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Screen-House Screening of Groundnut Germplasm (Arachis Hypogeae) for Drought Tolerance

Ibrahim A. Ozigi, Suleiman A. Musa and Alice Simeon Obaje

Department of Applied Biology, Kaduna Polytechnic, Kaduna, Nigeria

ABSTRACT

In the rainfed agro-ecological zone of northern Nigeria, late-season drought is the main abiotic stressor limiting peanut (Arachis hypogaea L.) yield. In order to identify drought-resistant germplasm, this study examined 10 peanut lines (from the International Institute for Crops in Semi-arid Tropics – ICGV-07081, ICGV-07219, ICGV-07240, ICGV-07241, ICGV-07245, ICGV-07247, ICGV-07262, ICGV-07268, ICGV-93533 and ICGV-96891) under controlled conditions in a greenhouse at the Kaduna Institute of Technology. A randomized complete block design (RCBD) experiment with two replicates was used to compare peanut growth under water stress (WS) versus non-water stress (NS) conditions. The data collected included phenological stages, crop components, harvest index, threshing rate, pod yield variability (PYD), and drought tolerance index (DTI). Analysis of variance (ANOVA) indicated highly significant genetic variation between treatments (P≤0.01). Water deficit significantly reduced the average pod yield per plant, from 14.7 grams under non-stressed conditions to 4.5 grams under water-stressed conditions. Pearson correlation analysis showed a significant positive relationship between pod yield and various physiological traits (such as aboveground biomass, harvest index, 100-seed weight, and drought tolerance index) under stress conditions (P≤0.01). The genotypes ICGV-07219, ICGV-07245, and ICGV-07262 exhibited superior performance, with high pod yields (10–14 g) and high drought tolerance index values (0.62–0.84). In contrast, the other seven lines were susceptible to drought, which led to a sharp decline in yield. The drought-tolerant genotypes identified in this study constitute valuable genetic resources that can be used directly in arid regions, or as parents in breeding programs.

Keywords: Groundnut (Arachis hypogaea), Terminal Drought Tolerance, Germplasm Evaluation.

1.0 Introduction

The groundnut (Arachis hypogaea L.) is an important food and economic crop; it ranks 13th among major food crops, 3rd among oilseed crops, and 2nd among legumes [8]. Peanuts are cultivated in over 100 countries across 27.5 million hectares, with an average yield of 1,590 kg per hectare [7,11]. This crop is widely grown in tropical and subtropical regions globally and is used for oil production, human consumption, and animal feed. The primary producers are China and India, followed by Nigeria, the United States, and Sudan [1]. Although Nigeria is one of the leading peanut producers in Africa, its yield levels remain very low (approximately 3.4 million tonnes per year) compared to China (15.7 million tonnes) and India (6.9 million tonnes) [7,21]. This low productivity in the country is attributed to various factors, including biotic (biological) and abiotic (environmental) stresses, as well as socio-economic conditions [3,20]. In Nigeria, peanuts are primarily grown by farmers in rural areas in the north, where agro-ecological conditions make the region prone to drought. Beyond its significance to the national economy, the peanut serves as a vital cash crop for rural communities. Peanut seeds are rich in high-quality edible oil (45–56%), easily digestible proteins (12–35%), and carbohydrates (10–20%). Furthermore, they contain significant amounts of essential vitamins and minerals. The hay and plant residues remaining after oil extraction are used as animal feed [2,16,18]. Two-thirds of the global peanut crop is grown in arid and semi-arid regions, where rainfall is often insufficient and unevenly distributed. Consequently, drought is the most significant abiotic factor limiting peanut yields [10,12]. Approximately 90% of peanut production in Nigeria takes place in drought-prone savanna regions or areas characteristic of semi-arid tropical zones. Frequent dry spells in these regions, caused by erratic rainfall patterns as well as the premature and unexpected end of the rainy season, represent the primary obstacle to increasing the production of this crop [20]. The severity of a drought is highly variable, depending on its onset, duration, and intensity. Drought can occur at any of four stages of plant development: germination (seedling emergence), the vegetative phase, or the periods either before or after the onset of flowering. Based on this, droughts can be classified according to when they occur: early, mid-season, or late (terminal). Climate change is projected to exacerbate the impact of drought on rainfed crops (those grown without artificial irrigation). Drought negatively affects both crop yield and produce quality [16,17]. Consequently, the continuous improvement of peanut and other crop varieties is crucial for enhancing agricultural productivity. Selecting genetic material (germplasm) or elite peanut lines from semi-arid regions to evaluate their drought tolerance including the assessment of promising breeding lines and core collections under controlled soil conditions (both with and without water stress) serves as the starting point in the breeding process. This study was conducted to identify groundnut genotypes that exhibit tolerance to end-

