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IDENTIFYING HIGH-YIELDING DROUGHT-RESILIENT GROUNDNUT GENOTYPES IN STRESS-PRONE ENVIRONMENT

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ABSTRACT: This study assessed 16 groundnut (*Arachis hypogaea* L.) genotypes, including registered varieties and local landraces, under drought-stressed conditions to identify traits associated with resilience and yield stability. Significant variation ($p \leq 0.05$) was observed for pod yield, while plants at harvest, pods per plant, and haulm yield showed highly significant differences ($p \leq 0.01$). Mai Atamfa recorded the highest pod yield (980 kg ha^{-1}), Mai Bargo excelled in haulm yield (27,124 kg ha^{-1}), and Samnut 10 produced the largest kernels (107 g per 100 seeds). Correlation and regression analyses highlighted pods per plant ($r = 0.88$, $R^2 = 0.84$) as the most reliable determinant of pod yield, while a strong positive association between haulm yield and shelling percentage ($r = 0.62$, $p < 0.01$) indicated potential for simultaneous improvement of grain and fodder value. These findings underscore the importance of integrating landraces and improved varieties in breeding pipelines. Crossing high-yielding types with dual-purpose and large-seeded genotypes could accelerate the development of drought-resilient, farmer-preferred cultivars for stress-prone environments.

Keywords: drought stress, *Arachis hypogaea*, yield traits, landraces, breeding, Nigeria

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a major oilseed crop cultivated across tropical and subtropical regions, with India, China, Nigeria, and the United States among the largest producers (FAOSTAT, 2023). In sub-Saharan Africa, especially semi-arid zones, it contributes to food security, household income, and livestock feeding due to its dual role in providing both grain and haulm (Ajeigbe *et al*., 2015). Groundnut kernels are rich in protein, beneficial fatty acids, and essential micronutrients, while its oil is valued for stability and nutritional quality (Buczkowski *et al*., 2019; Gandhi & Reddy, 2021).

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Despite this importance, productivity remains constrained by biotic and abiotic stresses, with drought recognized as the most critical yield reducing factor. Water shortages during flowering and pod filling severely affect pod development, seed filling, and assimilate distribution (Reddy *et al*., 2017). Climate change has intensified this challenge, as higher temperatures and erratic rainfall increase the frequency and severity of drought in rainfed systems (IPCC, 2022; Lobell *et al*., 2011).

Developing drought-tolerant cultivars is therefore a key breeding priority. Yet drought adaptation is complex, involving physiological and morphological mechanisms such as rooting depth, earliness, pod retention, and water-use efficiency (Vadez *et al*., 2013). Traits including pod number, haulm yield, shelling percentage, and kernel size have been identified as important contributors to yield stability under stress (Nigam *et al*., 2005; Upadhyaya, 2005). Farmer preferred landraces, though often overlooked, may possess adaptive features that could broaden the genetic base for resilience. Most breeding efforts, however, have concentrated on improved varieties, with limited direct comparisons involving landraces under drought stress. A broader evaluation of both categories is needed to strengthen breeding strategies that combine yield potential with adaptability and farmer preferred traits.

In this context, the present study was designed to evaluate the performance of registered varieties and local landraces of groundnut under drought stress, while also quantifying variation in key agronomic and yield related traits. The study further aimed to identify trait relationships that can guide the selection of drought-resilient, high yielding cultivars adapted to stress-prone environments.

MATERIALS AND METHODS

The trial was conducted during the 2025 dry season at the Institute for Agricultural Research (IAR), Samaru, Ahmadu Bello University, Zaria, Nigeria (11°11′N, 07°38′E; 640 m a.s.l.), in the northern Guinea savannah ecological zone. The site receives an average annual rainfall of ~1,200 mm, with sandy loam soils classified as Alfisols. The mean daily maximum temperature during the cropping period ranged from 31°C to 39°C.

Sixteen groundnut (*Arachis hypogaea* L.) genotypes were evaluated, comprising nine registered varieties (Samnut 10, Samnut 21–29) obtained from IAR and seven local landraces (Mai Bargo, Jar Gyada, Yar Dakar, Kwandala, Yar Zaki Biyam, Mai Atamfa) collected from local markets in Dawanau (Kano State) and Ikara (Kaduna State).

