RESEARCH ARTICLE Agricultural Science Digest, Volume 45 Issue 6: 951-958 (December 2025)

Evaluation of Drought-tolerant Groundnut (*Arachis hypogaea* L.) Breeding Lines for Agronomic Performance under Rainfed Conditions in Ethiopia

Addisu Getahun[1], Hemalatha Palanivel[2], Kasi Rao Mediga[3]

10.18805/ag.D-6322

ABSTRACT

Background: Drought stress has a significant impact on groundnut (*Arachis hypogaea* L.) production, causing severe yield losses, especially in semi-arid regions. The development of drought-tolerant cultivars is important to reduce the adverse effect of water constraint on groundnut productivity. This study aimed to evaluate the agronomic performance of 17 advanced drought-tolerant groundnut breeding lines and a standard control variety, Werer- 961, under rainfed conditions at Pawe Agricultural Research Center (PARC), Ethiopia, during the 2022 and 2023 cropping seasons.

Methods: The field experiment was conducted using a randomized complete block design (RCBD) with three replications over two consecutive years. The study evaluated 17 advanced groundnut breeding lines, including the standard check variety, Werer-961. Selection was based on their previously evaluated performance in drought-prone regions and demonstrated high yield potential under stress conditions. The chosen lines comprised both early- and late- maturing cultivars to assess their adaptability to varying drought intensities. Critical traits related to drought tolerance and yield potential in water-limited environments were recorded. Statistical analyses, including correlation analysis, histogram evaluation and Q-Q plot analysis, were performed to identify superior genotypes.

Result: The experiment depicted significant variation of genotypes against all the important agronomic characteristics, such as days to emergence, days to maturity, pod yield, seed yield, pods per plant and seed weight. Several lines, including RDRGVT ICGV SM 01514, RDRGVT ICGV 14788 and RDRGVT ICGV 8540, exceeded the check variety based on pod and seed yield. The genotype-by-environment interaction was significant for pod quantity per plant and seed weight. Correlation research showed that pod number per plant was very significantly related to both pod yield and seed production. These results are important findings in the development of drought-tolerant groundnut cultivars that can produce well under stressful conditions in the rainfed agriculture of Ethiopia.

Key words: Agronomic traits, Breeding lines, Drought tolerance, Genotype-by-environment interaction, Groundnut, Yield.

Abbreviations: ANOVA: Analysis of variance; CV: Coefficient of variation; DE: Days to emergence; DM: Days to maturity; GEI: Genotype-environment interaction; HSW: Hundred seed weight; LSD: Least significant difference; PARC: Pawe agricultural research center; PNPP: Pod number per plant/average number of pods per plant; PY: Pod yield; Q-Q plot: Quantile-quantile plot; RCBD: Rrandomized complete block design; SPP: Seeds per plant; SY: Seed yield.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), is one of the most widely grown legumes crop globally, with large-scale cultivation in tropical and semi-arid countries, accounting for millions of smallholder farmers' sources of protein, oil and income (Janila *et al.,* 2013; Hussainy *et al.,* 2020). However, water constraint significantly limits the production of groundnuts. Drought stress is among the most significant abiotic factors affecting its growth, development and yield (Celikkol Akcay *et al.,* 2010; Kokkanti *et al.,* 2021; Mediga *et al.,* 2025). In turn, drought stress can impair photosynthesis, hamper flower and pod developments and even produce poorly generated seeds, resulting in poor yields (Qiao *et al.,* 2024). This calls for critically developing drought-resistant groundnut cultivars for uniform production in these water-limited regions.

Ethiopian groundnut production is mainly rain-fed, and groundnut cultivations have been realized in areas with fluctuating water supplies and, therefore, also fluctuating water availability (Abady *et al.,* 2019). Climate change impacts that manifest as increased frequency and severity of drought enhance the problems in groundnut farming (Awal *et al.,* 2002). Therefore, breeding for drought tolerance has emerged as a prime objective in the research of Ethiopian

[1]Department of Crop Genetics and Plant Breeding, Injibara University, Ethiopia.
[2]Department of Genetics and Plant Breeding, School of Agriculture, Mohan Babu University, Tirupati-517 501, Andhra Pradesh, India.
[3]Department of Plant Pathology, School of Agriculture, Mohan Babu University, Tirupati-517 501, Andhra Pradesh, India.

Corresponding Author: Hemalatha Palanivel, Department of Genetics and Plant Breeding, School of Agriculture, Mohan Babu University, Tirupati-517 501, Andhra Pradesh, India.
Email: latasenthil@gmail.com

How to cite this article: Getahun, A., Palanivel, H. and Mediga, K.R. (2025). Evaluation of Drought-tolerant Groundnut (*Arachis hypogaea* L.) Breeding Lines for Agronomic Performance under Rainfed Conditions in Ethiopia. *Agricultural Science Digest*. **45(6):** 951-958. doi: 10.18805/ag.D-6322.

Submitted: 05-03-2025 **Accepted:** 10-07-2025 **Online:** 04-08-2025

agriculture. Drought-tolerant genotypes can improve peanut production and assist in food security in drought-prone regions (Puppala *et al.,* 2023).

