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Stability Analysis in Peanut (*Arachis hypogaea* L.) for Kernel Yield and its Contributing Traits

Suresh Gali, D. L. Reddy, A. Prasanna Rajesh, K. John, P. Sudhakar, V. Srinivasa Rao

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ABSTRACT

A field experiment was carried out with twenty six lines across seasons namely, summer 2020, *kharif* 2020 and *rabi* 2020-21 to study G × E interaction. The ANOVA of Eberhart and Russell model revealed significant differences among genotypes for all traits which indicates the presence of substantial variation in the per se performance of all the 26 peanut genotypes. Significant differences due to environments were observed for all traits except for shelling percentage and palmitic acid content indicating that the environments in which the genotypes evaluated were quite variable. The environments + (genotypes × environments) interaction was also observed to be significant for all traits studied except for 100 seed weight and palmitic acid content indicating considerable interactions of genotypes with environments (seasons). Significant genotype × environment interactions were recorded for all traits except for days to 50% flowering, days to maturity and 100 seed weight which inferred that differential performance of peanut genotypes under diverse environments. Plant height, number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant, pod yield per plant, kernel yield per plant, sound mature kernel per cent and 100 seed weight were recorded higher positive values of environmental index in *kharif* season indicating that *kharif* season was congenial for most of the yield contributing traits than summer and *rabi* seasons. Genotypes viz., ICGV 171334, ICGV 98432 and ICGV 99105 were observed to be stable across the seasons for high pod and kernel yield in conjunction with confectionary traits like 100 seed weight, protein content and oleic linoleic acid ratio.

Keywords Peanut, Stability analysis, Kernel yield.

Suresh Gali[1]*, D. L. Reddy[2], A. Prasanna Rajesh[3], K. John[4], P. Sudhakar[5] , V. Srinivasa Rao[6]

[1] Department of Genetics and Plant Breeding, Agricultural College ANGRAU, Bapatla, Andhra Pradesh 522101, India

[2]Professor and Uni. Head (Rtd)
Department of Genetics and Plant Breeding, S.V. Agricultural College ANGRAU, Tirupati, Andhra Pradesh 517502, India

[3]Principal Scientist (Oilseeds)
Department of Genetics and Plant Breeding, Agricultural Research Station, ANGRAU, Kadiri, Andhra Pradesh 518583, India

[4]Principal Scientist (Plant Breeding)
Department of Genetics and Plant Breeding, RARS, ANGRAU, Tirupati, Andhra Pradesh 517502, India

[5]Professor
Department of Crop Physiology, ANGRAU, Lam, Guntur, Andhra Pradesh 522034, India

[6]Professor and Uni. Head,
Department of Statistics and Computer Applications
Agricultural College, ANGRAU, Bapatla, Andhra Pradesh 522101, India
Email: sureshgali1993@gmail.com
*Corresponding author

INTRODUCTION

The peanut (*Arachis hypogaea* L.) is an annual legume crop planted for its superior edible oil and easily absorbed protein found in its seeds. India ranks second in peanut production (67.27 lakh tonnes) after China (175 lakh tones) with an export of 6,41,125 tonnes of confectionery types (FAO 2019). India is the largest exporter to Asean countries with the worth of 1836.12 crores in 2009-10, 4398.01 crores in 2014-15 and it has decreased to 2535.06 crores in 2018-19 (Palanisingh *et al*. 2020). The fluctuating trend of peanut exports in India is mainly due to instability of yields due to environmental effect, cultivation practices and lack of large seeded genotypes. The performance of a genotype is determined by three factors: Genotypic effect, environmental effect and their interactions. The adaptability and stability of a variety over diverse environments is usually tested by its degree of interaction with different growing environments (Okuno *et al.* 1971). Failure of genotypes to respond consistently to variable environmental conditions is attributed to genotype by environment interaction (GEI). Stability analysis is helpful in the identification of stable genotypes and in predicting the responses of various genotypes over altering environments. It is generally approved that the more stable genotypes fine-tune their phenotypic responses to provide some measure of consistency in spite of environmental fluctuations. The main goal of the breeders is to get environmentally buffered and high yielding genotypes, and for that evaluation of different genotypes in an array of environments may be the most practical approach. Knowledge of GEI is advantageous to increase efficiency of breeding program and selection of best genotypes.