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each plot consisted of two rows, 4 m in length, with 0.75 m inter row and 0.25 m intra row spacing. Two seeds were sown per hill to achieve a population density of ~106,667 plants ha^{-1}. The field was irrigated prior to harrowing and ridging to provide adequate soil moisture for subsequent seedling establishment. Single Super Phosphate (SSP) was applied at 100 kg ha^{-1} two weeks after planting. Weeding was carried out twice before flowering and once manually during pegging to minimize pod disturbance.

Sowing was done on 5th March 2025 to coincide with high heat intensity and absence of rainfall, ensuring natural drought pressure. To facilitate establishment, irrigation was applied twice weekly for the first 30 days after planting, then once weekly until 85 days after planting (DAP). Thereafter, irrigation was withheld to impose terminal drought stress, following the approach of Reddy *et al.* (2003).

Data recording began with flowering observations, where days to 50% flowering (DFF) was determined as the number of days from emergence until half of the plants in a plot had flowered. At 85 days after emergence, plant height (PH) was measured from the cotyledonary node to the terminal bud on five randomly selected plants per plot. At maturity, the number of plants at harvest (PAH) was counted to assess plant survival under drought stress.

At the same harvest stage, pods per plant (PPP) were determined from five randomly selected plants in each plot. The harvested pods were then dried to a moisture content of less than 10%, cleaned, and weighed to obtain the dry pod yield (DPY), which was expressed in kilograms per hectare. In parallel, haulms were collected, air dried in the field for 4–5 days, weighed, and converted to kilograms per hectare to determine the dry haulm yield (DHY).

From the dried pods, 100-kernel weight (HKW) was measured using 100 randomly selected, fully matured kernels per plot on an electronic balance. Shelling percentage (SP) was then calculated as the kernel weight divided by the pod weight, multiplied by 100. To facilitate comparison across genotypes, the relative pod yield index (RPYI) was calculated as the pod yield of each genotype expressed as a percentage of the highest pod yield in the trial, while the relative haulm yield index (RHYI) was computed as the haulm yield of each genotype expressed as a percentage of the highest haulm yield obtained.

Analysis of variance (ANOVA) was conducted using PROC GLM in SAS 9.4 (SAS Institute Inc., Cary, NC) to test for genotypic differences across measured traits. Descriptive statistics, including means, ranges, coefficients of variation, and standard errors, were computed using PROC MEANS to assess overall variability. Pearson's correlation coefficients were calculated to examine relationships among agronomic and yield-related traits. In addition, simple linear regression was performed using PROC REG to quantify the contribution of pods per plant to pod yield under drought stress.

RESULTS AND DISCUSSION

The analysis of variance (Table 1) showed that the evaluated genotypes differed significantly for several traits under drought stress. Highly significant differences ($p \leq 0.01$) were recorded for plants at harvest, pods per plant, and haulm yield, while pod yield was significant at the 5% level. In contrast, traits such as days to 50% flowering, plant height, hundred-kernel weight, and shelling percentage did not vary significantly among the genotypes. This suggests that while some characteristics remained relatively stable under water deficit, considerable diversity existed in traits directly linked to productivity.

Descriptive statistics (Table 2) further highlighted wide variability across genotypes. Pod yield ranged from 103 to 980 kg ha^{-1} with a mean of 425 kg ha^{-1}, while haulm yield ranged from 1,924 to 27,124 kg ha^{-1}, averaging 7,741 kg ha^{-1}. High coefficients of variation were observed for pods per plant (73%), kernel weight (91%), pod yield (75%), and haulm yield (71%), reflecting strong genotypic differentiation for these traits (Upadhyaya, 2005). The exceptionally high variation in shelling percentage (206%) indicated a strong influence of drought on pod filling and kernel development. Whereas pod yield, pods per plant, and haulm yield showed wide variability and thus greater potential for selection, days to 50% flowering (13%) and plant height (20%) displayed comparatively narrow coefficients of variation, reflecting stability under drought but limited scope for direct selection.