Genotype-environment interaction (GEI) is an important factor to determine crop genotypes' performance in various environments (Kang *et al.,* 2004; Mediga *et al.,* 2023). GEIs are expected to affect groundnut varieties' stability and responsiveness to stress environments; therefore, it is important to test genotypes under various conditions to determine stable and high-yielding cultivars (Janila *et al.,* 2013). The aim of this study was to assess the agronomic performance of 17 improved drought-tolerant groundnut breeding lines under rainfed conditions in Ethiopia, investigate genotype-environment interaction, and determine promising lines for drought areas.

MATERIALS AND METHODS

Experimental site and design

The study was carried out at the Pawe Agricultural Research Center (PARC) in the northwestern part of Ethiopia. The Pawe region is described as a semi-arid zone with an irregular rainfall pattern and low water supply, and thus it is a suitable region for testing drought-resistant groundnut genotypes. The experiments were carried out during the 2022 and 2023 crop seasons, during which the annual rainfall was around 500 mm, a figure that has been considered too low for the realization of optimal crop yields in rainfed agriculture systems.

The experimental design was based on randomized complete block design (RCBD) with three replications. Each genotype was grown in a 3 × 4 meter plot with a row distance of 30 cm and a plant distance of 10 cm. The evaluation involved a total of 17 advanced breeding lines of groundnut, which included the standard check variety, Werer-961 (Table 1), these lines were collected from Chitedze Agricultural Research Station, (13°34′48″S / 33°29′24″E), Malawi. Selection of the lines is based on their previous performance in drought-vulnerable areas and their proven capability for high yield when exposed to stress conditions (Falke *et al.,* 2019). The chosen lines included early and late-maturing cultivars to test their performance under varied drought conditions.

Agronomic traits and data collection

Agronomic data were collected on the following traits:

- Days to emergence (DE) is the duration of emergence of 50% of plants after sowing.
- Days to maturity (DM) is the duration of days from sowing to 95% of pods achieving physiological maturity.
- Pod yield (PY) is the yield of harvested pods per plot in kg/hectare.
- Seed yield (GY) is the yield of harvested seeds per plot in kg/hectare.
- Average number of pods per plant (PNPP) is computed per plot.
- HSW (Hundred Seed Weight) is 100 seed weight in grams.
- SPP is the average number of seeds per plant in each plot.

These were the critical traits for drought tolerance and yield capacity in water-constrained environments. Data was collected at appropriate times during the growing season, with the last harvest at physiological maturity (Lule *et al.,* 2020; Okada *et al.,* 2021).

Statistical analysis

SAS software version 9.4 was used to carry out an analysis of variance (ANOVA) on the data collected. The 5% level of significance was used to identify differences between genotypes for each characteristic. Genotype-by-environment interactions were also examined to determine the genotypes' stability and adaptability throughout two cropping seasons. Means were separated by the least significant difference (LSD) test. In addition, correlation analysis was carried out to find the associations of agronomic characteristics and this includes association between pod yield and seed yield (Hlanga *et al.,* 2024). Histograms and Q-Q plots were made for each of the traits for distribution analysis of data (Odesola *et al.,* 2023).

RESULTS AND DISCUSSION

Groundnut is the main legume and oil seed crop with major economic importance, renowned for the high protein and oil content necessary for food as well as for industrial purposes. The breeding activities of yield enhancement and quality attribute are essential because the demand in the world concerning food supply production has been drastically increasing. These factors affect productivity, including variation due to genetics, environmental condition,

Table 1: Advanced breeding lines used in the study and description of groundnut advanced breeding lines. (Collection site is Chitedze Agricultural Research Station (13°34′48″S/33°29′24″E), Malawi.

Breeding lines	Origin	Description (Drought tolerant)
RDRGVT(BAKA)	Malawi	Advanced line
RDRGVT ICGV 14788	Malawi	Advanced line
RDRGVT ICGV 00331	Malawi	Advanced line
RDRGVT ICGV SM 01514	Malawi	Advanced line
RDRGVT ICGV SM 03519	Malawi	Advanced line
RDRGVT ICGV SM 3520	Malawi	Advanced line
RDRGVT ICGV SM 3530	Malawi	Advanced line
RDRGVT ICGV SM 05723	Malawi	Advanced line
RDRGVT ICGV SM 06519	Malawi	Advanced line
RDRGVT ICGV SM 8528	Malawi	Advanced line
RDRGVT ICGV SM 8533	Malawi	Advanced line
RDRGVT ICGV SM 8538	Malawi	Advanced line
RDRGVT ICGV 8540	Malawi	Advanced line
RDRGVT ICGV SM 8547	Malawi	Advanced line
RDRGVT ICGV SM 8556	Malawi	Advanced line
KAKOMA	EIAR	Commercial variety
[a]WERER-961/ICGV-87108	Werer/EIAR	Commercial variety

and type of agronomy used. Pod yield (PY), grain yield (GY), seed per plant (SPP), and hundred seed weight (HSW) are some of the key parameters which are indicators of crop performance and have been well studied in crop development (Patel *et al.,* 1991; Anothai *et al.,* 2008).

Even with unprecedented advances in agronomic management and genetic improvement, the interaction of these elements remains unpredictable and multifaceted, with extensive research required to identify the most suitable genotypes to employ in breeding. The objective of this study is to summarize the performance of 17 genotypes of groundnut on the most important agronomic traits in the hope of identifying their ability to enhance the yield and quality characteristics. The trait variation, for example, seed number per plant and seed weight, will facilitate the selection of suitable genotypes for different conditions and farming systems. The ANOVA table represented hereunder for the key traits (Table 2) related to genotype × environment interaction including genotype, environment and genotype × environment mean sum of squares.

