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ORIGINAL RESEARCH ARTICLE

Genetic Diversity Studies in Groundnut (*Arachis Hypogaea L.*) using Morpho-Physiological Traits

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ABSTRACT

The importance of leguminous crops such as groundnut cannot be overemphasized globally. Due to the increase in global warming, water scarcity threatens the environment, thereby affecting plant growth and metabolic activities in both semi-arid and arid zones of the world. Drought stress has severely hindered groundnut yield because pod yield and other growth characteristics have been severely affected. Therefore, mitigating this hindrance requires a conscious selection of suitable genotypes that could withstand drought threats to groundnut production. The study aimed to identify drought-tolerant genotypes suitable for the groundnut breeding program. One hundred and seven (107) groundnut genotypes were screened for drought tolerance during the 2018 dry season in a split-plot design under non-stress and water-stress conditions. The mean squares for the morphological and physiological traits showed a highly significant (P≤0.01) difference between the genotypes under water stress and combined conditions. The mean performance using the Rank Summation Index revealed ICGV-IS-07902 as the top-performing genotype, followed closely by ICGX-5M-00017/5/P5/P2 and ICGV-IS-13978 while RS006F4B1-45(B) was the least ranked under water stress condition. Based on the PCA ranking under water-stress conditions, 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. The genotypes ICGV-IS-13115, RS006F4B1-45®, ICGV-IS-07853, and ICGV-IS-13989 were observed to be better for drought tolerance with high pod yield. It is suggested that these genotypes could be recommended for further breeding and variety release adapted to drought conditions.

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KEYWORDS

Cluster analysis, Non-stress, Principal Component Analysis (PCA), Water-stress.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important legume in Nigeria. It is a major source of protein when consumed, and it is highly used for oil production. In addition to high protein content (16-28%), it is considered the most popular oilseed in the world, ranked above soybean, cotton, and canola (Arruda *et al.*, 2015). Groundnut is being grown in Nigeria, in the sandy soil regions having low water holding capacity. This often yields low. The plant growth stage determines the extent of damage caused by water stress, intensity, and duration of the stress (Hamidou *et al.*, 2013). Despite enormous research efforts in groundnut, limited rainfall, and drought spells have led to poor yield, and other growth parameters have been severely affected (Pimratch *et al.*, 2008). Yield losses have been estimated to be 56-85% (Nageswara *et al.*, 1989) depending upon the growth stages when the crop was exposed to drought (Reddy *et al.*, 2003), drought intensities and duration (Nigam *et al.*, 2005). Drought resistance and variation is an important strategy to combat drought problems. This variation should provide a high pod yield under dry conditions. As noted by several researchers, direct selection for yield under water stress conditions may be effective, but the setback of this approach is 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 some physiological traits such as SPAD chlorophyll meter reading (SCMR) and Harvest Index. Both SCMR and HI have been utilized as surrogate traits for Water Use Efficiency (WUE).

Genetic variability for drought resistance has been reported in groundnuts (Songsori *et al.*, 2009). However, breeding for drought based on pod yield lags due to significant Genotype x Environment (G x E) interaction.

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Alternatively, breeding strategies using physiological traits have been proposed by some researchers. Rapid progress in drought resistance breeding has 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).

Genetic diversity studies on groundnuts have been well reported by several investigators, therefore providing a large scale on the importance of such studies (Zaman *et al.*, 2011; Singh *et al.*, 2015). Dao *et al.* (2014) reported that genetic diversity in different germplasms strengthens the adaptability to a reach of environments. Thus, the selection of the improved breeding population depends on the level of available genetic diversity (Amarasinge *et al.*, 2016). Phenotypic characterization is the first step for describing, assessing, and classifying germplasm collections to ascertain their use in groundnut breeding (Garba *et al.*, 2015). The assessment of the phenotype has proven effective for diversity analysis in some legumes and oil crops, including groundnut (Saritha *et al.*, 2018; Garba *et al.*, 2015; Oppong-Sekyere *et al.*, 2019). Multivariate analysis is a popular method for estimating genetic variability to study the components of variation and their genetic relationships between germplasm collections (Syafii *et al.,* 2015; Rahal-Bouziane *et al.*, 2015). Multivariate analyses have been used in many studies on groundnuts (Makinde *et al.*, 2013). Selection effectiveness depends on the extent of genetic variability present in the available germplasm for the trait of interest and its heritability value (Garba *et al.*, 2015). This study aimed to provide information on the extent of genetic diversity of the selected genotypes and the interrelationships between yield, morphological, and physiological, which is desirable for suggesting appropriate breeding procedures, especially under stressed conditions.

