-IS-07829	5.08	0.39	1.60	3.23	45
ICGV-IS-07845	0.79	0.83	1.87	3.15	46
RS006F4B1-17	1.02	0.37	0.02	3.14	47
ICGV-IS-07900	0.18	0.58	0.7	3.13	48
ICGV-IS-07843	0.36	0.01	1.25	3.06	49
ICGV-IS-13115	3.46	0.00	0.28	3.04	50
RS006F4B1-50	0.72	2.86	3.90	3.03	51
ICGV-IS-13911	1.92	0.78	1.75	2.91	52
ICGCV-IS-07889	2.31	3.08	0.34	2.86	53
RS006F4B1-45®	0.02	0.03	1.39	2.72	54
ICGV-IS-07893	1.77	0.53	0.00	2.71	55
ICG-IS-07947	3.08	0.62	4.98	2.69	56
ICG 9905	0.75	1.94	0.00	2.69	57
RS006F4B1-B5	5.65	0.2	0.01	2.65	58
ICG 12989	0.53	0.25	1.13	2.57	59
ICGV-IS-07849	0.37	1.24	0.26	2.49	60
ICG 10346	1.13	0.57	0.01	2.43	61
ICGV 07805	1.58	0.48	0.01	2.41	62
ICGV-91283	2.09	0.26	2.14	2.38	63
ICGV-5M00017/5/P1/P1	6.35	0.18	0.20	2.37	64
SAMNUT 24	4.60	3.28	0.15	2.35	65
J.L 11	1.91	0.21	0.13	2.32	66
ICG 15236	1.90	0.04	2.32	2.31	67
ICG 5236	0.53	0.73	0.10	2.30	68
RS006F3B1-22®	0.01	3.77	0.13	2.28	69
12CS-010	0.73	0.02	0.04	2.22	70

Table 5 Cont'd

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
ICG-SM-07541	0.67	4.60	0.02	2.21	71
12CS-102	0.58	0.99	0.78	2.14	72
ICG 4911	2.41	0.02	0.00	2.12	73
ICG 9777	0.77	1.23	0.13	2.11	74
ICG 11249	0.07	0.20	0.31	2.07	75
SAMNUT 23	0.04	0.70	0.03	1.99	76
ICGV-IS-07809	3.94	1.80	0.23	1.97	77
ICGV-IS-13938	3.55	2.13	0.14	1.91	78
ICGV-IS-03323	2.26	0.72	0.18	1.87	79
ICGX-IS-11057	0.37	1.07	0.19	1.87	80
ICGV-IS-13986	1.29	0.11	3.02	1.86	81
ICG 7906	0.88	1.75	0.02	1.77	82
ICGV-5M00010/P15/P2	0.00	1.76	0.01	1.72	83
ICG 2106	1.03	1.02	0.37	1.71	84
ICGV-IS-13097	0.07	0.12	0.20	1.66	85
ICGV-IS-13978	1.69	0.68	0.86	1.62	86
ICGX-IS-13011	0.99	0.00	1.23	1.60	87
RS006F4B-534	0.16	0.03	3.09	1.51	88
RS006F4B1-31	0.21	1.51	0.99	1.48	89
ICG 02148	3.35	0.94	0.04	1.48	90
RS006F4B1-53(B)	4.88	0.65	0.08	1.46	91
RS006F4B-21	2.24	1.65	0.02	1.44	92
ICG 6813	1.49	0.4	0.22	1.43	93
RS006F4B1-22	1.65	0.54	0.52	1.41	94
ICGV-IS-07853	3.06	3.31	1.11	1.4	95
SAMNUT 25	0.22	0.00	0.99	1.36	96
ICGV-IS-07891	2.05	0.1	0.14	1.30	97
ICGV-IS-13050	2.39	0.21	0.32	1.20	98
ICGV-IS-07883	0.09	0.83	0.09	1.01	99
RS066F3B1-57(B)	0.56	0.00	1.15	1.01	100
ICG-SM-07539	0.15	0.18	0.42	0.95	101
ICGV-IS-13989	2.01	1.11	2.05	0.78	102
ICGV-IS-07895	3.83	0.15	1.08	0.77	103
ICGV-IS-13982	0.06	0.09	1.84	0.75	104
ICG 1519	0.59	0.85	0.07	0.66	105
ICG 3421	0.18	0.04	0.79	0.58	106
ICGV-IS-13112	0.78	0.02	0.80	0.40	107