F-values were high and significant as well (≤0.001) in the pooled ANOVA analysis for the four traits, pod yield (PY), grain yield (GY), seeds per plant (SPP) and Hundred Seed Weight (HSW), suggesting substantial genotypic effects on all traits. F-value of 8.05 was observed for Py with genotype mean square of 28,221.50 and matching error mean square of 3,507.65. This indicates that the variation in quantity of pods produced was mostly due to genetic variation. High genotypic effect and substantial impact of genotypic variation on grain yield were additionally substantiated by the significant F-value for grain yield (GY) of 6.05 with the genotypic mean square (41,612.29) was significantly higher than the error mean square (6,874.56). The SPP had a moderate genotypic effect, as shown by its F-value of 2.60 and a genotype mean square of 121,226.43, suggesting that there is a moderate contribution of genotype to variation in seed number per plant. It still suggested a significant genotypic effect, however. Hundred seed weight (HSW) also exhibited a high genotypic effect on seed size, as indicated by the F-value of 3.62. The genotype mean square was quite bigger (98.56) than the error mean square (27.24).

This discovery serves to emphasize the importance of genotype in the selection of elite breeding lines for drought tolerance. Selective breeding toward specific genotypic traits associated with the performance for yield and seed

Table 2: Pooled ANOVA for pod yield, grain yield, seeds per plant and hundred seed weight in groundnut genotypes at PARC, Ethiopia.

Trait	SS_ genotype	df_ genotype	MS_ genotype	SS_ error	df_ error	MS_ error	F-value	p-value
Pod yield (PY)	451.544.07	16	28.221.50	119.321.82	34	3.507.65	8.05	0.001
Grain yield (GY)	665.796.58	16	41.612.29	233.935.28	34	6.874.56	6.05	0.001
Seeds per plant (SPP)	1.938.762.90	16	121.226.43	1.584.440.56	34	46.611.77	2.60	0.001
Hundred seed weight (HSW)	1.577.02	16	98.56	926.18	34	27.24	3.62	0.001

Table 3: LS mean separation values of important agronomic traits.

Genotype code.	Name of the breeding lines	PNPP	PY (Kg/ha)	GY (Kg/ha)	SPP	HSW (gm)
101	RDRGVT(BAKA)	20^{cde}	1606.7^{fg}	1322.2^{ef}	27.5^{bcde}	30^{cde}
102	RDRGVT ICGV 14788	24.7^{ab}	2062.9^{cde}	1666.7^{bcde}	38.7^{abc}	30.7^{cde}
103	RDRGVT ICGV 00331	21.7^{abcd}	1652.5^{fg}	1400^{def}	33.1^{abcde}	27.3^{e}
104	RDRGVT ICGV SM 01514	25.7^{a}	2547.5^{ab}	2044.4^{a}	40.3^{ab}	36^{abcd}
105	RDRGVT ICGV SM 03519	18.7^{def}	1824^{defg}	1500^{cdef}	29.1^{abcde}	31.3^{cde}
106	RDRGVT ICGV SM 3520	18.3^{def}	1752^{efg}	1455.6^{cdef}	26^{cde}	35^{abcd}
107	RDRGVT ICGV SM 3530	15.3^{f}	1508^{g}	1211.1^{f}	21.2^{e}	37^{abc}
108	RDRGVT ICGV SM 05723	23.7^{abc}	2074.4^{cde}	1688.9^{bcde}	37.1^{abcd}	30.7^{cde}
109	RDRGVT ICGV SM 06519	22^{abcd}	2331.7^{abc}	1855.5^{ab}	30.1^{abcde}	34^{bcde}
110	RDRGVT ICGV SM 8528	19^{def}	1682.4^{efg}	1322.2^{ef}	24.1^{de}	41^{ab}
111	RDRGVT ICGV SM 8533	22.3^{abcd}	2195.3^{bcd}	1855.6^{ab}	37.7^{abcd}	29.3^{de}
112	RDRGVT ICGV SM 8538	19^{def}	2070.4^{cde}	1666.6^{bcde}	28.7^{abcde}	41.7^{ab}
113	RDRGVT ICGV 8540	24.7^{ab}	2172.6^{cd}	1700^{bcd}	41.2^{a}	36.7^{abcd}
114	RDRGVT ICGV SM 8547	22^{abcd}	2608.8^{a}	2033.3^{a}	33.7^{abcde}	37.3^{abc}
115	RDRGVT ICGV SM 8556	21^{bcde}	1918^{def}	1611.1^{bcde}	31.3^{abcde}	36.7^{abcd}
116	KAKOMA	20.3^{cde}	2075^{cde}	1755.6^{abc}	31.9^{abcde}	37.3^{abc}
117	WERER -961 (Check)	17^{ef}	1717.5^{efg}	1355.5^{def}	29.1^{abcde}	32^{cde}
Mean		20.90	1988.21	1614.38	31.80	34.35
CV (%)		10.26	10.28	11.20	21.52	11.21
LSD		2.85	183.24	229.87	456.2	12.13
R^2		0.74	0.79	0.74	0.55	0.63

quality attributes would have a significant effect in enhancing performance under low rainfall (as practiced in the study area of the Pawe Agricultural Research Center), as the high significance levels for all traits indicated. In contrast, SPP had a relatively low F-value but considerable variation among genotypes, which implied its potential importance in the breeding strategies for improving the total production. The findings support the need for sustained breeding efforts to improve yield components for drought-prone conditions such as hundred seed weight, grain yield and pod yield.