The performance of individual genotypes illustrated this variability clearly. Bar charts (Figures 1 and 2) showed that Mai Atamfa achieved the highest pod yield, whereas Mai Bargo excelled in haulm production. Relative yield indices further clarified these trends: Mai Atamfa attained the maximum Relative Pod Yield Index (RPYI = 100%), confirming its superiority for pod productivity, while Mai Bargo recorded the highest Relative Haulm Yield Index (RHYI = 100%) due to its exceptional vegetative biomass. In contrast, Samnut 24 and Samnut 26 had the lowest RPYI and RHYI values, respectively, underscoring their poor adaptability under moisture stress. The superiority of landraces such as Mai Atamfa and Mai Bargo confirms earlier reports that traditional varieties often harbor resilience under stress conditions in West Africa (Ajeigbe *et al*., 2015; Hamidou *et al*., 2013), highlighting the value of integrating farmer preferred landraces into formal breeding programs.

Table 1: Mean squares from analysis of variance (ANOVA) for pod yield and agronomic traits of 16 groundnut genotypes under drought-stressed conditions at Samaru, Nigeria, in 2025.

Source of Variation	df	PAH	DFF	PH (cm)	PPP	HKW	SH (%)	DPY (Kg ha^{-1})	DHY (Kg ha^{-1})
Rep	2	98.58	26.22	126.32	69.64	566.99	10150.76	209090.4	37823533
Entry	15	107.11**	21.33	15.55	41.12**	1174.31	14935.76	223674.19*	10708636**
Error	30	25.27	30.53	13.81	15.36	1268.38	12895.47	102798.75	29906877

Note: PAH = Plants at harvest; DFF = Days to 50% flowering; PH = Plant height; PPP = Pods per plant; HKW = Hundred kernel weight; SH = Shelling percentage; DPY = Dry pod yield; DHY = Dry haulm yield. * and ** denote significance at 5% and 1% probability levels, respectively

Table 2:. Mean performance, ranges, coefficients of variation (CV), and standard errors (S.E.) for pod yield and agronomic traits of 16 groundnut genotypes under drought-stressed conditions at Samaru, Nigeria, in 2025.

S/n		PAH	DFF	PH (cm)	PPP	HKW	SH (%)	DPY (Kg ha^{-1})	RPYI (%)	DHY (Kg ha^{-1})	RHYI (%)
1.	Samnut 10	25.33	42.33	15.92	5.45	107.25	33.50	428.97	44	8638.43	32
2.	Samnut 21	15.67	43.33	15.85	3.66	22.18	23.31	248.28	25	4091.98	15
3.	Samnut 22	19.00	43.67	18.87	8.13	32.35	26.75	527.40	54	4582.60	17
4.	Samnut 23	18.67	42.00	21.30	7.04	36.35	39.94	685.12	70	8380.32	31
5.	Samnut 24	17.33	41.00	20.70	2.12	29.16	37.22	201.70	21	1923.90	7
6.	Samnut 25	13.33	34.77	20.93	1.16	34.83	30.44	118.64	12	2388.89	9
7.	Samnut 26	23.00	44.00	23.07	1.03	30.90	38.30	102.92	11	4725.77	17
8.	Samnut 27	19.33	43.33	19.70	4.10	33.36	47.01	363.62	37	7545.90	28
9.	Samnut 28	11.33	42.00	17.83	3.63	31.63	24.05	268.50	27	8745.21	32
10.	Samnut 29	18.67	41.33	18.76	6.78	36.46	55.97	592.44	60	4286.80	16
11.	Mai Bargo	3.00	46.00	15.17	3.80	44.36	316.24	190.32	19	27124.44	100
12.	Jar Gyada	12.67	44.67	18.90	9.02	25.31	41.73	838.28	86	9280.01	34
13.	Yar Dakar	8.67	46.00	15.93	3.72	33.43	34.15	174.41	18	9815.93	36
14.	Kwandala	10.00	44.67	17.25	3.11	55.29	60.81	335.97	34	3318.63	12
15.	Yar Zaki Biyam	7.33	43.67	20.43	6.92	42.59	25.45	742.35	76	12521.23	46
16.	Mai Atamfa	12.00	45.00	18.73	15.97	28.56	36.16	979.91	100	6485.97	24
	Mean	14.71	42.99	18.71	5.35	39.21	55.11	424.93		7741.00	
	Range	3-25	35-46	15-23	1-16	22-107	23-316	103-980		1924-27124	
	CV (%)	34.18	12.85	19.87	73.21	90.84	206.04	75.45		70.64	
	S.E±	2.9	3.2	2.15	2.28	20.8	65.64	184.97		3161	