Table 6: Principal component analysis for 107 groundnut genotypes screened under water-stress condition at Samaru 2018

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
ICGV-IS-13115	5.91	20.61	1.11	27.64	1
RS006F4B1-45®	14.31	4.78	0.00	19.10	2
ICGV-IS-07853	8.97	8.78	0.41	18.16	3
ICGV-IS-13989	12.17	0.18	5.46	17.81	4
RS006F4B-534	10.37	0.12	0.20	10.69	5
ICG 3312	0.02	10.21	0.10	10.32	6
ICGV-IS-13978	1.95	7.16	1.13	10.24	7
ICG 10346	7.03	0.08	1.77	8.88	8
ICG 5195	3.77	0.82	3.98	8.57	9
RS006F4B1-17	0.16	0.81	6.45	7.42	10
ICG 15236	4.48	1.69	1.14	7.32	11
ICGV-IS-13990	5.19	0.01	2.02	7.22	12
ICGV-91283	6.30	0.18	0.17	6.65	13
ICGV-IS-03323	5.42	0.08	0.37	5.86	14
ICGV-IS-07843	4.33	1.05	0.01	5.39	15
ICG 9777	3.10	0.76	1.42	5.27	16
ICG 9905	3.01	1.54	0.34	4.89	17
RS006F4B1-4(B)	2.82	0.58	1.46	4.86	18
SAMNUT 24	4.75	0.02	0.00	4.77	19
ICG-IS-07919	4.00	0.00	0.72	4.71	20
ICGV-IS-07842	1.66	2.82	0.07	4.55	21
ICG 1519	2.94	1.04	0.51	4.49	22
RS006F4B1-85	1.26	1.72	1.41	4.40	23
ICG 6813	3.68	0.32	0.30	4.29	24
ICG 12991	1.98	0.74	1.50	4.22	25
ICGV 07805	2.27	1.52	0.42	4.21	26
ICGV-IS-07895	3.70	0.03	0.44	4.16	27
ICG 2106	3.44	0.50	0.21	4.15	28
ICGV-IS-13112	2.81	0.45	0.83	4.09	29
ICGV-IS-078513	2.31	0.25	1.53	4.09	30
RS066F3B1-57(B)	3.09	0.42	0.24	3.74	31
ICGV-IS-07849	1.73	0.29	1.71	3.73	32
RS006F4B1-49	0.85	0.20	2.49	3.54	33
ICG 1274	0.75	0.00	2.68	3.43	34
ICGV-IS-13911	3.06	0.26	0.09	3.41	35