of-season drought. Such drought-tolerant genotypes can be cultivated in the savanna zones of Nigeria, the primary, drought-prone groundnut -growing regions or used as parental lines in the development of new varieties resistant to end-of-season drought.

2.0 MATERIALS AND METHODS

2.1 Experimental site and Design

The germplasm was evaluated in pot-based greenhouse experiments for bean yield and its components; the studies were conducted in an insect-proof facility (screen house) at the Department of Applied Biology, Kaduna Polytechnic. Selection was carried out under two different environmental conditions such as water stress (WS) and non-stress (NS) using a randomized complete block design (RCBD) with two replications for each condition.

2.2 Genetic Materials

A collection of ten (10) groundnut germplasm accessions (all of ICRISAT origin) was obtained from the Institute of Agricultural Research (IAR), Samara, Zaria, Kaduna State. The accessions (genotypes) used were: ICGV-07081 (G1), ICGV-07219 (G2), ICGV-07240 (G3), ICGV-07241 (G4), ICGV-07245 (G5), ICGV-07247 (G6), ICGV-07262 (G7), ICGV-07268 (G8), ICGV-93533 (G9), and ICGV-96891 (G10).

2.3 PREPARATION OF PLANTING CONTAINERS

For the experiment, 400 plastic pots, each 25 cm in diameter and 20 cm in height, were prepared. Three holes were made in the bottom of each pot to allow for the drainage of excess water during irrigation. The pots were filled with a mixture of sandy-loam soil and manure (in a 3:1 ratio), leaving a 5 cm space from the top rim to facilitate watering. Each experimental environment was allocated 200 pots (100 pots per replication), with 10 pots assigned to each genotype.

2.4 SEED TREATMENT AND SOWING

One day prior to sowing, the soil in the pots was thoroughly watered until fully saturated. Before sowing, the seeds were treated with a powdered insecticide-fungicide formulation (Seed Plus 30 WS) at a rate of 10 g per 4 kg of seeds to prevent seed-borne diseases. Following this, 2–3 seeds of the corresponding genotype were sown in each pot at a depth of 2.5 cm (ERLS, 2005). Sowing was carried out according to a set design, with two replicates for each of the two experimental conditions (NS and WS). Irrigation regimes and the induction of stress conditions:

After sowing, all pots were watered once daily (between 8:00 and 10:00 AM) for 15 days after sowing (DAS). By this time, the seedlings had become well-established; they were then thinned, leaving two plants per pot. Subsequently, the control group (non-stressed) received adequate irrigation twice a week (on Mondays and Thursdays) until harvest. For the plants under water-stress conditions, this irrigation schedule was maintained until 55 DAS. Starting from day 56, watering was completely stopped for 14 days (until 70 DPT) to simulate drought at a late stage of development, which usually coincides with the gynophore formation ("pegging") phase. On day 71, the plants were watered, after which moisture availability was restricted again for 14 days (until 85 DAS); The period from the 72nd to the 85th day corresponds to the bean filling phase. From day 86 until harvest (the maturation phase), the plants were watered once a week. By day 95, plants in both experimental groups (no stress and water stress) had reached a harvestable stage. Throughout the entire experimental period, agronomic management practices were applied uniformly to both groups. After the seedlings emerged, the main fertilizer, simple superphosphate, was added to the soil at a rate of 100 kg/ha. Weeding was carried out manually as needed.

