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Research Article

Genetic Variability and Correlation for Traits Related to Drought Tolerance in Groundnut (*Arachis hypogaea* L.) under Different Water Regimes

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ABSTRACT

The understanding of the variability existing in a population base of crop is pivotal to crop improvement. This study examined the variance components, heritability estimates and correlations between some morphological and physiological traits related to drought tolerance in groundnuts under two water regimes, to speed up the selection and breeding of groundnut genotypes tolerant to drought. The experiment was carried at the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University. Data collected for performance evaluation were number of days to 50% flowering, plant height, number of pods/plant, seed weight/plant and pod yield/plant. Physiological traits related to drought tolerance measured included, Harvest Index (HI), SPAD Chlorophyll meter reading (SCMR) at 40, 60 and 80 Days after showing (DAS). Variance components, Genetic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV) and broad-sense heritability were calculated for all the traits recorded. Results showed that number of pods/plant, seed weight/plant, SCMR at 60 DAS and HI showed a strong positive and highly significant (P<0.01) with pod yield/plant in all watering conditions. Heritability of the traits ranged from 8.16%- 60.00% with pod yield/plant having the highest value and days to 50% flowering having the lowest values in non-stress (NS), while under water stress condition, heritability was low to moderate from 0.53-53.33%. The SCMR at 60 DAS, number of pods/plant and HI had moderate heritability and significant correlation with pod yield/plant under water stress condition, these traits could be useful criteria in drought tolerance selection.

Keywords: Correlation, Groundnut, Heritability, SPAD Chlorophyll meter reading (SCMR), Water stress

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important leguminous crop in the world grown in over 100 countries for oilseed, food and fodder (Jasem *et al*., 2013). Groundnut is an allotetraploid that possess 2n = 4x = 40 chromosomes (Mamadou, 2011). Breeding and selection of groundnuts tolerant to drought have been conducted for a long time based on pod yield, but it has been unsuccessful in getting drought-tolerant genotypes (Wunna *et al*., 2009). Since breeding method using selection for pod yield has been unsuccessful for a long time, recently, Jongrungklang *et al*. (2008) suggested using surrogate traits such as Soil Plant Analysis Development (SPAD) Chlorophyll Meter Reading (SCMR) and Harvest Index (HI) for drought tolerance selection in breeding program. Wunna *et al*. (2009) reported the use of HI for yield and yield components in drought tolerance selection. 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 SPAD chlorophyll meter reading (SCMR) in groundnut.

Higher SCMR under water stress condition show that, the groundnut genotypes could continue to have a high photosynthesis rate per unit leaf area regardless of water stress. In groundnut SCMR has a strong relationship with pod yield under water stress conditions (Bootang *et al*., 2010). The groundnut harvest index is the ratio of pod weight to total biomass and it varies depending on the severity and timing of water stress relative to pod set. Smart (1994) reported that, differences in pod yield among groundnut genotypes during a terminal drought were due to differences in harvest index which was associated with variation in pods and the effective duration of the pod filling developmental stage.

Genetic variability for drought resistance has been reported in groundnut (Songsori *et al*., 2009). However, breeding for drought based on pod yield is lagging due to significant Genotype x Environment (G x E) interaction. Alternatively, breeding strategies using physiological traits have been proposed by some researchers. Rapid progress in drought resistance breeding have been achieved based on characters like Harvest Index (HI) and SPAD Chlorophyll Meter Reading (SCMR) (Nigram *et al*., 2005).

Heritability is the measure of the relative importance of genetic and non-genetic factors in the expression of phenotypic differences among genotypes in a population. Heritability in the broad sense is the proportional of the phenotypic variance of family means that is due to all genetic effects. Heritability is used to estimate the expected response to selection and to choose the best breeding approach to improve the target trait(s) (Mashamba *et al*., 2016). The study aimed at determining the variance component and heritability estimates, as well as the correlation between pod and morphological and physiological traits related to drought tolerance in some groundnut genotypes under two watering regimes.

MATERIALS AND METHODS

The experiment 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. During dry season 2019.

Population Development

The groundnut genotype selected comprised of four drought susceptible genotypes (ICG 12989, SAMNUT 23, ICG 5195 and ICG 3312) and three drought tolerant genotypes (ICGV-IS-07813, RS006F_4B_1-50 and ICGV-IS-07831) were randomly selected from a screening experiment. The parents were crossed in a half diallel mating design (resulting in 21 F_1 crosses) as described by Dabholkar (1992).) The F_1 seeds were multiplied to obtain enough F_2 seeds for evaluation as suggested by Hallauer *et al.* (1992) for self-pollinating crops.