MATERIALS AND METHODS

The present investigation comprised of 26 peanut genotypes, obtained from ICRISAT (Hyderabad), ARS (Kadiri) and RARS (Tirupati). Three rows of each genotype, each measuring 3 meters in length, were sowed in the experiment in three replications using a randomized block design, with a spacing of 45 cm between the rows and 15 cm between the plants for the period of across seasons namely, summer 2020, *kharif* 2020 and *rabi* 2020-21 at Agricultural College Farm, Bapatla, Guntur, AP. The experimental plot at growing season was done with recommended agronomic practices to raise healthy crop. The data were recorded from five randomly selected plants in each of the genotype per replication for yield traits. Days to 50% flowering and days to maturity were recorded on plot basis. Quality traits like oil content, protein content and fatty acids were estimated by using NIRS (model XDS RCA-FOSS Analytical AB, ICRISAT). Total soluble sugars content and free amino acids were estimated by adopting the method suggested by Sadasivam and Manickam (1992). The recorded data was statistically analyzed in INDOSTAT 9.2 Version. The standard method of Eberhart and Russell model (1966) of stability analysis was utilized in the present investigation.

RESULTS AND DISCUSSION

The results revealed significant differences among genotypes for all traits which indicates the presence of substantial variation in the per se performance of all the 26 peanut genotypes and results are in conformity with reports made by El-aziz and Ibrahim (2018) and Hasankhan *et al.* (2018). Significant differences due to environments were observed for all traits except for shelling percentage and palmitic acid content indicating that the environments in which the genotypes evaluated were quite variable and results are in agreement with results noticed earlier by Minde *et al.* (2017) and Hasankhan *et al.* (2018). The environments + (genotypes × environments) interaction was also observed to be significant for all traits studied except for 100 seed weight and palmitic acid content indicating considerable interactions of genotypes with environments (seasons) and also the distinct nature of environments and genotype × environment interactions in phenotypic expression and similar results were reported earlier by Mekontchou *et al.* (2006) for 100 seed weight and Reddy *et al.* (2016) for all traits. Significant genotype × environment interactions (GEI) recorded for all traits except for days to 50% flowering, days to maturity and 100 seed weight inferred that differential performance of peanut genotypes under diverse environments and the findings are in match with earlier results registered by Minde *et al.* (2017) and Hasankhan *et al.* (2018) for days to 50% flowering; Hariprasanna *et al.* (2008) and Hasankhan *et al.* (2018) for 100 seed weight. Mean sum of squares due to environment (linear) were found to be significant for all traits studied in the current investigation except for palmitic acid content indicating that the environment plays a major role in

Table 1. Stability analysis of variance (ANOVA) for kernel yield component traits and quality traits over seasons in large seeded peanut.

Sl. No.	Source	DF	DFF	DM	PH	NPP	NSPP	NMPP
1	Genotype	25	7.049**	6.703*	31.746**	0.936**	3.591**	9.400**
2	Environment	2	56.427**	75.425**	774.659**	9.027**	28.370**	66.962**
3	Envi+(G×E)	52	4.781*	6.469*	35.531**	0.840**	2.343**	7.091**
4	Envi (linear)	1	112.855**	150.849**	1549.318**	18.055**	56.741**	133.924**
5	G×E (linear)	25	2.748	3.948	9.146**	0.710*	1.915**	7.998**
6	Pooled deviation	26	2.578**	3.339**	2.68	0.302	0.662**	1.341*
7	Pooled error	150	0.47	1.241	2.105	0.207	0.253	0.815

Table 1. Continued.

Sl. No.	Source	DF	NIMPP	PYP	KYP	SMKP	SHP
1	Genotype	25	10.511**	23.764**	12.156**	77.730**	46.719**
2	Environment	2	23.199**	37.636**	20.385*	7.12**	21.287
3	Envi+(G×E)	52	6.431*	13.050*	5.834*	3.114**	13.662*
4	Envi (linear)	1	46.399**	75.271**	40.770**	14.248**	42.573*
5	G×E (linear)	25	8.063*	16.785*	7.308*	5.051**	20.390**
6	Pooled deviation	26	3.325**	7.066	3.073**	0.824	6.081
7	Pooled error	150	0.430	5.550	1.526	1.407	13.578

Table 1. Continued.