2.5 Data Collection

Data were collected on the following 13 traits/parameters for each plant and averaged per genotype in both environments.

i) Number of days to emergence (DE)

ii) Number of days to 50% flowering (DFF)

iii) Number of days to 100% flowering (DHF)

iv) Number of days to maturity (DM)

v) Number of pods per plant (NP/P)

vi) Pod yield per plant (PY/P) g

vii) Haulm yield per plant (HY/P) g

viii) 100 seed mass per plant (HSM)g

ix) Shelling percentage per genotype (SP)

where:

$$SP = \frac{Weight\ of\ dry\ prod\ sample}{Weight\ of\ seeds\ from\ the\ sample} x\ \frac{100}{1}$$

x) Harvest index per genotype (HI)

where:

$$HI = \frac{Pod\ weight\ \ of\ groundut\ sample}{Haulm+pod\ wt\ .of\ the\ sample}$$

xi) Pod yield difference (PYD)g

where:

(PYD)g = Mean pod yield in NS – Mean pod yield in WS

xii) Mean pod yield per genotype in both replications for each environment (MPY)g

Wher

$$(MPY)g = \frac{Pod\ yield\ per\ genotype\ in \quad +Pod\ yield\ per\ gen???}{2}$$

xiii) Drought tolerance index (DTI)

where:

$$DTI = \left[\frac{Mean\ pod\ yeild\ in\ NS\ X\ Mean\ pod\ yield\ in\ WS}{Mean\ pod\ yeild\ in\ NS} \right]^2$$

2.6 STATISTICAL ANALYSIS

Data collected on all the traits were subjected to Analysis of Variance (ANOVA) to determine their levels of significance (P≤0.01 and P≤0.05) among the traits in each environment and in combined environments, using SPSS software.

3.0 RESULTS

Analysis of variance (ANOVA) showed highly significant genotypic differences (P≤0.01) in traits such as maturity days, number of pods per plant, pod yield per plant, 100-seed weight, and threshing rate (seed ratio in pods) under both non-stress (NS) and water stress (WS) conditions. Furthermore, significant differences were also observed in pod yield difference, average pod yield, and drought tolerance index. Stressful conditions led to a significant decrease in yield: the average number of pods per plant decreased from 12 under non-stress conditions to 4 under stress conditions; pod yield per plant decreased from 14.7 g to 4.5 g; 100-seed weight decreased from 37.6 g to 25.7 g; harvest index decreased from 0.25 to 0.12; and threshing rate decreased to 25.83%. Although most genotypes exhibited lower yields under stress conditions, germplasms ICGV-07219 and ICGV-07262 maintained high pod yields under both conditions. Phenotypic correlation analysis showed a significant positive correlation between pod yield and traits such as plant biomass yield, harvest index, and grain percentage (P≤0.05), with even stronger correlations with average pod yield, pod yield difference, and drought tolerance index (P≤0.01). These data indicate significant genetic variation and point to effective indirect traits that can be used for selecting for drought resistance (i.e., drought resistance exhibited in later stages of plant development).

Table 4.1: Analysis of Variance (ANOVA) for Pod Yield and its Components in 10 Groundnut Germplasm Evaluated under NS and WS Conditions in the screenhouse.

Source of Variation	df	DE		FPF		DM		NP/P		(PY/P)g		(HY/P)g		(HSM)g		HI	
		NS	WS	NS	WS	NS	WF	NS	WF	NS	WS	NS	WS	NS	WS	NS	WS
Replication	1	0.15	-	0.06	-	0.01	40.32	95.63**	40.32**	83.89**	2.51**	9.57	0.51	9.38	131.46	0.02	0.01
Genotypes	9	2.81*	-	4.23**	-	141.16**	89.89**	18.39**	32.30**	16.36*	39.58**	11.53	7.06	33.61**	415.04**	0.004*	0.03*
Error	9	0.61	-	0.56	-	30.00	50.32	9.00	4.76	8.30	5.71	9.41	4.98	11.2	83.28	0.002	0.005

Table 4.1 Contd.