LS Mean table (Table 3) gives least square means (adjusted against any variables) of different agronomic traits across genotypes, with statistical comparison to determine significant differences between treatments.

Mean values of the measured traits across all genotypes were significantly different, ranging from plant number per plot (PNPP) from 15.3 to 25.7, pod yield (PY, kg/ha) from 1508.0 to 2547.5 and grain yield (GY, kg/ha) from 1211.1 to 2044.4. Seed per plant (SPP) ranged from 21.2 to 41.2 and hundred seed weight (HSW, gm) ranged from 27.3 to 41.7.

Coefficient of variation (CV) showed there was high uniformity among traits under study and that SPP had the highest CV value at 21.52% with the highest seed number variability than other traits being studied. Least significant difference (LSD) values obtained were 183.24, 229.87, 456.2 and 12.13 for PY, GY, SPP and HSW, respectively, and allowed for determination of statistically significant differences among the genotypes.

The research also showed that genotype 104 (RDRGVT ICGV SM 01514) had the highest values of both PY (2547.5 kg/ha) and GY (2044.4 kg/ha) and the lowest values of both parameters were obtained by genotype 107 (RDRGVT ICGV SM 3530) (PY = 1508.0 kg/ha, GY = 1211.1 kg/ha). The highest average SPP was in genotype 113 (RDRGVT ICGV 8540) at 41.2 and the lowest seed number per plant was in genotype 107 at 21.2. For HSW, genotypes 110 and 112 had the highest seed weight of 41.0 g, while the lowest seed weight of 27.3 g was in genotype 103.

The data presented here demonstrate considerable variability in the agronomic characteristics of the genotypes tested, which is essential for choosing high-yielding varieties with desirable traits for breeding programs. The highest GY recorded in genotype 104, RDRGVT ICGV SM 01514, is in line with earlier studies where a higher yield potential was associated with enhanced pod and seed development (Kebede *et al.,* 2017). The performance of these genotypes suggest that it might be appropriate for high-input agricultural systems which are seeking to optimize grain yield.

In contrast, genotype 107 (RDRGVT ICGV SM 3530) had the lowest yields, which may be an indication of poor environmental adaptation or suboptimal genetic expression under the current field circumstances. This result is in line with the results of Chaudhary *et al.* (2021), who found that genotypes with weaker adaptation to some settings have lower production potential.

Based on seed number per plant SPP, Genotype 113 or RDRGVT ICGV 8540 exhibited superiority over others and produced up to 41.2 seeds per plant. It is said that the crop yields are considerably dominated by quantity per plant through which seeds; on the positive aspect, shows good linkage towards the pod yields, as confirmed in Baker *et al.* (2003). Probably, there can be possible causes of variance because of SPP genotypes attributed to genetics in seed-set parameters and reproductivity functions. According to Patel *et al.* (2024), improving this feature is important to increase yields in leguminous crops.

The hundred seed weight (HSW) is another critical characteristic needed for production and quality. The highest HSW occurred in genotypes 110 and 112, with an average of 41.0 g. This characteristic, often linked to environmental factors such as nutrient availability and water stress (Wang *et al.,* 2023), suggests that these genotypes might be suitable for situations where seed size becomes the major factor in being marketable or processed.

The coefficient of variation for SPPI and HSW shows that these traits were relatively more variable between genotypes than PY or GY, which had lower CVs. This underlines the requirement for selection to be made for consistency in these attributes, especially seed number per plant, in a breeding programme aimed at enhancing yield potential. Moreover, the correlation between PY and GY further supports the hypothesis that higher pod yield could be directly translated to higher grain yield, as has been previously suggested by Patel *et al.* (2024).

The LS Mean values and statistical significance on LSD, show success in the selection of genotype, since it assured yields above other genotypes, among them was genotype 104, RDRGVT ICGV SM 01514. Howsoever, environmental issues and management strategies combined with genotypic interactions require more research for practical application in an agricultural field setting (Gulluoglu *et al.,* 2017).

Genotypic variability and performance

All agronomic traits presented significant genotypic differences; hence, the groundnut lines analyzed exhibited a high level of genetic variation. Significant GEIs were reported for pod number per plant and seed weight. This implies that the environmental conditions prevailing in every cropping season impacted the performance of the traits under study (Kalarani *et al.,* 2023). This is justified for testing groundnut genotypes in different conditions in order to obtain the best stable lines for drought tolerance.

Some of the genotypes, such as RDRGVT ICGV SM 01514, RDRGVT ICGV 14788 and RDRGVT ICGV 8540, performed better than the control variety Werer-961 in pod and seed yield in both seasons. The high yield performance of these genotypes can be explained by the high number of pods per plant and seed weight (Tadesse *et al.,* 2018). For example, RDRGVT ICGV SM 01514 produced 3.2 tons per hectare, which was significantly higher than the control

variety yield of 2.5 tons per hectare (Fig 1). Moreover, these lines had improved resistance to drought stress, as indicated by their ability to produce more pods and seeds even under reduced water availability.

Correlations among agronomic traits

The correlation matrix (Table 4) shows the Pearson correlation coefficients between agronomic traits, which express the direction and strength of the linear relationship that exists between each pair of traits among the genotypes tested.

