Plant Archives Vol. 25, No. 2, 2025 pp. 2709-2713 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.391

MULTI SEASON STABILITY ANALYSIS OF GROUNDNUT GENOTYPES BASED ON EBERHART AND RUSSELL'S REGRESSION MODEL

Nandini Agrawal*, Shrikant Laxmikantrao Sawargaonkar, Nandan Mehta, Ajit Kumar Singh Sharon, Garima Daniel, Joshline Ekka and Dharavath Nagaraju

Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur - 492 001, Chhattisgarh, India.

*Corresponding author E-mail : nandiniagrawal9102000@gmail.com

(Date of Receiving-25-06-2025; Date of Acceptance-07-09-2025)

ABSTRACT

Groundnut (*Arachis hypogaea* L.) is a key oilseed crop in India, with Chhattisgarh as an important producing state under rainfed conditions. Seasonal variability affects its yield, making stability analysis through the Eberhart and Russell model crucial for identifying adaptable genotypes. A study on stability analysis was conducted at the research field of the College of Agriculture and Research Station, Raigarh (C.G.), under IGKV, Raipur (C.G.) in three distinct seasons: *Kharif* (2023), Summer (2024), and *Kharif* (2024) across 25 groundnut genotypes, including four checks. The experiment was laid out in a Randomized Block Design with three replications, and observations were recorded for Kernel yield (kg/ha). Stability analysis using Eberhart and Russell's model identified genotypes ICGV-221008, ICGV-201011, CGTM, CGM-1 and TG-86 as stable performers with wide adaptability, exhibiting regression coefficients close to unity and non-significant deviations. Genotypes like TG-89, TAG-24, ICGV-211184, ICGV-15038, ICGV-211007, JL-776 and ICGV-211168 showed specific adaptability to favorable environments, whereas others, such as ICGV-201010, ICGV-211086, DGRMB-32, ICGV- 211169, ICGV-211075, ICGV-211260 and ICGV-211191, demonstrated resilience under stress conditions.

Key words : Groundnut, Stability, Adaptability, Kernel yield and Eberhart-Russell model.

Introduction

Groundnut (*Arachis hypogaea* L.), commonly known as peanut, is a vital oilseed and legume crop cultivated extensively across the tropics and subtropics. In the 2015–16 period, India cultivated about 4.56 million hectares of groundnut, yielding 6.77 million tonnes at an average productivity of 1,486 kg/ha (Gayathri, 2018). Despite fluctuations in area, production and yield have demonstrated positive trends, driven primarily by productivity gains (Suthar *et al.*, 2024). Within India, Chhattisgarh has emerged as a noteworthy groundnut-growing state, particularly under rainfed conditions. Growth rate analysis between 1993-94 and 2012-13 in Raigarh district—an important groundnut hub—showed an increase in area from 15.20 to 30.82 hectares and production from 20.40 to 38.28 tonnes. Yield in the district rose by approximately 400 kg/ha, while the state average climbed by around 550 kg/ha during the same period (Kurrey *et al.*, 2018). Moreover, groundnut plays an essential role in rural livelihoods, providing oil, seed meal for livestock, and nitrogen fixation benefits for soil fertility (Patel and Chandrakar, 2022).

The inherent variability in environmental factors such as rainfall and soil fertility in groundnut-growing regions like Chhattisgarh leads to inconsistent yield performance across seasons and environments. Consequently, identifying genotypes that combine high productivity with stability becomes pivotal. The Eberhart and Russell model offers a robust methodology by evaluating genotypic performance through two key parameters—regression coefficient (β), reflecting response to environmental change and deviation from regression (S^2d_i) representing predictability. This dual assessment facilitates the selection of genotypes that are both adaptable and stable across variable environments, optimizing breeding outcomes under heterogeneous conditions.