Table 6 Cont'd

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
RS006F4B-21	0.48	2.52	0.33	3.33	36
ICGV-5M00010/P15/P2	1.81	1.49	0.00	3.3	37
ICGV-IS-07855	0.10	3.09	0.08	3.27	38
RS006F4B1-22	2.74	0.01	0.52	3.27	39
ICG 3421	2.42	0.77	0.02	3.21	40
SAMNUT 25	2.52	0.00	0.58	3.10	41
ICGV-IS-13050	1.24	0.14	1.67	3.05	42
ICG 294	0.46	0.20	2.34	3.00	43
ICG 297	1.47	0.39	1.08	2.94	44
ICGV-IS-07883	1.41	0.57	0.87	2.85	45
ICGX-IS-11057	2.41	0.04	0.38	2.82	46
ICGX-IS-13011	1.38	1.31	0.06	2.75	47
ICGV-IS-13097	0.9	1.14	0.66	2.70	48
ICGV-IS-07887	1.11	1.56	0.02	2.69	49
ICGV-IS-13938	0.12	0.86	1.69	2.67	50
ICG 311	0.54	2.09	0.02	2.66	51
ICG 5236	2.44	0.17	0.02	2.63	52
ICGV-5M00017/5/P1/P1	1.87	0.38	0.17	2.41	53
ICGV-IS-07812	0.54	0.54	1.33	2.41	54
ICGV-IS-07900	0.84	0.06	1.50	2.41	55
ICG-SM-07541	1.92	0.02	0.40	2.35	56
SAMNUT 23	0.00	0.38	1.95	2.33	57
ICGV-IS-07902	1.33	0.00	0.99	2.32	58
ICG-IS-07947	1.04	0.24	1.01	2.29	59
ICGV-IS-07894	0.19	1.46	0.57	2.22	60
ICGCV-IS-07889	0.65	0.46	1.05	2.15	61
ICG 12189	0.96	0.1	1.06	2.12	62
ICGV-IS-O7816	0.08	0.04	2.00	2.11	63
ICG-IS-07803	0.47	1.59	0.01	2.07	64
12CS-102	0.86	1.07	0.12	2.06	65
ICGV-IS-07893	0.57	1.45	0.02	2.04	66
ICG 2019	0.19	1.84	0.01	2.04	67
RS006F3B1-22®	0.24	1.56	0.20	2.00	68
ICGV-IS-07891	0.72	1.12	0.11	1.94	69
ICG 11249	0.55	0.42	0.96	1.93	70

Table 6 Cont'd

Genotypes	PC1	PC2	PC3	Ranking	Numeric Ranking
RS006F4B1-B5	1.77	0.12	0.00	1.89	71
ICGV-IS-07859	1.46	0.33	0.10	1.88	72
RS006F4B1-31	0.47	0.37	1.01	1.86	73
ICG-SM-07539	0.24	1.04	0.54	1.82	74
ICGV-IS-13075	0.38	0.08	1.33	1.79	75
ICG 1973	0.07	0.02	1.69	1.78	76
J.L 11	0.05	0.55	1.17	1.77	77
ICGX-IS-13988	0.62	0.80	0.35	1.77	78
ICG 231	0.10	1.57	0.06	1.74	79
ICGV-IS-13865	1.17	0.30	0.27	1.74	80
ICGV-IS-13878	0.02	1.39	0.31	1.73	81
ICGV-IS-07829	0.29	0.33	1.08	1.70	82
ICGV-IS-13007	0.02	1.25	0.36	1.63	83
SAMNUT 14	0.30	0.60	0.66	1.56	84
ICGV-IS-13986	0.76	0.36	0.39	1.50	85
ICGV-IS-13982	0.10	0.21	1.19	1.50	86
ICG 7906	0.38	0.08	1.04	1.49	87
ICG 3584	0.29	0.03	1.12	1.45	88
ICGX-5M-00018/5/4/P2	0.18	1.06	0.16	1.39	89
ICGX 11003	1.11	0.11	0.09	1.30	90
ICG 02148	0.01	0.68	0.6	1.28	91
SAMNUT 26	0.13	0.00	1.07	1.20	92
ICG 4911	0.58	0.20	0.42	1.20	93
ICGV-IS-07803	0.32	0.82	0.03	1.18	94
ICGV-IS-07845	0.08	0.05	1.03	1.16	95
ICGV-IS-07815	0.96	0.00	0.00	0.97	96
ICGX-5M-00017/5/P5/P2	0.27	0.62	0.01	0.90	97
ICG 12989	0.00	0.59	0.26	0.85	98
ICGV-IS-07841	0.46	0.25	0.13	0.84	99
RS006F4B1-50	0.00	0.12	0.57	0.69	100
RS006F4B1-53(B)	0.07	0.09	0.47	0.63	101
ICGV-IS-07813	0.23	0.06	0.12	0.41	102
ICGV-IS-07904	0.04	0.27	0.08	0.39	103
RS006F4B1-45(B)	0.1	0.24	0.05	0.38	104
ICGV-IS-07809	0.03	0.09	0.19	0.30	105
12CS-010	0.02	0.09	0.15	0.27	106
ICGV-IS-07828	0.17	0.01	0.00	0.18	107