Source of Variation	df	SP		(PYD)g	(MPY)g	DTI
		NS	WS			
Replication	1	74.58**	198.73**	115.41**	14.51	256.06
Genotype	9	30.66**	596.75**	19.73**	23.05**	1182.53**
Error	9	13.31	56.66	7.65	5.14	263.70

* and ** = significant (P≤0.05 and P≤0.01) respectively. NS = Non-Stressed, WS = Water-Stressed

Key

DE = Number of Days to Emergence

FPF = Days to 50% Flowering

DM = Days to Maturity

NP/P = Number of Pods Per Plant

PY/P = Pod Yield Per Plant (g)

HY/P = Haulm Yield Per Plant (g)

HSM = Hundred Seed Mass (g)

HI = Harvest Index

SP = Shelling %

PYD = Pod Yield Difference (g)

MPY = Mean Pod Yield (g); and

DTI = Drought Tolerance Index

Table 4.2: Mean Performance for Pod Yield and its Components in 10 Groundnut Germplasm Evaluated under NS and WS conditions in Screenhouse

Genotype	DE		FPF		DM		NP/P		PY/P		HY/P		HSM(g)	
	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS	NS	WS
ICGV-07081	8	-	39	-	110	100	31	10	16.8	5.0	38.4	23.9	40.1	00.0
ICGV-07219	7	-	35	-	95	90	40	23	19.3	14.0	56.8	41.7	47.9	34.2
ICGV-07240	8	-	38	-	115	100	30	5	10.6	3.5	36.0	27.4	38.4	26.5
ICGV-07241	8	-	37	-	105	100	33	6	12.8	4.0	41.2	29.6	42.4	30.2
ICGV-07245	6	-	37	-	90	90	41	12	16.1	10.2	38.4	25.4	38.7	26.8
ICGV-07247	8	-	36	-	100	90	30	5	11.2	2.0	36.0	26.4	40.1	28.4
ICGV-07262	8	-	36	-	95	90	37	21	16.3	11.9	48.2	32.9	42.8	32.8
ICGV-07268	8	-	39	-	110	100	34	8	13.2	5.0	40.3	26.1	37.1	22.0
ICGV-93533	10	-	38	-	100	95	31	5	10.9	3.0	33.9	24.5	35.8	0.00
ICGV-96891	9	-	37	-	115	100	33	7	11.4	4.0	35.5	24.0	37.0	27.1

Table 4.2 Cond.

Genotype	HI		SP		PYD(g)	MPY(g)	DTI
	NS	WS	NS	WS			
ICGV-07081	0.22	0.0	50.5	0.0	11.8	5.9	0.0
ICGV-07219	0.37	0.31	62.4	53.2	5.4	16.8	0.84
ICGV-07240	0.29	0.20	53.6	41.2	7.1	9.3	0.54
ICGV-07241	0.32	0.22	57.0	40.6	8.8	7.2	0.47
ICGV-07245	0.29	0.23	56.4	42.7	5.9	11.9	0.65
ICGV-07247	0.32	0.20	55.5	45.9	9.2	10.5	0.49
ICGV-07262	0.33	0.26	57.8	41.1	4.4	19.1	0.78
ICGV-07268	0.30	0.07	50.6	55.2	8.2	8.6	0.51
ICGV-93533	0.30	0.0	51.3	0.0	7.9	7.1	0.0
ICGV-96891	0.31	0.18	53.3	51.4	5.4	13.8	0.44

Key

DE = Number of Days to Emergence

FPF = Days to 50% Flowering

DM = Days to Maturity

NP/P = Number of Pods Per Plant

PY/P = Pod Yield Per Plant (g)

HY/P = Haulm Yield Per Plant (g)

HSM = Hundred Seed Mass (g)

HI = Harvest Index

SP = Shelling %

PYD = Pod Yield Difference (g)

MPY = Mean Pod Yield (g); and

DTI = Drought Tolerance Index



Table 4.3: Correlation coefficients (r_p) for pairs of traits in groundnut germplasm evaluated under NS and WS environmental conditions in the screen-house at IAR, Zaria, during 2012/13 post-rainy season.