MATERIALS AND METHODS

Experimental Site

The research was carried out at the Institute for Agricultural Research (IAR) Research Farm, 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 research was executed during the 2018 dry season.

Screening for Drought

A total of one hundred and seven (107) groundnut genotypes were selected from the IAR Groundnut Breeding unit in the Department of Plant Science. The genotypes were screened for drought tolerance under both non-stress and water-stress conditions.

Experimental Design

The suitable design for the research was a split-plot design with two replications for both non-stress and water stress. Whereby groundnut genotypes were assigned as main plots, and two soil moisture levels (no stress and water stress) were laid out in subplots. Each entry was planted in a row of 5m plots with a spacing of 0.75m inter-row and 0.25m intra-row spacing. The experimental field was calculated to be 1199m^2.

Crop Management

Across both treatments, the land was prepared for planting by harrowing followed by ridging. Fertilizers were applied at the rate of 18kg Single Super Phosphate (SSP) and 6kg NPK 15:15:15 a week after germination. Three to four seeds were planted per stand, and the seedlings were thinned to two plants per stand 14 days after sowing (DAS). Manual weeding was carried out 2, 4, and 6 weeks after planting.

Data Collection

Data was collected on the following parameters.

Days to 50% flowering: This was recorded from the sowing date until half of the plants in each plot had flowered.

Number of pods per plant: The number of pods per plant was counted from each plant in each plot.

SPAD Chlorophyll Meter Reading (SCMR): This was measured twice on each leaflet of a tetra foliate leaf along the mid-rib at 40, 60, and 80 days after sowing (DAS) using SPAD chlorophyll meter. The third fully-expanded leaves from each plant were used for determining the SCMR; this was carried out between 08:30 am and 10:00 am hours because, during this time, there is high stomatal conductance, which allows photosynthesis to take place since evaporation demand is low, particularly in stressed groundnut genotypes (Smartt, 1994).

Statistical Analysis

Analysis of variance was run for each treatment following a split-plot design using the Statistical Analysis System (SAS) package (SAS, 2002), and where there was a significant difference between treatment means, Fisher's protected Least Significant difference (LSD) test was used for comparison (Gomez and Gomez, 1984). Calculation procedures were based on a linear model for split-plot design as follows:

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

Table 1: List of genotypes assessed

12CS-010	ICGCV-IS-07889	ICGV-IS-07893	ICGX-IS-11057
12CS-102	ICG-IS-07803	ICGV-IS-07894	ICGX-IS-13011
ICG 02148	ICG-IS-07919	ICGV-IS-07895	ICGX-IS-13988
ICG 10346	ICG-IS-07947	ICGV-IS-07900	J.L 11
ICG 11249	ICG-SM-07539	ICGV-IS-07902	RS006F3B1-22®
ICG 12189	ICG-SM-07541	ICGV-IS-07904	RS006F4B1-17
ICG 1274	ICGV 07805	ICGV-IS-13007	RS006F4B1-22
ICG 12989	ICGV-5M00010/P15/P2	ICGV-IS-13050	RS006F4B1-31
ICG 12991	ICGV-5M00017/5/P1/P1	ICGV-IS-13075	RS006F4B1-4(B)
ICG 1519	ICGV-91283	ICGV-IS-13097	RS006F4B1-45(B)
ICG 15236	ICGV-IS-03323	ICGV-IS-13112	RS006F4B1-45 ®
ICG 1973	ICGV-IS-07803	ICGV-IS-13115	RS006F4B1-49
ICG 2019	ICGV-IS-07809	ICGV-IS-13865	RS006F4B1-50
ICG 2106	ICGV-IS-07812	ICGV-IS-13878	RS006F4B1-53(B)
ICG 231	ICGV-IS-07813	ICGV-IS-13911	RS006F4B1-85
ICG 294	ICGV-IS-07815	ICGV-IS-13938	RS006F4B1-B5
ICG 297	ICGV-IS-07828	ICGV-IS-13978	RS006F4B-21
ICG 311	ICGV-IS-07829	ICGV-IS-13982	RS006F4B-534
ICG 3312	ICGV-IS-07841	ICGV-IS-13986	RS066F3B1-57(B)
ICG 3421	ICGV-IS-07842	ICGV-IS-13989	SAMNUT 14
ICG 3584	ICGV-IS-07843	ICGV-IS-13990	SAMNUT 23
ICG 4911	ICGV-IS-07845	ICGV-IS-O7816	SAMNUT 24
ICG 5195	ICGV-IS-07849	ICGX 11003	SAMNUT 25
ICG 5236	ICGV-IS-078513	ICGV-IS-07891	SAMNUT 26
ICG 6813	ICGV-IS-07853	ICGX-5M-00018/5/4/P2	ICGV-IS-07887
ICG 7906	ICGV-IS-07855	ICGX-5M-00017/5/P5/P2	
ICG 9777	ICGV-IS-07859		
ICG 9905	ICGV-IS-07883		