Evaluation

The selected seven (7) parents, 21 F_1s of all combinations along with two checks were evaluated under non-stress (NS) and water-stress (WS) conditions in the screen house. The experiment was laid out in a randomized complete block design with three 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 1 to 2 cm depth in dark loamy soil in each pot and two healthy and vigorous seedlings in each pot were retained after germination. The first treatment, the non-stress (NS) were irrigated until maturity whenever soil moisture was depleted to 30% field capacity. The second treatment was water stress (WS), in which the treatments were irrigated regularly up to 30 days after sowing and watering was done at 2 weeks interval until maturity.

Data Collection

Days to 50% flowering: Number of days to 50% flowering was recorded from date of sowing till when half of the plants in each pot had flowered.

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

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

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

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

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) and where there is significant difference between treatment means, Fisher's protected Least Significant difference (LSD) test were used for 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.

$\mu =$ Grand mean of the experiment

$r_i =$ effect due to ith replicatio n

$g_j =$ effect due to jth genotype.

$\varepsilon_{ijk} =$ effects due to the residual or random error of the experiment.

Table 1: Form of Analysis of Variance 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

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

$$h_b = \frac{\sigma_g^2}{\left(\sigma_g^2 + \sigma_e^2\right)}$$

h_b = heritability in broad sense, σ_g^2 = genotypic variance σ_p^2 = (genotype mean square + residual mean square)/number of replications and σ_e^2 = residual mean square (environmental variance).

$\sigma_p^2 = \sigma_g^2 + \sigma_e^2$, where σ_p^2 = phenotypic variance.

Correlation Estimates

The correlation coefficients (r) among all the measured traits were determined using GenStat 14th edition Statistical package.

RESULTS

Analysis of Variance for Non-Stress and Water-Stress Conditions at Samaru 2019

Analyses of variance for morphological and physiological traits of groundnut genotypes evaluated under non-stress and water stress conditions at Samaru are presented in (Table 2 and Table 3) respectively. For the morphological traits (Table 2), 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 hundred-seed weight under the non-stress and water-stress condition. For physiological traits, the genotypes mean squares for genotypes were significant (P≤0.05) for all the traits recorded under the non-stress and water-stress condition (Table 3).

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 condition is presented in Table 4. The genotypes showed considerable variation for the different traits. For the morphological traits, days to 50% flowering has an overall mean of 39 days for both non-stress and water-stress conditions. Amongst the seven (7) parents used in this study, ICG 12989(P_4) and ICGV-IS-07813 (P_1) and showed the lowest *per se* performance for days to 50% flowering 38 and 39 days respectively, under non-stress and water-stress conditions signifying earliness while parents SAMNUT 23 (P_5), ICG 5195 (P_6)and ICG 3312 (P_7) recorded the highest days to 50% flowering (40 days) under non-stress condition and parents SAMNUT 23 (P_5) and ICG 3312 (P_7) recorded the highest days to 50% flowering (41 days) under water-stress condition, respectively.

The progenies, ICGV-IS-07813 x ICG 5195 and RS006F_4B_1-50 x SAMNUT 23 recorded the earliest for days to 50% flowering (36 and 38 days) under non-stress and water stress conditions, respectively.

Under non-stress condition, RS006F_4B_1-50 x ICGV-IS-07841, ICG 12989 x ICG 5195, ICGV-IS-07813 x ICG 12989, RS006F_4B_1-50 x ICG 12989 recorded the highest days to 50% flowering (42 days) whereas for water-stress condition, ICGV-IS-07813 x ICGV-IS-07841 and SAMNUT 23 x ICG 3312 had the highest days to 50% flowering (42 days). Plant height has an overall mean of 51.2 and 44.98 cm with respect to non-stress and water-stress, respectively. Under non-stress condition, plant height ranged from 38 cm for ICG 5195 (P_6) to 73.8 cm for SAMNUT 23(P_5) among the parents while it ranged from 39 cm for SAMNUT23 x ICG 3312 to 101.6 cm for ICGV-IS-07813 x ICG 12989. Also, under water-stress condition, plant height ranged from 33.1 cm RS006F_4B_1-50 x SAMNUT 23 to 79.7 cm for ICGV-IS-07813 x ICGV-IS-07841. Seed weight had an average of 5.2g and 2.6g under non-stress and water-stress conditions respectively and it ranged from 3.7g ICGV-IS-07813 (P_1) and ICG 12989 (P_4) to 11.7g for ICG 3312 (P_7) and 0.3g in RS006F_4B_1-50 (P_2) to 3.4g in ICG 12989 among the parents under non-stress and water-stress respectively. Under non-stress, it ranged from 1.2g in RS006F_4B_1-50 x ICGV-IS-07841 to 12.4g in ICGV-IS-07813 x ICG 5195 while under water-stress, it ranged from 0.9g in SAMNUT 23 x ICG 5195 to 3.5g for RS006F_4B_1-50 x SAMNUT 23. However, the check (SAMNUT 25) had highest seed weights (10g) under water stress condition. One hundred seed weight has a mean of 33.3g and it ranged from 21g in ICG 12989 to 29.6g in ICG 3312 among the parents under non-stress condition. Under water-stress condition, it has an overall mean of 27.43g and the parents ranged from 12.5g in RS006F_4B_1-50 to (78.4g) in ICG 3312. Under water-stress condition, the progenies: ICGV-IS-07813 x ICG 3312 recorded the lowest value of 13.3g for hundred-seed weight and the highest value of 120.3g 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 recorded the highest value (149.2g) for hundred-seed weight.

