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Phenotypic Stability of Kernel and Protein Yield in Groundnut (*Arachis hypogaea* L.)

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ABSTRACT

The present investigation was undertaken in groundnut (*Arachis hypogaea* L.) to identify the stable genotypes for characters that contribute to kernel yield. The study was conducted during 2005 and 2006 at the S. V. Agricultural College Farm, Tirupati, Andhra Pradesh, India using 22 groundnut prerelease and released genotypes. Kharif Inceptisols (Environment I), Rabi Inceptisols (Environment II) and Summer Alfisols (Environment III) served as the three contrasting environments for experimentation. Among the three environments, the genotypes ICG-7332, ICG-3245, ICG-7633, ICG-11386, ICG-2184, JL-24, TPT-4 and K-134 were highly responsive to Rabi Inceptisols in terms of yield and yield-contributing characters. Hence, they may be included as parents for developing a high-protein and kernel-yielding variety suitable for cultivation in all the environments studied.

Keywords: deviation from regression, genotype × environment interaction, environmental index, regression coefficient

INTRODUCTION

Groundnut is commonly called the poor man's nut. It is one of the principle economic crops of India. The productivity of groundnut crop in India is very low i.e., 893.9 kg/ha as against the world average of 1424 kg/ha (FAO 2005). Hence, there is a need to increase the productivity potential of this crop as the cultivated area under the crop cannot be increased owing to its location and soil specific adaptability. Apart from yield, quality has assumed importance in the changed world trade scenario. Groundnut protein is emerging as a valuable addition to the oil seed protein market. Yield and quality, however, are not unitary characters but they are the result of interaction of number of factors inherent both in the plant as well as in the environment in which plant grows.

Among the various causes put forth for low yields in India, lack of varieties with stability under different climatic situations and under different soil conditions are considered to be the foremost. It is also important to identify stable genotypes not only for kernel yield but also for protein and quality traits. Studies on phenotypic stability of morphological characters are many but those on quality characters are limited. It is therefore, necessary to evaluate the degree of response of the genotypes or stability to varying environmental situations so that genotypes with high stability can be identified and used for breeding varieties with high kernel and protein yield apart from other quality traits.

MATERIALS AND METHODS

The present investigation comprised of three experiments. These were conducted at the S. V. Agricultural College Farm, Tirupati, Acharya N. G. Ranga Agricultural University, which is located at an altitude of 182.9 masl, 79° E long. and 13° N lat. and situated in the Southern Agro-climatic zone of Andhra Pradesh, India. The first and second experiments were conducted in a wet land block (Inceptisols) of S. V. Agricultural College Farm, Tirupati during Kharif and Rabi seasons of 2005. The third experiment was conducted in dry land lock (Alfisols) of the S. V. Agricultural College Farm, Tirupati in the summer season of 2006. They served as three different seasons for experimentation. The soil pH for Alfisols was around 6.9 and for Inceptisols around 7.8.

The experimental material consisted of 22 genotypes provided by ICRISAT (International Crop Research Institute for Semi Arid Tropics), Patencheru; NRCG (National Research Center for Groundnut), Junagadh; BARC (Baba Atomic Research Center), Trombay; RARS (Regional Agricultural Research Station), Tirupati and ARS (Agricultural Research Station), Kadiri (details in **Table 1**). Each experiment was conducted in a Randomized Block Design, with three replications. Each genotype was grown in three rows, with a row length of 4.5 m and with a spacing of 45 × 15 cm. The experimental plots during the three seasons were supplied with fertilizers at 30 kg N, 40 kg P_2O_5 and 50 kg K_2O/ha. Gypsum at 500 kg/ha was applied at the time of first bloom.

Data were recorded for 14 characters viz., days to 50%

Table 1 Salient features of 22 groundnut genotypes.

Genotype	Botanical group	Source
ICG-50	Valencia	India
K-134	Spanish	India
ICG-3542	Spanish	India
ICG-3245	Spanish	Zaire
M-13	Virginia	India
TG-42	Spanish	Trombay
TPT-4	Spanish	India
ICGV-86564	Virginia	India
ICG-7633	Valencia	USA
ICG-1326	Spanish	India
ICG-2184	Spanish	India
ICG-7332	Virginia	Brazil
ICG-3509	Valencia	Argentina
ICG-7749	Virginia	Nigeria
JL-24	Spanish	India
BAU-13	Spanish	India
TCGS-29	Spanish	India
ICGV-89214	Virginia	India
ICGV-86584	Virginia	India
ICG-11386	Spanish	India
ICG-10352	Spanish	Zimbabwe
ICG-1416	Spanish	Sudan

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flowering, total biomass/plant, test weight, harvest index (HI), shelling percentage, SMK (sound mature kernel) percentage, methionine content, total sucrose content, protein content, tryptophan content, oil percentage, protein yield/plant, pod yield/plant and kernel yield/plant. Data on the 14 characters were subjected to statistical analysis.