Table 2: Form of Analysis of Variance for Split Plot Design for One Condition for Random Model.

Source of variation	DF	MS	EMS
Replication	$r-1$	MS_R	
Water Condition (C)	$a-1$	MS_W	$\sigma_{e_a}^2 + r\sigma_{gc}^2 + rg\sigma_c^2$
Error a	$(r-1)(a-1)$	MS_{EW}	$\sigma_{e_a}^2$
Genotype (G)	$b-1$	MS_G	$\sigma_{e_b}^2 + \sigma_{gc}^2 + rc\sigma_g^2$
(G x C)	$(a-1)(b-1)$	MS_{WxG}	$\sigma_b^2 + r\sigma_{gc}^2$
Error b	$a(r-1)(b-1)$	MS_{EG}	σ_b^2
Total	$rab-1$		

Where, r = number of replications, c = number of water condition, g= number of genotypes, MS= Mean Square;

σ_b^2= Variance due to environmental error (b)

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

σ_g^2= Genotypic Variance effect

σ_c^2= Variance due to water condition effect.

Principal Component Analysis (PCA)

The Principal Component analysis was produced using the XLSTAT 2007 programming package to determine the traits of the plants that give rise to variation among genotypes and the contributions that the various traits made to the total variability in the genotypes.

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

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

Cluster Analysis

The dendrogram for the genotypes was also initiated from the XLSTAT package, and cluster analysis was deployed in grouping the genotypes as described by Achola *et al.*, (2017). Genotypes in different clusters have contrasting attributes compared to each other.

RESULTS

Analyses of Variance

The morphological traits (days to 50% flowering and number of pods per plant) screened under non-stress and water stress conditions at Samaru are shown in Table 3. The mean squares for genotypes showed a highly significant (P≤0.01) difference for the two traits measured in both conditions, except for the number of pods per plant under non-stress conditions, which showed a non-significant (P>0.05) difference. The physiological traits (SPAD Chlorophyll Meter Reading (SCMR) at 40, 60, and 80 DAS) screened under non-stress and water stress conditions at Samaru are presented in (Table 3). The genotypes' responses to drought under combined conditions are shown in Table 4, along with various physiological parameters, such as SPAD Chlorophyll (SCMR) for 40, 60, and 80 DAS and days to 50% blooming and number of pods per plant. For all morphological and physiological variables, the genotype analysis of variance results and the genotype and water conditions interaction were very significant (P≤0.01) (Table 4).

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

Tables 5 and 6 list the top 15 genotypes that performed the best and the top 10 that performed the worst based on the number of pods per plant, SCMR at 40DAS, 60DAS, and LAI assessed using the rank summation index. The number of pods per plant for the top three genotypes—ICG 6813, ICG 12189, and ICG-SM-07541—was higher under non-stress conditions than the average performance of all genotypes by 42%, 62%, and 63%, respectively. On the other hand, among the 10 least performing genotypes, eight of the ten (10) genotypes had pods lower than the overall mean. For SCMR at 40DAS and 60DAS, all the top-performing genotypes were higher than the overall mean by (%), 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 5).