The overall mean for pod yield were 8.3 and 4.2g/plant under non-stress and water-stress respectively. Under non-stress, pod yield ranged from 4.4g/plant for RS006F_4B_1-50 to 12.7g/plant for ICG 12989 among the parents while among the progenies, pod yield ranged from 3.1g/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 0.8g/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 (2pods) among the parents and ICGV-IS-07813 x RS006F_4B_1-50 (5pods) among the progenies recorded the least number of pods.

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 5). Under non-stress condition, SCMR at 40DAS 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 40DAS.Under water-stress SCMR at 40DAS had an overall mean of 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 40DAS while SAMNUT 23 x ICG 5195 (55.3) recorded the highest 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 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 60DAS under non-stress and water-stress conditions respectively. For SCMR at 80DAS, 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 to 39.8 for ICG 5195 under non-stress and water-stress 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 80DAS under non-stress and water-stress respectively. Results for Harvest Index revealed that the overall mean was 17.7% and 14.6%, the parents ICG 3312 and ICG 5195 recorded the highest value (29.3% and 19%) while ICGV-IS-07841 and RS006F_4B_1-50 recorded the least Harvest Index under non-stress and water-stress conditions respectively. Among the progenies, Harvest Index ranged from 8% 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 5).

Table 2: Mean square for Morphological traits of Groundnut Genotypes Evaluated under Non-Stress (NS) and Water- Stress (WS) conditions at Samaru 2019

Source of variation	DF	DFF		PLT HGT (cm)		NPP		SWT(g)		Pod yield (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, PLTHT = plant height, NPP = Number of pods per plant, SWT = Seed Weight

Table 3: Mean square for physiological traits of groundnut genotypes evaluated under non-stress and water-stress conditions at Samaru 2019

Source of variation	DF	SCMR 40DAS		SCMR 60DAS		SCMR 80DAS		HI	
		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≤0.05) and (P≤0.01) probability level respectively, DF = Degree of Freedom, SCMR = SPAD chlorophyll meter reading, DAS = Days after sowing, HI = Harvest Index

Table 4: Mean performances for morphological traits of diallel parents and progenies evaluated under non-stress (NS) and water-stress (WS) conditions at Samaru 2019

	DFF		PLHT (cm)		SWT (g)		100 SWT (g)		Pod yield (g/plant)		NPP	
Genotypes	**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, PLTHT = plant height, NPP= Number of pods per plant, NSP = Number of Seeds per plant, WGT = Seed Weight, CV = Coefficient of Variation

Table 5: Mean performances for physiological traits of diallel parents and progenies evaluated under non-stress (NS) and water-stress (WS) conditions at Samaru 2019

Genotypes	SCMR 40DAS		SCMR 60DAS		SCMR80 DAS		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	45.0	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	48.0	40.3	38.8	37.3	39.8	15.7	19
ICG 3312 (P_7)	43.5	49.3	47.8	34.0	40.3	39.6	29.3	13
ICGV-IS-07813 x RS006F4B1-50	44.8	43.0	39.6	40.8	36.1	37.5	9.6	16.5
ICGV-IS-07813 x ICGV-IS-07841	43.9	39.5	41.0	41.0	31.2	37.0	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	43.0	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	39.0	41.8	40.6	8.0	11.9
ICGV-IS-07841 x SAMNUT 23	39.5	47.1	38.4	39.7	41.1	37.0	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	43.0	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	42.0	55.3	43.0	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	39.0	43.7	16.4	20.3
SAMNUT 24	43.8	51.1	41.3	38.1	38.8	37.0	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**	**16.0**