The Eberhart–Russell joint regression framework remains one of the most widely applied methods to dissect genotype × environment interaction (GEI) and quantify both adaptability (regression slope, b_i) and predictability (deviation from regression, S²di). The original formulation (Eberhart and Russell, 1966) defined stability as high mean performance with $b_i \approx 1$ and minimal S²di, providing an interpretable basis for selecting broadly adapted genotypes. In groundnut, early and subsequent studies consistently demonstrate the utility of E–R for ranking genotypes across seasons and locations. For example, analyses of Spanish bunch groundnut genotypes identified lines with b_i near unity and low S²di, highlighting candidates for wide adaptation while flagging specifically adapted types when $b_i \neq 1$ (Suneetha *et al*., 2016; Rani *et al*., 2018). More recent multi-environment trials in India reaffirm these patterns: pooled ANOVA often detects significant GEI for yield and yield components, after which E–R parameters clearly separate stable, high-mean performers from unstable entries (Nandini *et al*., 2019).

Contemporary groundnut studies also integrate E–R alongside multiplicative models such as AMMI and GGE to obtain complementary insights—E–R excelling at genotype-centric stability metrics, while AMMI and GGE visualize GEI structure and mega-environments. Cross-method comparisons in oilseeds and legumes show that conclusions about broadly adapted genotypes are generally concordant, with E–R providing simple, decision-ready parameters for breeders (Upadhyaya *et al*., 2002; Ajay *et al*., 2020). Overall, the groundnut literature supports the E–R model as a robust, breeder-friendly approach to quantify stability and adaptability across seasons and sites, especially where rainfed variability is high—as in much of India, including Chhattisgarh—thereby enabling selection of genotypes with consistent yield and predictable performance.

Materials and Methods

Twenty-five groundnut genotypes including four checks (Table 1) were evaluated in a randomized complete block design (RCBD) with three replications at research field of College of Agriculture and Research Station, Raigarh (C.G.), IGKV, Raipur (C.G.) during *Kharif* (2023), Summer (2024) and *Kharif* (2024) season. The experimental site is located at is located 215 meters above mean sea level and is situated in latitude 21.9°N and longitude 83.4°E. The genotypes were raised in net plot size of 4.8 × 0.9 m^2 plot keeping 30 cm × 10 cm spacing. The recommended agronomic practices were followed throughout the crop growth period. Data were recorded in each replication for various quantitative traits viz, kernel yield/plant, kernel yield/net plot and kernel yield (kg/ha).

Table 1 : Details of genotypes and checks.

ICGV-211188	ICGV-211191
ICGV-201011	ICGV-211007
ICGV-221008	ICGV-211174
ICGV-16668	ICGV-15038
ICGV-221011	ICGV-211086
ICGV-211075	TG-86
ICGV-211169	TG-89
ICGV-211168	DGRMB-24
ICGV-211206	DGRMB-32
ICGV-211260	TAG-24(check)
ICGV-201010	JL-776(check)
ICGV-211184	CGM-1(check)
	CGTM(check)

Eberhart and Russel (1966) model was utilized for stability analysis. In this model, three parameters were determined, *viz*. genotype mean across environments, regression of genotype on environmental index and the function of the squared deviation from the regression. A genotype having regression coefficient as unit i.e., b=1 and non-significant deviation from Zero i.e., $S^2d_i = 0$, was considered as stable with uniform response.

Results and Discussion

In the present study, groundnut genotypes were evaluated across three seasons – *Kharif* (2023), Summer (2024) and *Kharif* (2024). Before conducting pooled analysis, Bartlett's test was applied to assess the homogeneity of error variances across environments. The test revealed significant heterogeneity (p = 0.0024), indicating that the assumption of equal variances was not met. As a result, conventional models that assume homoscedasticity were deemed unsuitable for this dataset. To address this, the Eberhart and Russell (1966) model was employed, as it accommodates unequal error variances while still providing meaningful insights into the adaptability and performance consistency of the genotypes. This approach enhanced the accuracy and reliability of the stability assessment, thereby aiding in the identification of groundnut genotypes suited for cultivation under diverse and unpredictable seasonal conditions.