Table 3: Mean Square for Morphological and Physiological Traits Measured under Non-Stress and water-stress conditions at Samaru 2018

Source of Variation	DF	DFF		NPPT		SCMR 40DAS		SCMR 60DAS		SCMR 80DAS	
		NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
Rep	1	<0.001**	48.57**	2.00	158.79**	6.95	16.18**	25.43	17.17	2.75	17.17**
Genotype	106	45.43**	9.36**	28.7	79.49**	54.59	120.20**	64.05	152.10**	88.56**	152.12**
Error	106	1.75	<0.001	11.87	3.57	64.72	0.77	80.12	1.34	57.03	1.34

****:** 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, SCMR= SPAD Chlorophyll Meter Reading and DAS=Days after sowing

Table 4: Mean Square for Morphological and Physiological Traits Measured under Combined Conditions at Samaru 2018

Source of variation	DF	DFF	NPPT	SCMR 40DAS	SCMR 60DAS	SCMR 80DAS
Replication	1	93.99	98.23**	0.96	62.42	16.84
Water Condition(C)	1	171.15**	80.80**	709.83**	1295.62**	262.43**
Error a	1	90.43	10.56	45.36	57.68	25.89
Genotype (G)	106	590.39**	54.28**	83.77**	75.69**	114.69**
G x C	106	586.85**	53.92**	91.02**	98.32**	125.99**
Error b	213	56.71	7.98	32.69	40.25	29.06

****:** highly significant difference at (P≤0.01) probability level, *DF*= Degree of freedom, DFF= Days to 50% flowering, NPPT= Number of pods per plant, SCMR= SPAD Chlorophyll Meter Reading, DAS= Days after sowing.

Table 5: Rank Summation Index of Some Groundnut genotypes Screened under Non-Stress Conditions at Samaru 2018

Genotypes	NPPT	SCMR 40DAS	SCMR 60DAS	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.

Table 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.

Ten (10) of the best-performing genotypes under water stress exhibited pod counts per plant that were at least as high as the average for all genotypes. The number of pods per plant for the top three genotypes, ICGV-IS-07815, ICGV-IS-07841, and ICGV-IS-13978, was higher than the average performance of all genotypes by 47%, 57%, and 87%, respectively. Most top-performing genotypes (43.56) had SCMR at 40DAS values higher than the overall mean. The three best-performing genotypes (ICGV-IS-07843, ICG 9777, and ICG 1519) had SCMR at 40DAS values greater than the mean performance of all genotypes (16–19%), while eight (8) of the ten least performing genotypes had values lower than the mean. Six (6) of the lowest-performing genotypes had SCMR at 60DAS lower than the mean performance of all genotypes, whereas thirteen (13) of the best-performing genotypes had SCMR at 60DAS higher than the mean performance of all genotypes (3%–16%). Nine genotypes (9) for LAI ranked higher than the mean overall (Table 6).

Principal Component Analysis

For the morphological and physiological characteristics tested under non-stress and water stress, the findings of principal component analysis based on the correlation matrix are shown in Table 7. The morphological and physiological characteristics of the genetic variation among the groundnut genotypes under non-stress and water stress were explained by the total variance of the first three principal component (PC) axes in 70.04% and 70.81% of cases. Under non-stress and water-stress conditions, respectively, principal component axis one (PC1) explained 35.92% and 34.73%, PC2 17.36% and 20.33%, and PC3 accounted for 16.76% and 15.75% of the overall variation. Days to 50% blooming got the highest score for PC2 and PC3, SCMR 80DAS, while the number of pods per plant had the highest score for PC1 under non-stress conditions. Regarding physiological characteristics, SCMR 40, 60, and 80 DAS scored highly under PC1, SCMR 80 DAS and Leaf Area Index scored highly under PC2, and SCMR 80 DAS and LAI scored highly under PC3. When plants were under water stress, their morphological features showed that the number of pods on each plant had a high score under PC1, and the days to 50% flowering had a high score in PC2. Regarding physiological features, SCMR 40, 60, and 80 DAS scored highly under PC1, SCMR 60 DAS scored highly under PC2, and SCMR 40 DAS and LAI scored highly under PC3.

Tables 8 and 9 exhibited the principal component scores of the 107 groundnut genotypes based on the physiological and morphological parameters determined under non-stress and water-stress conditions. The contributions of each genotype to the major components were displayed in the results. The best genotypes were thought to contribute most of each component's impacts, as indicated by their higher percentage values.