For estimating the stability of genotypes, stability analysis was done as per the model of Eberhart and Russel (1966) as follows:

$$Y_{ij} = m + b_i I_j + \delta_{ij} \; (I = 1, 2, \ldots t \text{ and } j = 1, 2, \ldots\ldots, s)$$

where,

Y_{ij} = Mean of i^{th} genotype in j^{th} environment

m = Mean of all the genotypes over all the environments

b_i = The regression coefficient of the i^{th} genotype on the environmental index which measures the response of this genotype to varying environments

I_j = The environmental index is identified as the deviation of the mean of all the genotypes at a given location from overall mean. This is estimated as:

$$I_j = (\Sigma_i Y_{ij}/t) - (\Sigma_i \Sigma_j Y_{ij}/ts) \text{ with } \Sigma_j I_j = 0 \text{ and}$$

where

δ_{ij} = The deviation from the regression of i^{th} genotype at j^{th} environment

t = Number of genotypes

s = Number of environments

A genotype with unit regression coefficient (b_i=1) and the deviation not significantly differing from zero (S^2di=0) was assumed to be a stable genotype with unit response.

RESULTS AND DISCUSSION

Genotype × environment interactions are of major importance to plant breeders in developing new crop varieties, which perform consistently over a wide range of environments. Hence there is a need to identify a stable variety. The data collected on 14 characters on 22 genotypes over different environments were subjected to stability analysis. The mean sum of squares due to genotype × environment interactions for characters like total biomass/plant, HI, shelling %, SMK percentage, protein content, protein yield/plant, pod yield/plant and kernel yield/plant were significant (**Table 3**) i.e., the failure of a genotype to express the same phenotypic performance when grown under different environments is the reflection of a genotype × environment interaction (Verma and Gill 1975). Hence, stability analysis for these eight characters was carried out according to the Eberhart and Russel (1966) method.

Environmental indices (**Table 2**) for characters like shelling % (3.957) and protein content (0.168) were high in Environment (E) I. Similarly higher values were recorded for characters like total biomass/plant (29.561), HI (0.106), SMK % (11.811), pod yield/plant (26.861) and kernel yield/plant (13.091) in E II. In contrast, the environmental index values were low in E III for all the characters except for protein yield/plant (1.139). Based on these studies, among the three environments Rabi Inceptisols (E II) was very congenial for the genotypes to express their characters. It was followed by Kharif Inceptisols (E I); Summer Alfisols (E III) were unfavourable.

Table 2 Environmental Indices of groundnut genotypes in three different environments.

Environmental index	E_1	E_2	E_3
Days to 50% flowering	– 0.111	0.04	0.071
Total biomass/plant (g)	– 3.848	29.561	– 25.712
Test weight (g)	– 0.472	0.897	– 0.424
Harvest index	– 0.089	0.106	– 0.017
Shelling %	3.957	– 3.662	– 0.295
SMK %	– 6.342	11.811	– 5.469
Methionine content (g 100/g)	– 0.010	0.017	– 0.008
Total sucrose content (g 100/g)	– 0.474	0.415	0.059
Protein content (g 100/g)	0.168	0.145	– 0.313
Tryptophan content (g 100/g)	0.048	– 0.074	0.026
Oil %	– 0.037	– 0.252	0.289
Protein yield/plant (g)	0.933	– 2.072	1.139
Pod yield/plant	– 14.729	26.861	– 12.132
Kernel yield/plant	– 6.486	13.091	– 6.533

The results of stability analysis of variance are presented in **Table 4**. All the sources of variation were tested against pooled error for total biomass/plant, HI and protein content. As pooled deviation was non-significant against pooled error, the sources of variation for shelling percentage, SMK percentage, protein yield/plant, pod yield/plant and kernel yield/plant were tested against pooled deviation. The mean sums of squares of all eight characters for all the sources of variation were highly significant.