.Note: PAH = Plants at harvest; DFF = Days to 50% flowering; PH = Plant height; PPP = Pods per plant; HKW = Hundred kernel weight; SH = Shelling percentage; DPY = Dry pod yield; DHY = Dry haulm yield; RPYI = Relative pod yield index; RHYI = Relative haulm yield index.

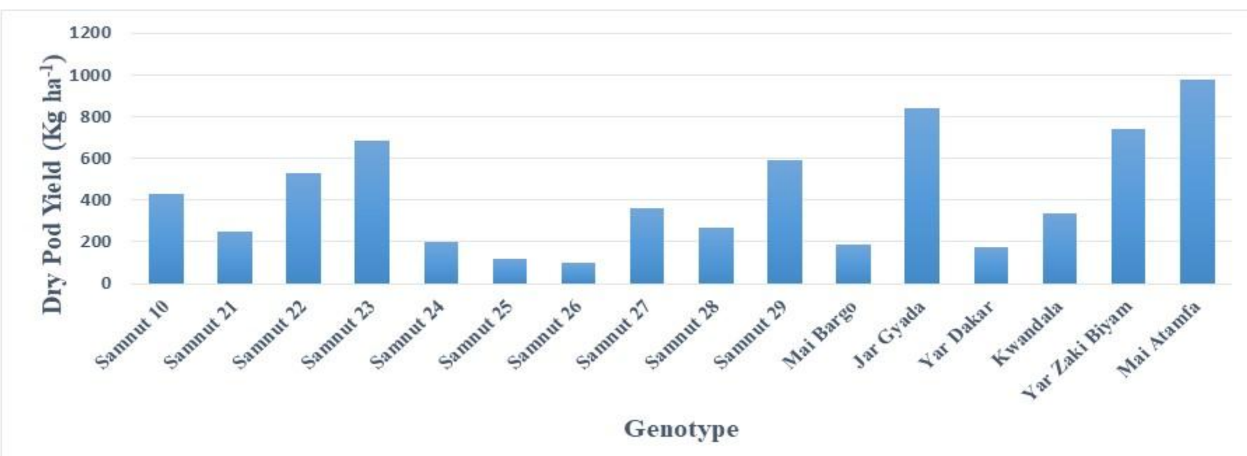

Figure 1. Mean pod yield of 16 *Arachis hypogaea* genotypes under drought-stressed conditions at Samaru, Nigeria (2025).