The findings under non-stress conditions showed that the characters in PC2 were most impacted by ICGV-IS-07803 (6.35), ICG 1274 (5.62), and ICG-SM-07541 (4.6), while the characters in PC1 were most contributed to by SAMNUT 14 (13.29), ICG 12189 (8.99), and RS006F4B1-49 (8.09). The three with the highest character contributions on PC3 were ICGV-IS-07803 (7.31), ICGV-IS-07813 (5.49), and ICGV-IS-07947 (4.98).

Table 7: Principal Component 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 40DAS	0.82	0.77	0.01	0.08	-0.06	0.03
SCMR 60DAS	0.77	0.74	0.01	0.18	0.01	-0.32
SCMR 80DAS	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 8: PCA 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	0.00	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	1.4	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	0.00	0.99	1.36	96
ICGV-IS-07891	2.05	0.10	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	0.8	0.4	107

Table 9: PCA 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®	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
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	0.3	105
12CS-010	0.02	0.09	0.15	0.27	106
ICGV-IS-07828	0.17	0.01	0.00	0.18	107

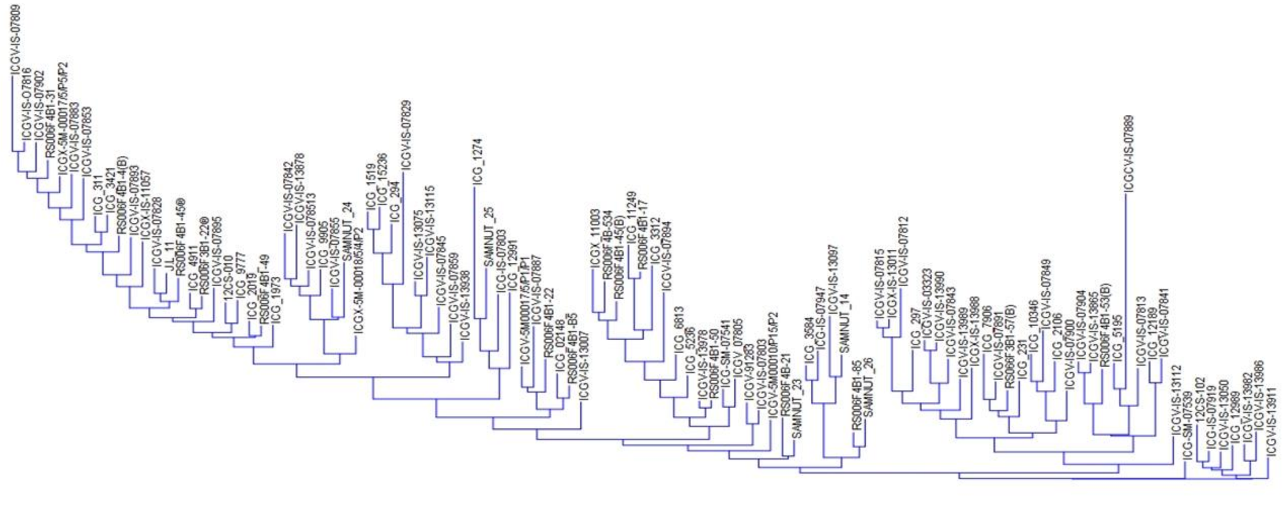

Figure 1: Dendrogram displaying genetic diversity among 107 groundnut genotypes screened under non-stress conditions at Samaru 2018