The stability parameters namely mean, regression coefficient and deviation from regression for all the eight characters were computed and are presented in the **Table 5**.

Total biomass/plant

The genotypes performed better in E II and expressed higher values for total biomass/plant. Stability analysis of variance (**Table 4**) indicated that the pooled deviation was significant against pooled error, which indicated that the genotypes differed in their regression on the environmental index and also the importance of the non-linear component. The significance of the non-linear component appeared to be due to the presence of genetic variability among the material tested (Perkins and Jinks 1968; Paroda *et al.* 1973; Henry and Daulay 1983). As both the linear and non-linear genotype × environment were found to be significant it was not possible to predict the performance of genotypes (Henry and Daulay 1983; Kandaswami *et al.* 1985; Dushyantha Kumar and Shadakshari 2006).

Ten out of 22 genotypes recorded a mean performance higher than the average. The highest mean performance was

Table 3 Pooled analysis of variance for yield and quality characters over three environments in groundnut.

Source of variation	Df	Days to 50% flowering	Total biomass per plant	Test weight	HI	Shelling %	SMK %	Methionine content
Environments	2	0.633	51142.00**	39.781*	0.64**	962.34**	6918.328**	0.015
Genotypes	21	73.998**	17059.81**	814.49**	0.04**	228.79**	266.678**	0.096**
Genotype × Environment	42	0.872	6164.79**	17.1	0.04**	12051**	224.808**	0.004
Error	132	0.819	782.48	12.557	0.004	32.26	27.255	0.009

Table 3 (Cont.)

Source of variation	Df	Total sucrose content	Protein content	Tryptophan content	Oil %	Protein yield/plant	Pod yield/plant	Kernel yield/plant
Environments	2	13.229*	4.859	0.281**	4.969	213.318**	35826.406**	8390.336**
Genotypes	21	16.420**	43.168**	0.224**	44.818**	16.090**	972.574**	296.424**
Genotype × Environment	42	1.995	22.884**	0.015	2.141	13.301**	883.254**	244.033**
Error	132	3.451	4.12	0.009	3.52	6.046	80.999	30.587

* Significant at 5%; ** Significant at 1%

Table 4 Stability Analysis of Variance for yield contributing characters in 22 genotypes of groundnut.

Source of variation	Degrees of freedom	Total biomass/plant	Harvest index	Shelling %	SMK %
Genotypes	21	5686.603**	0.014**	76.264++	88.891++
Environment + (genotype × environment)	44	2736.401**	0.024**	52.925++	176.353++
Environment (Linear)	1	34094.449**	0.428**	641.582++	4612.219++
Genotype x environment (Linear)	21	1919.200**	0.022**	67.575++	146.169++
Pooled deviation	22	2091.047**	0.007**	12.183	3.534
Pooled error	132	260.826	0.001	10.752	9.085

Table 4 (Cont.)

Source of variation	Degrees of freedom	Protein content	Protein yield per plant	Pod yield per plant	Kernel yield per plant
Genotypes	21	14.389**	5.363++	324.191++	98.808++
Environment + (genotype × environment)	44	7.991**	7.464++	823.860++	204.773++
Environment (Linear)	1	3.241**	142.212++	23884.268++	5593.557++
Genotype × environment (Linear)	21	5.240**	7.519++	582.489++	159.487++
Pooled deviation	22	10.834**	1.287	6.058	3.056
Pooled error	132	1.373	2.015	27	10.196

** Significant at 1% against pooled error; ++ Significant at 1% against pooled deviation

recorded by ICG-7749 (288.89) and TG-42 (280.56). Genotypes K-134, ICG-3542, ICG-3245, ICG-7633, ICG-1326, ICG-2184, ICG-3509, BAU-13, ICGV-89214, ICGV-86584, ICG-11386 and ICG-1416 showed a regression coefficient equal to unity. Genotypes like TPT-4, ICG-2184, ICG-73332, ICG-3509, TCGS-29, ICGV-86584 and ICG-10352 registered least deviation from regression ($S^2di=0$).

Harvest index

E II was highly favourable for the expression of HI. Pooled deviation was significant against pooled error (Joshi *et al*. 2003). As the genotype × environment (linear) relationship was significant when tested against the pooled error, it indicated less contribution by the non-linear regression. Since genotype mean squares were significant, the genotypes differed significantly in their response to environments, indicating the genetic control of response to environments and the independent nature of genetic systems in controlling stability parameters. Yadava *et al*. (1980) also found the importance of the independent nature of genetic systems in controlling stability parameters in groundnut. As the magnitude of the linear component of the genotype × environment interaction was higher than the non-linear component, it was possible to predict the performance of a genotype across environments (Yadava and Kumar 1978).