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

Genetic Variability Parameters and Heritability

Genetic variability parameters and heritability of morphological and physiological traits related to drought tolerance evaluated under non-stress and water stress conditions at Samaru are presented in Table 6. The estimates of Genetic Coefficient of Variation (GCV) were highest for pod yield (33.68% and 29.18%) followed by number of pods/plant (23.97% and 22.46%) under non-stress and water-stress respectively. Estimates of Phenotypic Coefficient of Variation (PCV) where highest for pod yield (43.51% and 55.04%) followed by harvest index (40.77% and 41.62%) under non-stress and water-stress respectively. The GCV and PCV were lowest for days to 50% flowering (1.11% and 1.16%) and (3.78% and 3.19%) under non-stress and water-stress respectively. Generally, PCV was higher than GCV for all traits measured under the two conditions.

High broad-sense heritability estimates were recorded for plant height (61.96% and 67.45%) under non-stress and water stress respectively. Moderate broad-sense heritability estimates were recorded for SCMR at 60 DAS (51.59% and 42.54%), SCMR at 40 DAS (48.19% and 53.33%), and number of pods per plant (41.10% and 31.87%) under non-stress and water-stress conditions respectively. Moderate broad-sense heritability was also recorded for pod yield (60.00%) under non-stress condition. while low values were recorded for most of the traits (Days to 50% flowering, plant height, pod yield, SCMR at 80 DAS) under water-stress condition. Days to 50% flowering (8.62% and 13.37%) recorded low broad-sense heritability values under non-stress and water-stress conditions respectively (Table 6).

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 7). Under non-stress condition, number of pods per plant and seed weight (g) had a strong positive and highly significant relationship ($r = 0.67$, $P \leq 0.01$; and $r = 0.80$, $P \leq 0.01$) with pod yield (g/plant). Seed weight (g) had a strong positive and highly significant relationship ($r = 0.50$, $P \leq 0.01$) with number of pods per plant. Number of pods per plant had a moderate negative and highly significant relationship ($r = -0.42$, $P \leq 0.01$) with days to 50% flowering. Plant height (cm) recorded a weak negative and non-significant relationship ($r = -0.07$, $P > 0.05$ and $r = -0.07$, $P > 0.05$) with pod yield (g/plant) and seed weight (g).

Under water-stress condition, number of pods per plant had a strong positive and highly significant relationship ($r = 0.71$, $P \leq 0.01$and $r = 0.65$, $P \leq 0.01$) with pod yield (g/plant) and seed weight (g) while moderate negative significant relationship ($r = -0.34$, $P \leq 0.05$) 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 ($r = -0.18$, $P > 0.05$, $r = -0.1$, $P > 0.05$ and $r = -0.12$, $P > 0.05$). Seed weight had a strong positive and highly significant relationship ($r = 0.93$, $P \leq 0.01$) with pod yield (g/plant).

For physiological traits (Table 8), under non-stress condition, SCMR at 40DAS recorded a moderate negative significant relationship with SCMR 80DAS ($r = -0.23$, $P \leq 0.05$) while a moderate and highly significant relationship ($r = 0.30$, $P \leq 0.05$) was observed with harvest index. SCMR 80DAS observed a moderate negative and highly significant relationship ($r = -0.35$, $P \leq 0.01$) with harvest index. Pod yield recorded a moderate positive and significant relationship ($r = 0.24$, $P \leq 0.05$ and $r = 0.25$, $P \leq 0.05$) with SCMR at 40DAS and SCMR 60DAS respectively while a high positive and highly significant relationship ($r = 0.79$, $P \leq 0.01$) was observed for Harvest index.

Under water-stress condition, pod yield (g/plant) had a strong positive and highly significant relationship ($r = 0.83$, $P \leq 0.01$) with harvest index. Harvest index observed a weak negative and non-significant relationship ($r = -0.05$, $P > 0.05$) with SCMR at 40DAS 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 80DAS and pod yield. SCMR 60DAS observed a moderate negative and highly significant relationship ($r = -0.35$, $P \leq 0.01$) with harvest index while a weak positive and highly significant relationship ($r = 0.31$, $P \leq 0.01$) was observed with SCMR 80DAS. Pod yield recorded a moderate positive and significant relationship ($r = 0.40$, $P \leq 0.05$) with SCMR at 60DAS.