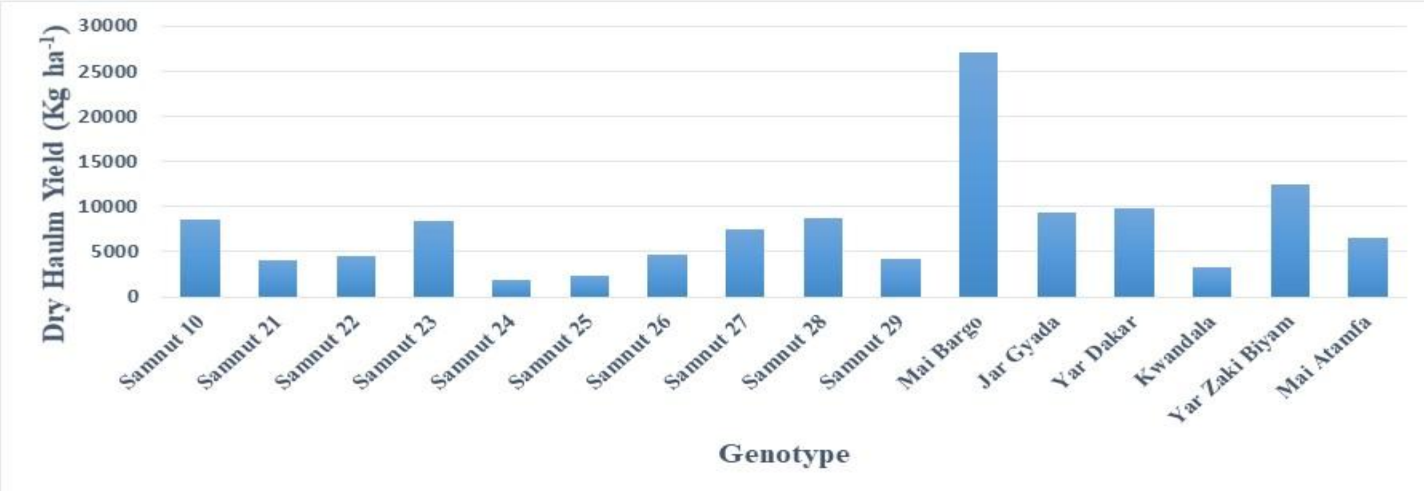

Figure 2. Mean haulm yield of 16 *Arachis hypogaea* genotypes under drought-stressed conditions at Samaru, Nigeria (2025)

Regression analysis (Figure 3) indicated that the number of pods per plant was the single most important factor explaining pod yield, with an R^2 of 0.84. Genotypes such as Mai Atamfa, which combined high pod number with high yield, clearly stood out, whereas Samnut 25 and Samnut 26, which produced fewer pods, recorded low yields. This agrees with earlier findings that pod number is one of the most dependable selection indices for yield under drought in groundnut (Nigam *et al*., 2001; Songsri *et al*., 2009).

Correlation analysis (Table 3) revealed additional insights into trait relationships. Plant height showed a weak but significant positive correlation with survival ($r = 0.35$, $p < 0.05$), suggesting that taller plants had slightly better persistence under stress, though this did not translate into yield advantages. Interestingly, haulm yield was negatively correlated with survival ($r = –0.40$, $p < 0.01$), implying that fewer surviving plants often compensated by producing greater vegetative biomass. Moreover, a strong positive correlation was observed between haulm yield and shelling percentage ($r = 0.62$, $p < 0.01$), indicating that genotypes capable of maintaining higher vegetative growth also sustained effective seed filling. Such relationships reinforce the potential of dual purpose breeding, where biomass and grain yield are simultaneously improved (Dwivedi *et al*., 1996), a concept that continues to guide groundnut improvement programs.

Overall, three genotypes were particularly noteworthy: Mai Atamfa for its high pod yield, Mai Bargo for its high haulm yield contributing to its dual-purpose value, and Samnut 10 for its large seed size. These results suggest that combining the attributes of these parents could accelerate the development of drought-resilient, farmer-preferred cultivars. Pod number per plant and shelling percentage emerged as the most critical selection criteria, given their strong associations with yield components. The evidence supports the strategy of integrating both landraces and improved varieties in breeding pipelines to harness complementary traits for resilience and productivity.

CONCLUSION AND RECOMMENDATIONS

This study demonstrated substantial genetic variability among 16 groundnut genotypes evaluated under drought stress. The landrace Mai Atamfa stood out for high pod yield, Mai Bargo for superior haulm production, and Samnut 10 for large seed size. The strong influence of pods per plant on yield confirms its reliability as a selection index, while positive associations between biomass production and seed filling suggest that both grain and fodder value can be improved simultaneously.