For HI the highest mean performance was exhibited by ICG-7633 (0.43) followed by ICG-11386 (0.40) whereas mean performance above the average was recorded by eight genotypes. All the genotypes had a regression coefficient equal to unity except for ICG-50, ICG-3245, ICG-1326, ICG-7749, BAU-13, ICGV-89214, ICG-10352, TG-42, M-13, ICGV-86564, ICG-7633 and ICG-7332. The least deviation from the regression coefficient was shown by genotypes ICG-3542, ICG-3245, TG-42, ICG-7633, ICG-1326, ICG-7749, BAU-13, TCGS-29, ICGV-89214, ICGV-86584 and ICG-11386.

Shelling percentage

The genotypes for shelling percentage showed the best performance in E I. The non-linear component of genotype × environment interaction was non-significant against pooled error and the magnitude of genotype × environment (linear) was higher indicating the possibility to predict the performance of genotypes across the environments (Senapathi *et al*. 2004). As genotype mean squares were significant, the genotypes differed significantly in their response to environments indicating genetic control of response to environments and independent nature of genetic systems in controlling stability parameters (Yadava *et al*. 1980).

The highest mean performance for shelling percentage was recorded by ICG-1326 (69.87) whereas mean performance above the average was shown by seven genotypes. Except the genotypes K-134, TG-42, TPT-4, ICg-7633, ICG-1326, ICG-7332, ICG-11386, ICG-10352, ICGV-86564, ICG-7749 and ICG-1416 all other genotypes showed regression coefficient equal to one. All the genotypes except ICG-3245, TPT-4, ICGV-86564, ICG-7749 and ICG-1416 showed the least deviation from regression.

SMK percentage

E II was the most favourable for the expression of SMK percentage. Non-linear component of genotype × environment was non-significant and genotype × environment (linear) was of higher magnitude. Hence, it was possible to predict the performance of genotypes across the environments. The genotypes differed significantly in their response to environments indicating genetic control of response to environments and independent nature of genetic systems in controlling stability parameters (Yadava *et al*. 1980) as evidenced by significant genotype mean squares.

The genotype ICG-11386 (33.05) exhibited the highest mean performance for SMK percentage. Ten genotypes recorded higher mean values than the average. The genotypes K-134, TPT-4, ICG-2184, ICGV-86584 and ICG-11386 showed regression coefficient equal to unity. All genotypes did not show deviation from regression except the genotype, ICGV-89214.

Protein content

Protein content expressed well in E I. Both the linear and non-linear components of genotype × environment interactions were significant indicating the genotypes differed in their regression on the environmental index and also the importance of non-linear component in determining the interaction of genotypes with the environment (Bhatade and Bhale 1983). As such the performance of the genotypes was difficult to predict (Kumaresan and Nadarajan 2005). The genotype mean squares were significant (**Table 4**) indicating that the genotypes differed significantly in their response to environments.

The genotype JL-24 (31.94) exhibited high mean performance for protein content and it was followed by ICG-3542 (30.28). Ten other genotypes excelled above the average. The genotypes K-134, ICG-7749 and TCGS-29 showed regression coefficient equal to one. Most of the genotypes showed significant deviation from regression except TG-42, K-134, ICG-1326, ICG-7749 and TCGS-29 (**Table 5**).

Table 5 Stability parameters of characters over three environments for 22 groundnut genotypes.