The correlation analysis indicated high positive correlations between hundred seed weight and seed yield (r = 0.79) and between number of pods per plant and pod yield (r = 0.82). These findings indicate that selection for seed weight and number of pods can potentially increase pod and seed yield under drought stress (Zhang *et al.,* 2019). Seed yield and number of days to maturity also indicated a high negative correlation (r = -0.62), indicating that early-maturing genotypes perform better under drought stress conditions due to their shorter growth duration and lower water requirement (Mubai *et al.,* 2020). The growth-related characteristics included increased leaf area, greater dry matter accumulation, enhanced yield components and increased availability of nutrients during the growing season. (Ananda and Sharanappa, 2017). In addition to having more space available to the groundnut plant, which increases photosynthetic activities and leads to higher growth and yield attributes, the presence of groundnut in the paired row system most likely had more synergistic effects than antagonistic ones. These factors ultimately reflected in the groundnut yield (Hadiyal, 2020). Groundnut quality and productivity are influenced by environmental factors as well as enhanced agronomic techniques, particularly planting techniques, which are crucial to increasing groundnut crop yield (Olayinka *et al*., 2020).

The association of the traits remained consistent between both study years, indicating that association among agronomic traits was maintained irrespective of varying environmental conditions (Almeida *et al.,* 2014). The findings highlight the requirement of selection for multiple traits such as pod number, seed weight and maturation period during breeding for groundnut drought tolerance.

Normality and statistical analysis

Normality test and statistical analysis include testing the distribution of data to check whether it is normally distributed and then using statistical methods for appropriate analysis and interpretation. This graph uses a histogram drawn

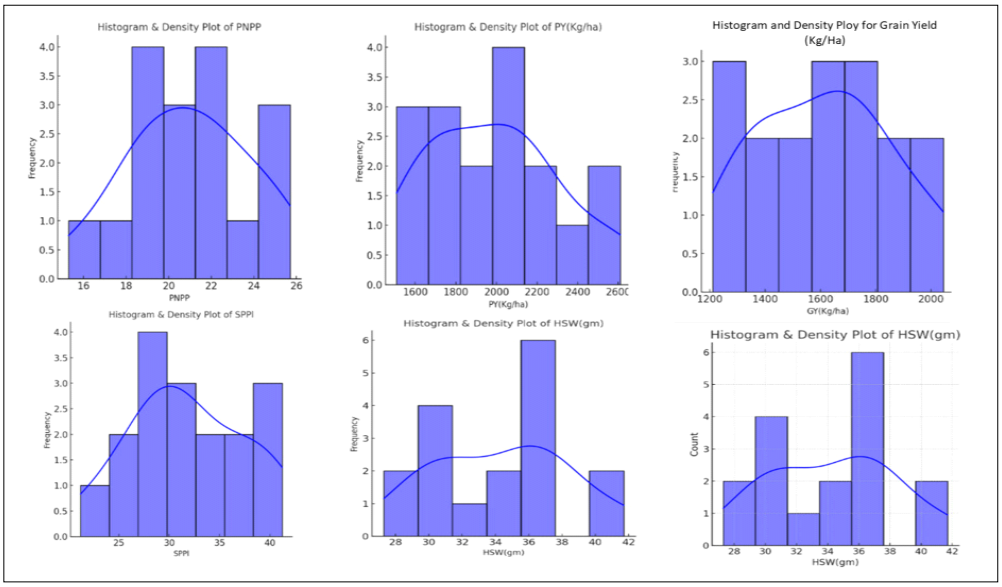


Fig 1: Histogram of agronomic traits.

Table 4: The correlation between the agronomic traits.

Correlation	SP	PNPP	PY	GY	SPP	SPP	HSW
SP	1						
PNPP	0.06	1					
PY	-0.15	0.67	1				
GY	0.12	0.69	0.96	1			
SPP	0.14	0.79	0.57	0.63	1		
SPP	0.09	0.18	0.20	0.25	0.73	1	
HSW	-0.19	-0.13	0.20	0.15	-0.15	-0.10	1

using blue bars to show the frequency distribution of PNPP values. An estimated probability distribution is marked by an overlaid density curve (smooth blue line). The histogram gives information on the spread and skewness in the data. Distribution of agronomic characteristics was examined through histograms and Q-Q plots. The quantile-quantile (Q-Q) plot compares the ordered PNPP values (y-axis) with theoretical quantiles (x-axis) of a normal distribution. The red diagonal line represents the expected normal distribution, while the blue dots indicate actual data points. Deviations from the red line suggest departures from normality. Most of the characteristics were normally distributed, with slight deviations recorded from hundred seed weight and seed yield (Fig 1 and 2). These deviations would have been due to environmental factors to modify these characteristics, in this case, variations in rainfall and temperatures during the cropping season (Reig-Valiente *et al.,* 2018). Findings on pod number per plant and seed weight, however, showed very well standard distributions, with signs pointing towards the use of these characteristics being effective and indicative measures of drought resistance (Fig 1).