The pooled ANOVA revealed highly significant differences among genotypes (F = 3.861, p = 0.0007), environments (F = 144.77, p<1), and the genotype × environment interaction (F = 4.70, p<1), indicating the presence of substantial genetic variability as well as differential responses of genotypes to environmental

Table 2 : Pooled analysis of variance for stability of Kernel yield per hectare (kg).

Source	DF	Mean Squares
Genotype	24	43624.77**
Environment	2	11654006.11**
Genotype × Environment	48	93341.46**
Env + Genotype × Environment	50	185256.01
Environment (Linear)	1	7769337.40**
Environment X Genotype (Lin)	24	50458.10**
Pooled Deviation	25	11298.75*
Pooled Error	150	6,351.53
Total	74	

(*) at 5% probability and (**) at 1% probability.

Table 3 : Ranking (Environment Index) of season according to index value and mean of kernel yield kg per hectare.

Rank	Environments	Mean	Index Value
I	Summer (E2)	2143.2099	416.370
II	*Kharif* 2023 (E1)	1677.9140	-48.925
III	*Kharif* 2024 (E3)	1359.3949	-367.444

Table 4 : Estimation of different stability parameters for kernel yield.

Genotype	Grain yield (Mean)	Reg coefficient (b_i)	Stability parameter (S^2d_i)	Deviation (sd)
ICGV-221008	2005.504	1.067	-6481.0670 NS	0
ICGV-201011	1929.783	1.057	-6130.9906 NS	0.002
TG-86	1915.484	1.174	-187.0282 NS	0.021
CGTM (check)	1903.600	1.136	-6076.7100 NS	0.002
ICGV-211191	1848.662	0.703	-3083.2249 NS	0.011
TG-89	1805.557	1.332	7617.3418 NS	0.046
ICGV-201010	1803.036	0.408	17748.9628 NS	0.078
CGM-1(check)	1798.661	0.944	-6034.5271 NS	0.002
ICGV-211007	1720.783	1.193	-2881.7465 NS	0.012
TAG-24(check)	1720.010	1.543	18756.6981 NS	0.082
JL-776(check)	1718.724	1.042	-6616.1280 NS	0
ICGV-211086	1714.043	0.881	-6551.4107 NS	0
ICGV-211169	1711.112	0.573	11131.1056 NS	0.057
ICGV-211184	1692.643	1.172	-5581.7388 NS	0.003
ICGV-15038	1688.013	1.204	-3967.2327 NS	0.009
ICGV-211188	1670.061	2.160	59661.6189 **	0.213
ICGV-16668	1660.184	0.086	57443.3276 **	0.206
DGRMB-32	1651.698	0.959	-5863.1742 NS	0.002
ICGV-211075	1634.773	0.572	11238.9479 NS	0.057
ICGV-211260	1627.520	0.823	-3702.7686 NS	0.009
ICGV-211168	1619.651	1.145	-6560.0651 NS	0
ICGV-211174	1611.830	0.869	-6589.4278 NS	0
ICGV-211206	1591.668	0.627	7767.6434 NS	0.046
ICGV-221011	1578.293	0.995	-5756.7157 NS	0.003
DGRMB-24	1549.693	1.335	7763.3307 NS	0.046
Pooled Mean	1726.839			

changes. The significant environment mean squares confirmed the diverse nature of the test environments, while the significant G × E interaction highlighted the influence of environmental factors on genotype performance.

More importantly, the G × E interaction was further partitioned, where the linear component was found to be significant, suggesting that a portion of the interaction could be explained by predictable environmental trends. Additionally, the significance of the deviation from regression means squares indicated that some genotypes exhibited unpredictable responses across environments.

Environment index reveals the favorability of an environment at a particular location. Breeze (1969) pointed out that the estimates of environment index can provide the basis for identifying the favorable environment for the expression of maximum potential of the genotype.

In multi-seasonal trials, season with the highest environmental index value was Summer (2024) {E2} which was classified as favorable environment that support higher genetic performance. Conversely, environments such as *Kharif* (2023) {E1} and *Kharif* (2024) {E3} with negative indices represent stressful environments.