Sl. No.	Source	DF	HSW	OC	PC	FAA	TSS
1	Genotype	25	731.499**	10.645**	9.152**	0.223**	10.972**
2	Environment	2	13.189*	5.782**	16.572**	0.0139**	11.781**
3	Envi+(G×E)	52	1.661	0.943*	2.887*	0.004**	1.552**
4	Envi (linear)	1	26.377**	11.564**	33.146**	0.027**	23.561**
5	G×E (linear)	25	1.084	0.990*	3.061*	0.005**	2.141**
6	Pooled deviation	26	1.265	0.490	1.555	0.002*	0.140**
7	Pooled error	150	2.922	0.456	1.393	0.001	0.030

Table 1. Continued.

Sl. No.	Source	DF	PAC	SAC	OAC	LAC	OLR
1	Genotype	25	1.133**	0.378**	17.006**	22.388**	0.215**
2	Environment	2	0.103	0.156**	13.567**	7.570**	0.131**
3	Envi+(G×E)	52	0.092	0.054**	3.261**	6.426**	0.053**
4	Envi (linear)	1	0.205	0.312**	27.134**	15.141**	0.263**
5	G×E (linear)	25	0.125*	0.086**	4.757**	12.696**	0.098**
6	Pooled deviation	26	0.055	0.014	0.905**	0.063	0.002**
7	Pooled error	150	0.108	0.012	0.265	0.088	0.001

* - Significantly different at 5 % probability level ** - Significantly different at 1 % probability level.

DFF- Days to 50 % flowering
DM- Days to maturity
PH- Plant height
NPP- Number of primary branches per plant
NSPP- Number of secondary branches per plant
NMPP- Number of mature pods per plant
NIMPP- Number of immature pods per plant
PYP- Pod yield per plant (g)
KYP- Kernel yield per plant (g)
MKP- Sound mature kernel per cent
SHP- Shelling percentage
HSW- 100 seed weight (g)
OC- Oil content (%)
PC- Protein content (%)
FAA- Free amino acids (μg g^{-1})
TSS- Total soluble sugars (%)
PAC- Palmitic acid content (%)
SAC- Stearic acid content (%)
OAC- Oleic acid content (%)
LAC- Linoleic acid content (%)
OLR- Oleic linoleic acid ratio

Table 2. Estimation of environmental index values for kernel yield and quality traits in large seeded peanut.

Sl. No.	Character	Environment (seasons)		
		Summer 2020 (E I)	*kharif* 2020 (E II)	*rabi* 2020-21 (E III)
1	Days to 50 % flowering	-1.128	-0.538	1.667
2	Days to maturity	1.419	-1.889	0.470
3	Plant height (cm)	-2.526	6.264	-3.738
4	Number of primary branches per plant	0.139	0.507	-0.646
5	Number of secondary branches per plant	-0.815	1.178	-0.363
6	Number of mature pods per plant	-1.788	1.315	0.473
7	Number of immature pods per plant	-0.664	-0.417	1.081
8	Pod yield per plant (g)	0.489	0.882	-1.371
9	Kernel yield per plant (g)	0.393	0.621	-1.014
10	Sound mature kernel per cent	0.092	0.472	-0.563
11	Shelling percentage	-0.027	-0.891	0.918
12	100 seed weight (g)	-0.757	0.657	0.100
13	Oil content (%)	-0.521	0.122	0.398
14	Protein content (%)	0.628	0.271	-0.898
15	Free aminoacids (μg g^{-1})	0.026	-0.009	-0.018
16	Total soluble sugars (%)	0.412	-0.777	0.364
17	Palmitic acid content (%)	-0.72	0.031	0.041
18	Stearic acid content (%)	0.085	-0.066	-0.020
19	Oleic acid content (%)	0.581	0.228	-0.809
20	Linoleic acid content (%)	-0.326	-0.297	0.623
21	Oleic linoleic acid ratio	0.048	0.034	-0.082

stability of genotypes over seasons or locations and similar results were made by Reddy *et al*. (2016), Minde *et al.* (2017) and Hasankhan *et al.* (2018). Pooled deviation which is unpredictable portion of G × E interaction was significant for days to 50 % flowering, days to maturity, number of secondary branches per plant, number of mature pods per plant, number of immature pods per plant, kernel yield per plant, free amino acids, total soluble sugars, oleic acid content and oleic linoleic acid ratio when their mean sum of squares were tested against pooled error and these findings are in agreement with Hariprasanna *et al.* (2008) for kernel yield per plant and Hasankhan *et al*. (2018) for number of mature pods per plant (Table 1).