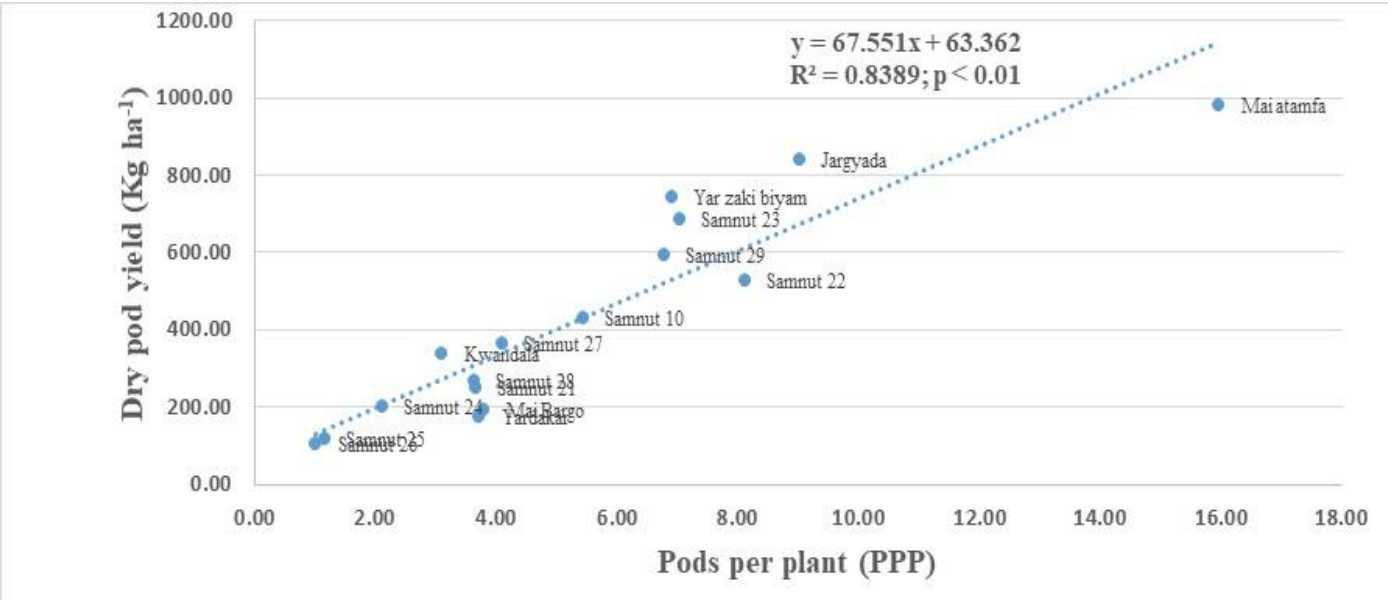

Figure 3. Relationship between pods per plant and pod yield in 16 groundnut genotypes under drought-stressed conditions at Samaru, Nigeria (2025).

Table 3. Phenotypic correlation coefficients among pod yield and agronomic traits of 16 groundnut genotypes under drought-stressed conditions at Samaru, Nigeria, in 2025.

	PAH	DFF	Plant Height (cm)	HKW	SH (%)	PPP	DPY (Kg ha^{-1})
PAH							
DFF	-0.00						
Plant Height (cm)	0.35*	-0.01					
HKW	0.1	-0.1	-0.11				
SH (%)	-0.27	-0.5	0.06	0.13			
PPP	0.02	0.01	0.21	-0.02	-0.12		
DPY (Kg ha^{-1})	0.03	-0.12	0.24	0.01	-0.15	0.88**	
DHY (Kg ha^{-1})	-0.4**	0.24	0.07	0.09	0.62**	0.13	0.06

Note: PAH = Plants at harvest; DFF = Days to 50% flowering; PH = Plant height; PPP = Pods per plant; HKW = Hundred kernel weight; SH = Shelling percentage; DPY = Dry pod yield; DHY = Dry haulm yield. * and ** denote significance at 5% and 1% probability levels, respectively.

The findings highlight the potential of combining traits from high-yielding landraces and improved varieties to develop drought-resilient, farmer-preferred cultivars. In particular, crossing dual-purpose types with high-yielding and large-seeded genotypes offers a practical breeding strategy for enhancing productivity in stress prone environments.

Future efforts should focus on validating these results across multiple locations and seasons, while incorporating physiological and molecular screening tools to accelerate selection for drought resilience. Such an integrated approach will strengthen groundnut improvement programs and contribute to sustainable food security and income generation in semi-arid regions.

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