Table 6: Variance component and heritability estimates for morphological and physiological traits related to drought tolerance in groundnut genotypes evaluated under non-stress and water-stress conditions at Samaru 2019 dry season

Traits	σ_e^2		σ_g^2		σ_p^2		GCV (%)		PCV (%)		h_b (%)	
	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	72.60	81.81	118.25	17.30	190.85	99.10	21.25	9.25	27.00	22.13	61.96	67.45
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
Pod yield	5.19	4.74	7.76	0.66	12.95	5.40	33.68	19.18	43.51	55.04	60.00	62.14
SCMR at 40DAS	1.74	9.83	1.62	11.23	3.36	21.06	2.98	7.20	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	4.80	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	25.90	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 varianc σ_{gc}^2 = Genotype x e, Condition Variance, σ_p^2 = Phenotypic variance, GCV = Genotypic Coefficient of Variation, PCV = Phenotypic Coefficient of Variation, h_b = Broad-sense Heritability

Table 7: Correlation estimates between pod yield and morphological traits evaluated under non-stress (NS) and water-stress (WS) conditions at Samaru 2019

NON-STRESS							Traits	WATER-STRESS				
Traits		1	2	3	4	5		1	2	3	4	5
DFF	1	1.00					1	1.00	0.10	-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, PYD = Pod yield, SWT = Seed Weight

Table 8: Correlation estimates between pod yield and physiological traits evaluated under non-stress (NS) and water-stress (WS) conditions at Samaru 2019

Traits		NON-STRESS						Traits	WATER-STRESS					
		1	2	3	4	5	6		1	2	3	4	5	6
SCMR 40 DAS	1	1.00						1	1.00	0.04	0.06	0.02	0.06	-0.05
SCMR 60 DAS	2	-0.03	1.00					2		1.00	0.31**	-0.04	0.45**	-0.07
SCMR 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**
Pod Yield	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, NPP = Number of pods per plant and HI = Harvest Index

DISCUSSION

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 (Flavio and Alexandre, 2013). In this study, a 7 x 7 Diallel Mating Design Model II was used to develop segregating population and evaluated using randomized complete block design with 2 replications. The results of this evaluation revealed a significant difference among the genotypes for morphological and physiological traits measured under the two water conditions at individual and combined conditions. 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 40DAS, SCMR at 60DAS and Leaf Area Index (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 the same manner. Similar results were reported by Mhike *et al*. (2011) who reported environmental differentials indicated that the environments were unique. The genotype × condition interactions were significant for all the traits. For that reason, suitable hybrids could be developed for specific environments. This agreed 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.

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 favorably 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 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 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, the reduced yield under water stress could be due to reduced plant height and number of pods per plant and increased days to 50% flowering. Similar results were reported by Betran *et al*. (2003) 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 (Emmanuel *et al*., 2021). 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 different 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 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 broad sense heritability of SCMR at 40DAS and days to 50% flowering increased with increasing drought stress, whereas that of pod yield, number of pods per plant, SCMR at 60 and 80DAS and harvest index decreased with increasing drought stress. An increase in error variance under stress conditions has been reported to cause decrease in heritability estimates by 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 water-stress condition, suggesting that these traits cannot be improved substantially. Similar findings were obtained by Gravois and Milligan (1992).

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 might 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 60DAS and pod yield, this means that knowing the value of SCMR at 60DAS 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/plants gives a greater accuracy prediction of pod yield. This study supports the earlier study of Jogloy *et al.* (2011) on strong and positive relationship between HI and number of pods/plant with pod yield.

Under water-stress, SCMR at 60DAS had a moderate positive significant ($P\leq0.05$) with pod yield. This means that, understanding the values of SCMR at 60DAS 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 and pod yield (Bootang *et al*., 2010). Positive and highly significant relationship between SCMR at 60DAS, 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 and because of thicker leaves they have more leaf carbon exchange rate and chlorophyll content and therefore leads to high pod yield. The higher significant correlation between SCMR 60DAS 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 (Mashamba *et al*., 2016). 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.

CONCLUSION

To attain an effective selection of genotypes for drought tolerance, correlation of drought tolerant related traits with pod yield and among themselves is important. In this study SCMR at 60 DAS, number of pods/plant and HI showed a strong positive and highly significant correlation with pod yield under water-stress condition. A heritable estimate of trait is also important for the purpose of information on the variation of genotypes on certain trait on genetic bases. Heritability was estimated from HI, SCMR and number of pods/plant. Therefore, these selected traits can be good criteria to be used in breeding and selection programs in the improvement of drought tolerance in groundnut.

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Conflict of Interest

The authors have no conflict of interest

Data Availability

Data are available with the corresponding author (Nafisa Abdurrasheed) and it can be made available on request.

Authors' Contribution

Nafisa Abdurrasheed - Conceptualization, study design, data collection, analysis and manuscript writing

Alhassan Usman – Conceptualization, Supervision, manuscript writing

Muhammad Musa – Data curation, Data analysis, manuscript writing

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