Environmental index (I) revealed the fittingness of an environment for different traits of peanut. Based on the positive values of environmental index, for 26 large seeded peanut genotypes (Table 2), summer season was found to be most favorable season for days to maturity, protein content, free amino acids, total soluble sugars, stearic acid content, oleic acid content and oleic linoleic acid ratio indicating that most of the qualitative traits may be in favor of higher temperatures and these findings were supported by Shruti (2020) for protein content. Plant height, number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant, pod yield per plant, kernel yield per plant, sound mature kernel per cent and 100 seed weight were recorded higher positive values of environmental index in *kharif* season which showed that all the yield attributing traits favor high rainfall with moderate temperatures and these results are supported by Shruti (2020) for plant height, number of mature pods per plant, pod yield per plant and kernel yield per plant and Reddy *et al.* (2016) for pod yield per plant, sound mature kernel per cent, kernel yield per plant and 100 seed weight. In rabi traits viz., days to 50 % flowering, number of immature pods per plant, shelling percentage, oil content, palmitic acid content and linoleic acid content were exhibited higher positive values of environmental index which implied that these traits adopt to low temperatures and these conclusions are supported by Sreekala and Kumar (2009) and Shruti (2020) for days to 50% flowering and Shruti (2020) for shelling percentage and oil content.

Table 3. Distribution of stable large seeded peanut genotypes ($S^2d_i = 0$) with high mean on the basis of regression coefficient (bi).

Parameter	DFF	DM	PH	NPP	NSPP	NMPP	NIMPP	PYP	KYP	SMKP
Stable genotypes identified ($S^2d_i = 0$)	18	21	22	24	23	22	13	24	23	26
Unstable genotypes ($S^2d_i \neq 0$) with high mean	2	4	1	2	3	3	7	2	3	
Genotypes with high mean and stability ($S^2d_i = 0$)	11	10	8	11	6	13	6	10	10	16
Genotypes with high mean, stability ($S^2d_i = 0$) and wide adaptability ($b_i = 1$)	10	10	7	10	6	13	6	9	9	15
Genotypes with high mean, stability ($S^2d_i = 0$) and suitable for favourable environment ($b_i > 1$)			1	1						1
Genotypes with high mean, stability ($S^2d_i = 0$) and suitable for poor environment ($b_i = 1$)	1							1	1	

Table 3. Continued.

Parameter	SHP	HSW	OC	PC	FAA	TSS	PAC	SAC	OAC	LAC	OLR
Stable genotypes identified ($S^2d_i = 0$)	26	26	24	25	22	24	26	25	21	24	19
Unstable genotypes ($S^2d_i \neq 0$) with high mean			2		2	1				1	3
Genotypes with high mean and stability ($S^2d_i = 0$)	12	13	11	12	6	8	13	11	11	14	11
Genotypes with high mean, stability ($S^2d_i = 0$) and wide adaptability ($b_i = 1$)	9	13	11	12	6	3	12	11	9	4	9
Genotypes with high mean, stability ($S^2d_i = 0$) and suitable for favourable environment ($b_i > 1$)	1					2	1			7	
Genotypes with high mean, stability ($S^2d_i = 0$) and suitable for poor environment (bi = 1)	2					3			2	4	2

DFF- Days to 50 % flowering	PYP- Pod yield per plant (g)	FAA- Free amino acids (µg g-1)
DM- Days to maturity	KYP- Kernel yield per plant (g)	TSS- Total soluble sugars (%)
PH- Plant height	SMKP- Sound mature kernel percent	PAC- Palmitic acid content (%)
NPP- Number of primary branches per plant	SHP- Shelling percentage	SAC- Stearic acid content (%)
NSPP- Number of secondary branches per plant	HSW- 100 seed weight (g)	OAC- Oleic acid content (%)
NMPP- Number of mature pods per plant	OC- Oil content (%)	LAC- Linoleic acid content (%)
NIMPP- Number of immature pods per plant	PC- Protein content (%)	OLR- Oleic linoleic acid ratio

The number of stable genotypes identified for various traits studied along with the number of stable genotypes with high or desirable mean and their categorization as widely adaptable or adaptable for only favorable or poor environments, based on the regression coefficient, bi value, is presented in Table 3. The results revealed maximum number of stable genotypes (26) for sound mature kernel per cent, shelling percentage, 100 seed weight, and palmitic acid content and minimum for number of immature pods per plant (13). Further, genotypes with value greater than the general mean and non significant deviation from regression were higher for sound mature kernel per cent (16) and minimum for number of secondary branches per plant (6), number of immature pods per plant (6) and free amino acids (6). The study

Table 4. Details of promising and stable large seeded peanut genotypes identified for cultivation across seasons.