The kernel yield per hectare among the 25 genotypes exhibited considerable variation, ranging from 2005.504 kg ha^{-1} in the genotype (ICGV-221008) to 1549.693 kg ha^{-1} in (DGRMB-32). This wide range reflects substantial genetic variability in yield potential among the tested genotypes. Notably, 8 genotypes recorded higher-than-average mean yields per hectare, suggesting their potential for direct cultivation or use in breeding programs targeting enhanced productivity. Such results underscore the importance of identifying and utilizing high-yielding genotypes to improve crop performance, consistent with findings reported by earlier studies emphasizing genetic variation as a basis for yield improvement (Kumari *et al.*, 2022).

In this study, five groundnut genotypes met all the stability criteria, signifying both high productivity and broad

Table 5 : Stable genotypes.

Genotype	Yield (kg/ha)	b_i	S^2d_i
ICGV-221008	2005.504	1.067	-6481.067 NS
ICGV-201011	1929.783	1.057	-6130.990 NS
TG-86	1915.484	1.174	-187.028 NS
CGTM	1903.600	1.136	-6076.710 NS
CGM-1	1798.661	0.944	-6034.527 NS

Table 6 : Classification of genotypes based on the mean performance and regression coefficient (b_i) values across diverse environments.

S. no.	Environment	Remark	Genotypes	
1.	Summer 2024{E2}	Favorable	ICGV-221008 ICGV-201011 CGTM CGM-1 TG-86	TG-89 TAG-24 ICGV-211184 ICGV-15038 ICGV-211007 JL-776 ICGV-211168
2.	*Kharif* (2023){E1} *Kharif* (2024){E3}	Unfavorable	ICGV-221008 ICGV-201011 CGTM CGM-1 TG-86	ICGV-201010 ICGV-211086 DGRMB-32 ICGV-211169 ICGV-211075 ICGV-211260 ICGV-211191

adaptability.

These groundnut genotypes not only exhibited consistently high mean kernel yield across different seasons, but also showed regression coefficients (b_i) close to unity and non-significant deviations from regression (S^2d_i). This combination reflects both wide adaptability and phenotypic stability. Such genotypes are considered ideal for cultivation under variable agro-ecological conditions, as they offer a balance between productivity and resilience to environmental fluctuations, including seasonal variability. These findings are in accordance with earlier research by Eberhart and Russell (1966), Crossa (1990) and Shukla *et al*. (2004), who emphasized that genotypes with b_i H” 1 and low, non-significant S^2d_i values are best suited for general adaptation. Therefore, groundnut genotypes such as ICGV-221008, ICGV-201011, CGTM, CGM-1 and TG-86 may be regarded as promising candidates for multi-season trials and hold potential for varietal release across diverse environmental conditions.

Several groundnut genotypes demonstrated specific adaptability to favorable or stress-prone environments, as indicated by their mean yields, regression coefficients (b_i) and non-significant deviations from regression (S^2d_i).

Genotypes such as TG-89, TAG-24, ICGV-211184, ICGV-15038, ICGV-211007, JL-776 and ICGV-211168 recorded bi values greater than 1, suggesting specific adaptability to favorable environments. These genotypes are likely to perform well under optimal climate conditions, such as temperature, rainfall, and humidity.

In contrast, ICGV-201010, ICGV-211086, DGRMB-32, ICGV- 211169, ICGV-211075, ICGV-211260 and ICGV-211191 showed b_i values less than 1, indicating adaptation to stress-prone environments where input levels are lower or conditions are suboptimal. These genotypes may maintain relatively stable yields under challenging agro-ecological conditions. These results underscore the importance of selecting genotypes not only for high yield but also for their specific or general adaptability, depending on the target production environment.

Several groundnut genotypes exhibited significant deviations from the regression line (S^2d_i), highlighting their lack of stability and inconsistent performance across different environments and seasons. For instance, genotypes such as ICGV-211188 and ICGV-16668 demonstrated regression coefficients (b_i) that deviated substantially from unity, along with statistically significant S^2d_i values, indicating unpredictable yield behavior.