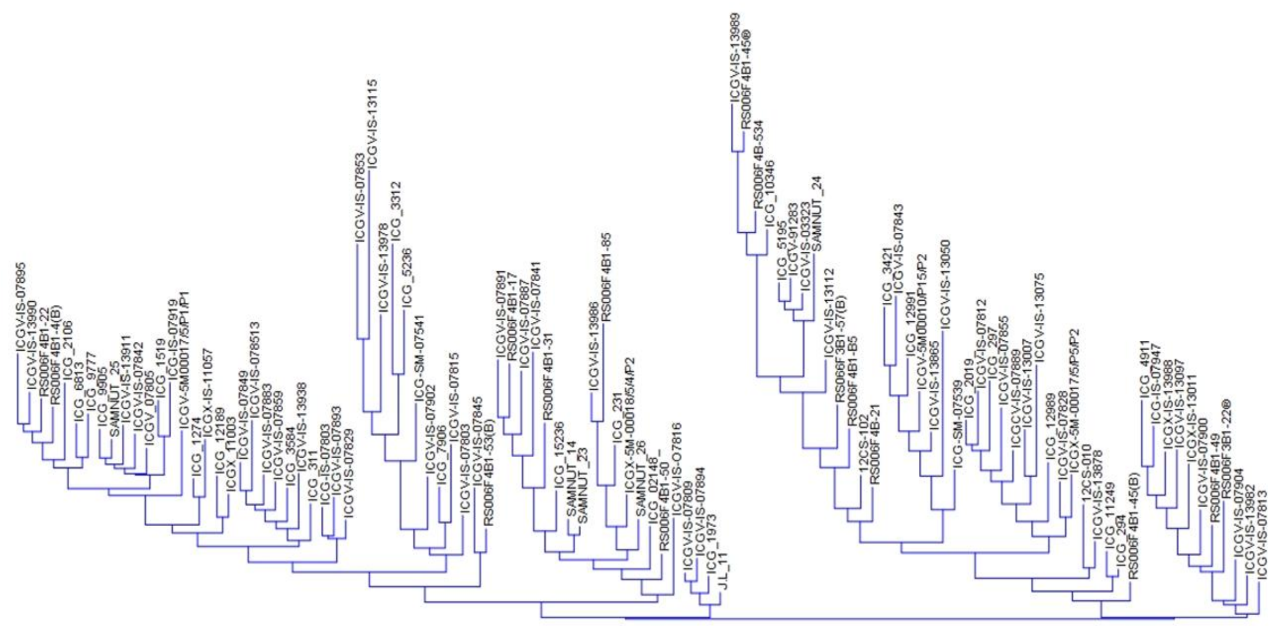

Figure 2: Dendrogram displaying genetic diversity among 107 groundnut genotypes screened under water-stress conditions at Samaru 2018

The first three principal components under water stress conditions reveal that RS006F4B1-45® (14.31) had the highest score in principle component 1, closely followed by ICGV-IS-13989 (12.17) and RS006F4B-534 (10.37). In principal component 2, ICGV-IS-13115 (20.61) has the highest score, followed by ICG 3312 (10.21) and ICGV-IS-07853 (8.78). In principle component 3, the greatest scores were obtained by RS006F4B1-17 (6.45), ICGV-IS-13989 (5.46), and ICG 5195 (3.98). SAMNUT 26 (17.98), ICGV-IS-07812 (15.13), and ICG 3312 (10.18) had the highest pooled ranking genotypes in non-stress conditions, whereas ICGV-IS-13112 (0.4), ICG 3421 (0.58), and ICG 1519 (0.66) had the lowest ranking genotypes. RS006F4B1-45® (19.1), ICGV-IS-07853 (18.16), and ICGV-IS-13115 (27.64) had the highest pooled ranking under water stress conditions, while ICGV-IS-07828 (0.18), 12CS-010 (0.27), and ICGV-IS-07809 (0.3) had the lowest pooled ranking genotypes.

Clustering of Genotypes

Of the 107 groundnut genotypes screened under non-stress conditions, the average linkage grouping approach employing the morphological and physiological factors identified for Principal Component Analysis (PCA) yielded two major clusters and four clusters (Figure 1). With 35 genotypes (32.71%), cluster I was the largest, followed by cluster II with 20 genotypes (18.69%). The smallest group, represented by Cluster IV, comprises 11 genotypes (10.28%). Cluster I (Figure 2) contains genotypes with strong yield adaptation to water stress, while Cluster IV contains low yield adaptation. ICGV-IS-07828 and 12CS-010 genotypes were assigned to cluster III. While genotypes ICGV-IS-07828, ICGV-IS-07813, and ICGV-IS-07904 were adapted under non-stress conditions and not under water stress, genotypes ICVG-IS-07853 and ICGV-IS-13989 were not adapted under non-stress conditions and were highly adapted under water stress conditions.