SL. No.	Genotype	Mean	bi	S^2di	Stable traits observed for the genotypes
For days to 50 % flowering and days to maturity					
1	ICGV 93058	28.222 119.222	-0.388 -0.379	-1.160 1.778	Number of primary branches per plant, 100 seed weight, oil content, total soluble sugars, oleic acid content and oleic linoleic acid ratio
2	ICGV 11310	28.111 119.444	0.851 2.307	0.241 -0.057	Sound mature kernel percent, shelling percentage, 100 seed weight and protein content
3	ICGV 171376	26.222 119.222	1.713 1.873	-0.246 0.694	Number of mature pods per plant, pod yield per plant, sound mature kernel per cent and protein content
For pod yield per plant					
1	ICGV 99105	23.054	1.542	-5.182	Days to maturity, number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant, kernel yield per plant, sound mature kernel percent, 100 seed weight, protein content, total soluble sugars, palmitic acid content, stearic acid content, linoleic acid content and oleic linoleic acid ratio
2	ICGV 98432	22.451	6.577	4.183	Plant height, number of primary branches per plant, number of secondary branches per plant, kernel yield per plant, shelling percentage, 100 seed weight, protein content, palmitic acid content and oleic linoleic acid ratio
3	ICGV 00441	24.494	3.891	1.912	Number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant, kernel yield per plant, sound mature kernel percent, shelling percentage, palmitic acid content and oleic acid content
For kernel yield per plant					
1	ICGV 171334	14.522	2.105	-0.443	Days to 50 % flowering, number of mature pods per plant, shelling percentage, 100 seed weight, protein content, oleic acid content and oleic linoleic acid ratio
2	ICGV 12218	14.856	1.768	-1.478	Days to 50 % flowering, days to maturity, plant height, number of primary branches per plant, number of mature pods per plant, sound mature kernel per cent, shelling percentage, palmitic acid content, oleic acid content and oleic linoleic acid ratio
3	ICGV 15366	15.164	3.102	-0.104	Days to 50 % flowering, number of mature pods per plant, sound mature kernel percent, shelling percentage, 100 seed weight, free amino acids, stearic acid content and palmitic acid content

also revealed greater number of genotypes with wider adaptability across seasons for various traits studied, compared to genotypes adapted to specific season (poor / favorable). Nine genotypes were noticed to possess high pod yield per plant in addition to wide adaptability across the seasons studied. Similarly, nine genotypes were noticed to possess high kernel yield per plant in addition to wide adaptability across the seasons studied. For oil content, 11 genotypes had recorded low oil content and wide adaptability across the seasons studied. For protein content, 12 genotypes had showed high protein content and wide adaptability across the seasons studied. Among all (26), nine genotypes had high oleic linoleic acid ratio, stable and widely adaptable to all environments (seasons).

The genotypes identified in the current investigation ICGV 93058, ICG 11310 and ICGV 171376 were identified as promising genotypes for both days to 50 % flowering and days to maturity; ICGV 99105, ICGV 98432 and ICGV 00441 for pod yield per plant and ICGV 171334, ICGV 12218 and ICGV 15366 for kernel yield per plant (Table 4) and suitable for cultivation across the seasons. Further, the genotypes ICGV 93058, ICGV 11310, ICGV 171376, ICGV 99105, ICGV 98432, ICGV 00441, ICGV 171334, ICGV 12218 and ICGV 15366 had recorded stability for majority of yield traits and quality traits along with superior kernel yield mean performance and hence, may also be utilized in future breeding program aimed at stability (Table 4).

CONCLUSION

From results of ANOVA of Eberhart and Russell model revealed that significant differences due to genotypes, environments, environments + (genotypes × environments) interaction, genotype × environment interactions (GEI) and environment (linear) for most of the traits indicating that the environments play a major role in phenotypic expression of genotype for specific trait in respective environment. Genotypes viz., ICGV 171334, ICGV 98432 and ICGV 99105 had recorded stable performance across the seasons for confectionery traits like 100 seed weight, protein content and oleic linoleic acid ratio along with high pod and kernel yield.

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