Fitted value plots are graphical representations of the model's predictions of dependent agronomic traits for

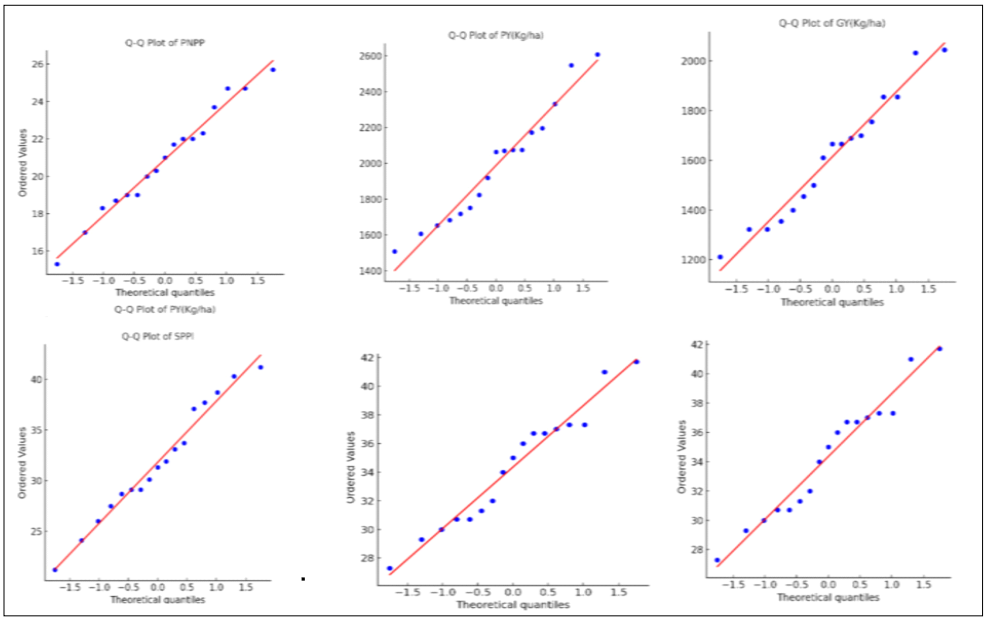


Fig 2: Q-Q plot for normality of agronomic data.

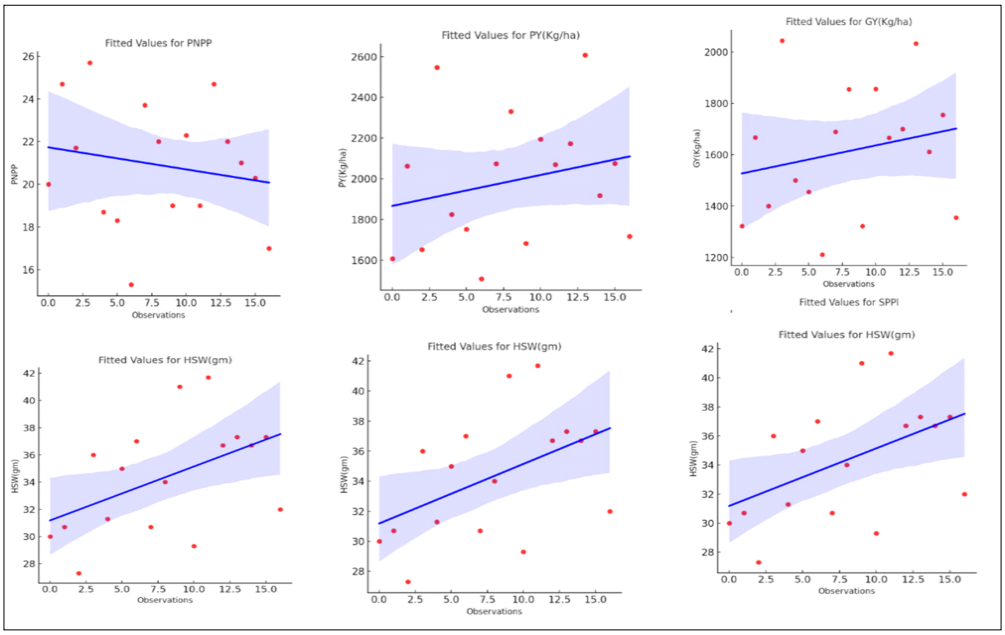


Fig 3: Model fit and residual analysis for agronomic traits.

different genotypes or treatments (Fig 3). It was shown (as red dots) in comparison to the predicted values based on the regression model. A blue regression line, with a shaded confidence interval, represents the trend in the trait values. The slight decline indicates a weak the trend. The plots describe the relationship between predicted and observed values, thus enabling a determination of the model's fit to the empirical data. Fitted values are the predicted outcomes of the statistical analysis, while the residuals being the difference between observed and fitted values indicate the accuracy of the predictions. Fitted value plots are crucial for trend detection, model assumption checking, and the identification of patterns that could reflect model inadequacy or unexplained variation.

CONCLUSION

This study identified several drought-resistant groundnut breeding lines in Ethiopia with desirable agronomic performance under rainfed conditions. The genotypes RDRGVT ICGV SM 01514, RDRGVT ICGV 14788 and RDRGVT ICGV 8540 had high pod and seed yields and were suitable candidates for planting in drought-prone areas. The lines also had high correlation with desirable agronomic traits like number of pods per plant and seed yield, and the significance of selecting multiple traits to improve drought resistance in groundnut. There were strong genotype-by-environment interactions for traits such as number of pods and seed weight, indicating that genotype performance is influenced by environmental conditions and requires attention in breeding. Overall, the study emphasizes the development of drought-tolerant groundnut cultivars, which have the potential to improve food security and sustainable agriculture in the semi-arid areas.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

Abady, S., Shimelis, H. and Janila, P. (2019). Farmers' perceived constraints to groundnut production, their variety choice and preferred traits in eastern Ethiopia: Implications for drought-tolerance breeding. *Journal of Crop Improvement*. **33(4):** 505-521.