	DE	**FPF**	**DM**	**NP/P**	**PY/P**	**HY/P**	**HKW**	**HI**	**SP**	**PYD**	**MPY**	**STI**
DE	1.0 …	.211 …	.088 (.170)	.037 (.021)	.029 (.103)	.109 (.113)	-.211 (-.145)	-.074 (-.043)	.131 (.150)	(.047)	(.115)	(.098)
FPF		1.0	.404* (.377*)	.449** (.469**)	.392* (.441**)	.258 (.312*)	-.419* (.509**)	-.239 (-.185)	.126 (.208)	(.319*)	(.220)	(.322*)
DM			1.0 (1.0)	.374** (.396**)	.399** (.463**)	-.364* (-.341*)	-.287 (.399**)	.418** (.437**)	.277 (.401*)	.. (.341*)	.. (.321*)	.. (.469**)
NP/P				1.0 (1.0)	.437** (.488**)	.250 (.237)	-.186 (-.271)	.470** (.432**)	.071 (.118)	.. (.493**)	.. (.400**)	.. (.449**)
PY/P					1.0 (1.0)	373* (.381*)	.213 (296*)	.366* (.318*)	.394** (.365*)	.. (.520**)	.. (..490**)	.. (.435**)
HY/P						1.0 (1.0)	.094 (.065)	.110 (.219)	.027 (.210)	.. (.311*)	.. (.239)	.. (.396*)
HKW							1.0 (1.0)	.191 (.074)	-.261 (.298*)	.. (.285)	.. (-.317*)	.. (.533**)
HI								1.0 (1.0)	.115 (099)	.. (-.310*)	.. (.290)	.. (-.344*)
SP									1.0 (1.0)	.. (.249)	.. (.186)	.. (.378*)

	DE	**FPF**	**DM**	**NP/P**	**PY/P**	**HY/P**	**HKW**	**HI**	**SP**	**PYD**	**MPY**	**STI**
PYD										.. (1.0)	.. (-.339*)	.. (.009)
MPY											.. (1.0)	.. (.010)
STI												.. (1.0)

* and ** = significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$), respectively.

Upper values = Non-stressed (NS) environment, Lower values (in parenthesis) = Water-stressed (WS) environment.

KEY:

DE = Days to emergence

FPF = Days to 50% flowering

DM = Days to maturity

NP/P = Number of pods per plant

PY/P = Pod yield per plant (g)

HY/P = Haulm yield per plant (g)

HKW = 100 seed mass (g)

HI = Harvest index

SP = Shelling percent

PYD = Pod yield difference (g)

MPY = Mean pod yield (g); and

STI (%) = Stress tolerance index.

4.0 DISCUSSION

Germplasm resources are a key source of genetic variation for crop improvement. The World Germbank maintained by the International Crops Institute for Semi-Arid Tropics (ICRISAT) facilitated the evaluation of ten peanut germplasm resources under water stress (WS) and non-stress (NS) conditions to screen for drought-tolerant varieties. Pod yield difference (PYD) and drought tolerance index (DTI) were used as reliable indicators for selection, in accordance with established methods emphasizing pod and dry matter yield. Analysis of Variance (ANOVA) revealed significant genotypic variation across different conditions, reflecting a genetic architecture modulated by environmental interactions. Physiological differences confirmed that the induced water deficit was sufficient to elicit distinct phenotypic responses, aligning with previous findings by [1,3]. Despite an overall decrease in performance due to water stress, genotypes ICGV-07219, ICGV-07245, and ICGV-07262 maintained excellent pod yield, favorable yield components,

and high DTI values, indicating their excellent adaptability to late-stage drought. These germplasm resources are well suited for direct planting in drought-prone savanna ecosystems or as parental donors in breeding programs. In contrast, the remaining seven germplasm resources exhibited high drought tolerance, but yields were severely reduced due to poor pod penetration, embryo abortion, and seed shrinkage. Furthermore, significant positive correlations were found between pod yield and auxiliary traits such as harvest index, threshing rate, and 100-seed weight, confirming the effectiveness of these traits as reliable alternative selection criteria for drought tolerance.

5.0 CONCLUSION

The three groundnut genotypes identified as resistant to late-season drought stress (ICGV-07219, ICGV-07245, and ICGV-07262) exhibited the highest average pod yield and the highest drought tolerance index (>0.80) under diverse environmental conditions (normal irrigation and drought conditions). These genotypes can be further evaluated under late-season drought-prone field conditions, with the aim of validating their drought tolerance and yield potential; They can then be used as groundnut varieties in drought-prone areas, or as parents for the cultivation of new drought-resistant varieties.

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