Conclusion

Out of 25 evaluated groundnut genotypes, only a few showed stable and consistent performance based on Eberhart and Russell's stability model. This model uses mean performance, regression coefficient (b_i) and deviation from regression (S^2d_i) to assess stability. The analysis confirmed significant genotype, environment and genotype-by-environment interaction effects, with Summer (2024) identified as the best environment for performance. Five genotypes—ICGV-221008, ICGV-201011, CGTM, CGM-1, and TG-86—demonstrated high yields and stability across seasons. Other genotypes like TG-89 and TAG-24 showed good performance in favorable conditions, while genotypes such as ICGV-201010 and ICGV-211086 excelled in stress-prone environments. Some genotypes displayed significant deviations from the regression line, indicating instability, such as ICGV-211188 and ICGV-16668, highlighting the importance of selecting genotypes based on adaptability and yield stability.

References

Ajay, B.C., Aravind J. and Rao A.R. (2020). Stability: An R package for analysis of phenotypic stability. *J. Plant Biochem. Biotechnol.*, **29(4)**, 779–783.

Breeze, V.G. (1969). Predicting the stability of crop genotypes. *J. Agricult. Sci.*, **72(3)**, 399–406.

Crossa, J. (1990). Statistical analyses of multilocation trials. *Adv. Agron.*, **44**, 55–85.

Eberhart, S.A. and Russell W.A. (1966). Stability parameters for comparing varieties. *Crop Science*, **6(1)**, 36–40.

Gayathri, J. (2018). A Trend Analysis of Area, Production and Yield of Groundnut in India, *Shanlax Int. J. Econ.*, **6(3)**, 15-21.

Kumari, P., Tirkey S.K., Ahmad E., Mahto C.S., Ekka J.P. and Swapni (2022). Identification of selection parameters for evaluating superior stable genotypes of groundnut (*Arachis hypogaea* L.). *The Pharma Innov. J.*, **12(6)**, 843–848.

Kurrey, D., Jain B.C., Rajput Y.S. and Dhruw P. (2018). Economics of Groundnut Crop in Raigarh District of Chhattisgarh State. *Int. J. Pure Appl. Biosci*., **6(2)**, 2320-7051.

Nandini, B., Basavaraja G.T., Mahalingam A. and Gowda M.V.C. (2019). Stability analysis for yield and its attributes in groundnut (*Arachis hypogaea* L.). *Elect. J. Plant Breed.*, **10(3)**, 1216–1223.

Patel, K.P. and Chandrakar M.R. (2022). Cost and return analysis of groundnut (*Arachis hypogaea*) cultivation in Raigarh District of Chhattisgarh. *Agricult. Sci. Digest*, **43(2)**, 196–200.

Rani, P., Vanisree S., Babu D.R., Venkateswarlu O. and Reddy V.P. (2018). Stability analysis in groundnut (*Arachis hypogaea* L.) using Eberhart and Russell model. *Int. J. Chem. Stud.*, **6(1)**, 1069–1073.

Shukla, S., Das A. and Dixit G.P. (2004). Stability analysis in groundnut (*Arachis hypogaea* L.) using Eberhart and Russell model. *Indian J. Gene. Plant Breed.*, **64(3)**, 235–240.

Suneetha, N., Reddy B.V.R., Rani P.L. and Vanisree S. (2016). Stability performance of Spanish bunch groundnut genotypes across environments. *Elect. J. Plant Breed.*, **7(2)**, 308–314.

Suthar, B., Pundir R.S., Gundaniya H. and Mishra K. (2024). Growth and instability analysis of area, production and yield of groundnut in selected states of India. *Environ. Conser. J.*, **25(1)**, 192–198.

Upadhyaya, H.D., Nigam S.N. and Sharma B. (2002). Stability analysis for pod yield and resource-use efficiency in groundnut. *Indian J. Gene. Plant Breed.*, **62(1)**, 25–28.