Almeida, W.S.D., Fernandes, F.R.B., Teófilo, E.M. and Bertini, H.C.D.M. (2014). Bertini. Correlation and path analysis in components of grain yield of cowpea genotypes. *Revista de Ciencias Agricolas*. **45(4):** 726-736.

Ananda, M.R. and Sharanappa, S. (2017). Growth, yield and quality of groundnut as influenced by organic nutrient management in groundnut (*Arachis hypogaea* L.)-finger millet (*Eleusine coracana* L.) cropping system. *Mysore J. Agric. Sci.* **51(2):** 385-391.

Anothai, J., Patanothai, A., Jogloy, S., Pannangpetch, K., Boote, K. and Hoogenboom, G. (2008). A sequential approach for determining the cultivar coefficients of peanut lines using end-of-season data of crop performance trials. *Field Crops Research*. **108(2):** 169-178. https://doi.org/10.1016/j. fcr.2008.04.012.

Awal, M.A. and Ikeda, T. (2002). Effects of changes in soil temperature on seedling emergence and phenological development in field-grown stands of peanut (*Arachis hypogaea*). *Environmental and Experimental Botany*. **47:** 101-113.

Baker, G.L., Cornell, J.A., Gorbet, D.W., O'keefe, S.F., Sims, C.A., and Talcott, S.T. (2003). Determination of pyrazine and flavor variations in peanut genotypes during roasting. *Journal of Food Science*. **68(1):** 394-400. https://doi.org/10.1111/j.1365-2621.2003.tb14171.x.

Celikkol Akcay, U., Ercan, O., Kavas, M., Yildiz, L., Yilmaz, C., Oktem, H.A. and Yucel, M. (2010). Drought-induced oxidative damage and antioxidant responses in peanut (*Arachis hypogaea* L.) seedlings. *Plant Growth Regulators*. **61:** 21-28.

Chaudhary, M.V and Thakur, Nidhi. (2021). Future prospects of organic farming: A review. *Bhartiya Krishi Anusandhan Patrika*. **36(2):** 108-111. doi: 10.18805/BKAP274.

Falke, A.B., Hamidou, F., Halilou, O. and Harou, A. (2019). Assessment of groundnut elite lines under drought conditions and selection of tolerance associated traits. *Advances in Agriculture*. **2019(1):** 3034278. https://doi.org/10.1155/2019/3034278.

Gulluoglu, L., Bakal, H., Onat, B. and Kurt, C. *et al.* (2017). Comparison of agronomic and quality characteristics of some peanut (*Arachis hypogaea* L.) varieties grown as main and double crop in Mediterranean region. *Turkish Journal of Field Crops*. **22(2):** 166-177. https://doi.org/10.17557/tjfc.356208.

Hadiyal, J.G. (2020). Crop intensification and diversification through groundnut (*Arachis hypogaea* L.) + Sweet corn (*Zea mays* var. *saccharata*) intercropping system (doctoral dissertation, JAU, Juanagdh).

Hlanga, N.C., Modi, A.T., Mathew, I. and Sibiya, J. (2024). Integrated analysis of agronomic traits and nutritional composition in Bambara groundnut: correlation, regression and path coefficient approaches. *Acta Agriculturae Scandinavica Section B - Soil and Plant Science*. **74(1).** https://doi.org/10.1080/09064710.2024.2396972.

Hussainy, S.A.H., Brindavathy, R. and Vaidyanathan, R. (2020). Production potential of groundnut (*Arachis hypogaea* L.) under intercropping system-A review. *Crop Res.* **55:** 36-47.

Janila, P., Nigam, S.N., Pandey, M.K., Nagesh, P. and Varshney, R.K. (2013). Groundnut improvement: Use of genetic and genomic tools. *Frontiers in Plant Science*. **4:** 23. https://doi:10.3389/fpls.2013.00023.

Kalarani, M.K., Senthil, A., Punitha, S., Sowmyapriya, S., Umapathi, M. and Geethalakshmi, V. (2023). Abiotic Stress Responses in Groundnut (*Arachis hypogaea* L.): Mechanisms and Adaptations. In: Legumes: Physiology and Molecular Biology of Abiotic Stress Tolerance. [Muthu Arjuna Samy, P., Ramasamy, A., Chinnusamy, V., Sunil Kumar, B. (eds)] Springer, Singapore. https://doi.org/10.1007/978-981-19-5817-5_11.

Kang, M.S., Prabhakaran, V.T. and Mehra, R.B. (2004). Genotype-by-Environment Interaction in Crop Improvement. In: Plant Breeding. [Jain, H.K., Kharkwal, M.C. (eds)], Springer, Dordrecht. https://doi.org/10.1007/978-94-007-1040-5_23.

Kebede, A., Abady, S., Endale, D., Abdulahi, J.,Getahun, A., Robsa, A. and Petros, Y. (2017). Registration of 'babile-1','babile-2' and 'babile3' groundnut varieties. *East African Journal of Sciences*. **11(1):** 59-64. doi: 10.36344/ccijavs.2023.v05i05.003.

Kokkanti, R.R., Vemuri, H., Gaddameedi, A. and Rayalacheruvu, U. (2021). Variability in drought stress-induced physiological, biochemical responses and expression of DREB2A, NAC4 and HSP70 genes in groundnut (*Arachis hypogaea* L.). *South African Journal of Botany*. **144:** 448-457. https://doi.org/10.1016/j.sajb.2021.09.025.