DISCUSSION

Knowing how groundnuts withstand drought stress can aid in identifying key characteristics for effective germplasm screening, future breeding, and genetic improvement research. Prior research on groundnut drought has mostly focused on screening for yield and certain agronomic features under stress, as well as in regions of Nigeria where groundnuts are not often produced. This study is unique in that it used an integrated method to combine a few agro-morphological and physiological variables to effectively identify relevant genotypes and features that should be targeted for implementing drought tolerance breeding programs in Nigeria. The degree of genetic diversity in the population determines how much genetic improvement can be made in a given collection of genotypes (Falconer and Mackay, 1996). The present study showed a significant variation in the genotypes for every characteristic assessed in the two water conditions. The study clearly showed that there is considerable variability among them, thus indicating that selection may be able to advance the situation. This finding is consistent with that of (Asfaw and Blair, 2014). The genotype expressions across the two growing water conditions were not static and non-responsive, according to the significant effect of genotypes, water conditions, and the genotype x water condition interaction for the various traits. The 107 groundnut genotypes studied showed a wide range of drought tolerance. RS006F4B1-45(R), ICGV-IS-07853, ICGV-IS-13989 and RS006F4B-534) were among the genotypes that were more drought tolerant, according to the PCA ranking, whereas ICGV-IS-07828, 12CS-010, ICGV-IS-07809, RS006F4B1(B), and ICGV-IS-07904 were among the genotypes that were substantially more sensitive to drought.

The mean performance of the genotypes according to the Rank Summation index showed a decrease in chlorophyll content among the genotypes under drought stress. A crucial aspect of current physiological research comprehends physiological modifications to enhance photosynthetic efficiency in groundnuts (Long *et al.*, 2006). Drought-stressed *Catharanthus roseus* (Jaleel *et al.*, 2008) and *Helianthus annus* (Reddy *et al.*, 2004) showed decreased chlorophyll content. The study's conclusions on this topic support their observations. According to Nguyen *et al.* (1997), there may be a genetic variation in chlorophyll content under water stress conditions due to variations in their water usage efficiency. Thus, in conditions of water stress, genotypes exhibiting high SPAD values may demonstrate greater water usage efficiency by significantly reducing stomatal conductance without compromising the rate of carbon absorption. Certain genotypes may have lower SPAD values under water stress conditions because of the generation of reactive oxygen species, which can impair pigment biosynthesis pathways, degrade the chloroplast membrane, or increase lipid peroxidation (Jaleel *et al.*, 2009). Finally, this may reduce net photosynthesis (Grzesiak *et al.*, 2006).

The availability of moisture in the soil throughout the crop's life cycle, which promotes vegetative development and causes the plants to grow taller and produce more chlorophyll, caused the increased leaf chlorophyll content shown in the non-stressed condition in this study. Previous studies have acknowledged LAI's role in photosynthesis and yield calculation (Jaleel *et al.*, 2009). The study's findings about lowering LAI under the water-stress impact suggest that decreasing PSII activity may cause rapid losses in cell division, size, and mortality (Pandey and Shukla, 2015). The findings of this investigation corroborate the findings of Fukai and Cooper (1995), who concluded that dry circumstances may result in severe leaf rolling and reduced leaf expansion, both of which may have a negative impact on stomatal conductance and transpiration rate. Genetic variation in leaf area may result from differences in genotypes' root length, transpiration rate, and tolerance to dryness (Grzesiak *et al.*, 2006). According to Nguyen *et al.* (1997), genotypes with greater LAI under drought treatments may have the capacity to sustain leaf water potential through osmotic control and epicuticular wax load. Except for LAI, which measured negatively, all the qualities measured were positively correlated with the first component (PC1), according to PCA performed on the investigated characters. Higher loadings for LAI, SCMR at 80DAS, and days to 50% flowering were seen in the second component (PC2). The third component (PC3) showed a negative correlation with the number of pods per plant and the SCMR at 40DAS but a positive correlation with the days to 50% blooming, SCMR at 60 and 80DAS, and LAI. Under water stress, except for LAI, which measured negatively, all the qualities measured were positively correlated with the first component (PC1), according to PCA performed on the investigated characters. Higher loadings for LAI, days to 50% flowering, and SCMR at 60DAS were seen in the second component (PC2). Days to 50% flowering and SCMR at 40DAS were positively correlated with the third component (PC3), but LAI, number of pods per plant, and SCMR at 60 and 80DAS were negatively correlated.

Consequently, there was a discernible difference between the 107 genotypes that were examined based on the six examined features. Additionally, the kind and degree of genetic variability among the genotypes are explained by cluster analysis. There was a high degree of genetic variety based on the pattern of genotype divergence and convergence. In conditions of water stress, cluster II yielded the majority of the genotypes resistant to drought; however, some were also discovered in clusters I and III.

CONCLUSION

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 drought tolerant, and forty-four (45) were drought susceptible.

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