Lule, D., Tadesse, T., Chibsa, T., Asefa, K., Jogora, K., Wako, K., Alemu, T., Ahimed, K., Letta, T., Woltedji, D., Daba, C., Mengistu, G., Jobie, T., Ararsa, E., Tufa, S. and Geleto, T. (2020). Oromia Agricultural Research Institute Workshop Proceeding on Adaptation and Generation of Agricultural Technologies. 23-27 December, 2020, Batu, Ethiopia.

Mediga, K.R., Sharma, B., Joshi, R., Palanivel, H., Kuruva, M. and Sunkad, G. (2025). Potential of Wild Relatives of Wheat: Ideal Gene Pool for Enhancing Drought Tolerance in Modern Wheat Cultivars. In: Wheat Wild Relatives. Academic Press, Elsevier. pp. 91-140.

Mediga, K.R., Sunkad, G., Kulkarni, S., Chandran, U.S.S., Ghosh, R., Kshirsagar, D., Sonnappa, M., Katravath, S., Parthasarathy, A. and Sharma, M. (2023). Multi-environment testing based G EInteractions reveal stable host-plant resistance against sterility mosaic disease in pigeonpea. *Agronomy*. **13:** 2859. https://doi.org/10.3390/agronomy13122859.

Mubai, N., Sibiya, J., Mwololo, J., Musvosvi, C., Charlie, H., Munthali, W., Kachulu, L. and Okori, P. (2020). Phenotypic correlation, path coefficient and multivariate analysis for yield and yield-associated traits in groundnut accessions. *Cogent Food and Agriculture*. **6(1).** https://doi.org/10.1080/23311932.2020.1823591.

Odesola, K.A., Olawuyi, O.J., Paliwal, R., Oyatomi, O.A. and Abberton, M.T. (2023). Genome-wide association analysis of phenotypic traits in Bambara groundnut under drought-stressed and non-stressed conditions based on DArTseq SNP. *Frontiers in Plant Science*. **14:** 1104417. https://doi.org/10.3389/fpls.2023.1104417.

Okada, M.H., Oliveira, G.R.F., Sartori, M.M.P., Crusciol, C.A.C., Nakagawa, J. and Amaral da Silva, E.A. (2021). Acquisition of the physiological quality of peanut (*Arachis hypogaea* L.) seeds during maturation under the influence of the maternal environment. *PloS one*. **16(5):** e0250293. https://doi.org/10.1371/journal.pone.0250293.

Olayinka, B.U., Abdulbaki, A.S., Mohammed, R.T., Alsamadany, H., Murtadha, R.B., Alzahrani, Y., Abdulaziz, A., Abdul-kareem, K.A., Etejere E.O. (2020). Effect of planting methods on growth and yield of groundnut cultivars. *Legume Research*. **44(1):** 74-80. doi: 10.18805/LR-546.

Patel, K.K., Patel, J.M., Patel, J.A., Chauhan, K.J. and Patel, R.M. (2024). Optimizing nutrient content and uptake in groundnut through integrated nutrient management under North Gujarat conditions. *International Journal of Advanced Biochemistry Research*. **8(12S):** 612-616.

Patel, M.S. and Golakiya, B.A. (1991). Effect of water stress on yield and yield attributes of groundnut (*Arachis hypogaea* L.). *Madras Agricultural Journal*. **78:** 178-181.

Puppala, N., Nayak, S.N., Sanz-Saez, A., Chen, C., Devi, M.J., Nivedita, N., Bao, Y., He, G., Traore, S.M., Wright, D.A., Pandey, M.K. and Sharma, V. (2023). Sustaining yield and nutritional quality of peanuts in harsh environments: Physiological and molecular basis of drought and heat stress tolerance. *Frontiers in Genetics*. **14:** 1121462. https://doi.org/10.3389/fgene.2023.1121462.

Qiao, M., Hong, C., Jiao, Y., Hou, S. and Gao, H. (2024). Impacts of drought on photosynthesis in major food crops and the related mechanisms of plant responses to drought. *Plants*. **13(13):** 1808. https://doi.org/10.3390/plants13131808.

Reig-Valiente, J.L., Marqués, L., Talón, M. and Domingo, C. (2018). Genome-wide association study of agronomic traits in rice cultivated in temperate regions. *BMC Genomics*. **19(1):** 706. https://doi.org/10.1186/s12864-018-5086-y.

Tadesse, S.T., Oenema, O., van Beek, C. *et al.* (2018). Diversity and nutrient balances of urban and peri-urban farms in Ethiopia. *Nutr. Cycl. Agroecosyst.* **111:** 1-18. https://doi.org/10.1007/s10705-018-9911-0.

Wang, Z., Zhang, Y., Yan, L., Chen, Y., Kang, Y., Huai, D., Wang, X., Liu, K., Jiang, H., Lei, Y. and Liao, B. (2023). Correlation and variability analysis of yield and quality related traits in different peanut varieties across various ecological zones of China. *Oil Crop Science*. **8(4):** 236-242. https://doi. org/10.1016/j.ocsci.2023.12.001.

Zhang, H., Yasmin, F. and Song, B.-H. (2019). Neglected treasures in the wild-legume wild relatives in food security and human health. *Curr. Opin. Plant Biol.* **49:** 17-26. doi: 10.1016/j.pbi.2019.04.004.