Genotypes	Total biomass per plant			Harvest Index			Shelling %		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
ICG 50	153.89	2.58	2516.07**	0.22	0.03	0.03**	54.58	0.93	– 10.00
K-134	156.11	0.85	2890.53**	0.36	1.53	0.01**	57.68	2.34*	– 2.19
ICG 3542	164.44	1.34	1681.14**	0.38	1.59	0.00	56.8	1.48	– 7.22
ICG 3245	163.33	0.98	1651.09**	0.34	1.93	– 0.00	62.38	0.89	12.44**
M-13	148.33	0.34	1933.35**	**0.39**	3.04**	0.00**	57.2	1.15	– 10.18
TG-42	**280.56**	0.01	8040.95**	0.21	– 0.81**	– 0.00	56.87	0.34	– 10.25
TPT-4	208.33	0.13	– 71.40	0.31	1.46	0.01**	52.21	2.16	15.48**
ICGV-86564	**259.33**	3.41*	1394.67**	0.27	– 0.98**	0.01**	**64.07**	– 2.92**	25.93**
ICG 7633	156.11	0.8	1816.79**	**0.43**	2.48*	– 0.00	58.87	1.73	– 8.76
ICG 1326	176.89	1.09	287.47**	0.29	1.91	0.00	**69.87**	2.07	3.81
ICG 2184	200	0.58	– 73.88	0.23	1.22	0.00*	62.32	0.63	– 10.40
ICG 7332	220.56	2.87	30.39	0.31	– 0.41*	0.04**	56.54	0.06	– 6.85
ICG 3509	217.78	1.36	– 131.88	0.27	1.47	0.00**	49.57	0.98	– 8.63
ICG 7749	**288.89**	2.88	5424.42**	0.17	0.11	– 0.00	**64.97**	– 2.68**	36.03**
JL 24	247.22	– 1.15	5838.11**	0.27	1.41	0.01**	59.42	1.35	– 8.33
BAU 13	251.67	1.29	1979.18**	0.22	– 0.21	– 0.00	55.01	0.62	– 3.80
TCGS 29	212.22	– 0.06	118.59	0.25	0.55	0.00	54.59	1.28	– 8.96
ICGV 89214	246.67	0.77	852.97**	0.27	0.06	– 0.00	54.59	1.01	– 4.93
ICGV 86584	193.33	0.69	– 128.73	0.32	1.09	0.00	56.24	1.54	– 10.65
ICG 11386	193.89	0.72	189.99**	**0.4**	1.45	– 0.00	51.48	1.91	– 5.31
ICG 10352	187.78	– 0.38	– 233.66	0.3	2.04	0.01**	57.28	0.71	– 0.36
ICG 1416	153.89	0.88	4258.72**	0.27	1.07	0.01**	49.29	4.41**	54.63**
Average mean	203.69			0.29			57.35		

Table 5 (Cont.)

Genotypes	SMK %			Protein content			Protein yield per plant		
	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
ICG 50	10.14	26.28	4.87	26.28	4.87	26.28	4.87	0.93	– 10.00
K-134	23.63	26.84	0.88	26.84	0.88	26.84	0.88	2.34*	– 2.19
ICG 3542	28.75	**30.28**	– 8.25	**30.28**	– 8.25	**30.28**	– 8.25	1.48	– 7.22
ICG 3245	27.77	28.03	– 4.53	28.03	– 4.53	28.03	– 4.53	0.89	12.44**
M-13	26.19	28.41	– 7.04	28.41	– 7.04	28.41	– 7.04	1.15	– 10.18
TG-42	27.28	28.68	1.59	28.68	1.59	28.68	1.59	0.34	– 10.25
TPT-4	27.38	27.49	2.72	27.49	2.72	27.49	2.72	2.16	15.48**
ICGV-86564	**32.42**	27.76	– 2.58	27.76	– 2.58	27.76	– 2.58	– 2.92**	25.93**
ICG 7633	29.55	29.26	– 7.88	29.26	– 7.88	29.26	– 7.88	1.73	– 8.76
ICG 1326	29.09	28.16	1.52	28.16	1.52	28.16	1.52	2.07	3.81
ICG 2184	22.82	22.61	7.81	22.61	7.81	22.61	7.81	0.63	– 10.40
ICG 7332	27.25	28.72	8.84	28.72	8.84	28.72	8.84	0.06	– 6.85
ICG 3509	25.33	28.77	8.38	28.77	8.38	28.77	8.38	0.98	– 8.63
ICG 7749	27.38	28.91	1.31	28.91	1.31	28.91	1.31	– 2.68**	36.03**
JL 24	**32.22**	**31.94**	– 7.13	**31.94**	– 7.13	**31.94**	– 7.13	1.35	– 8.33
BAU 13	24.6	25.63	– 2.29	25.63	– 2.29	25.63	– 2.29	0.62	– 3.80
TCGS 29	23.14	25.9	0.82	25.9	0.82	25.9	0.82	1.28	– 8.96
ICGV 89214	29.35	22.59	– 5.00	22.59	– 5.00	22.59	– 5.00	1.01	– 4.93
ICGV 86584	27.96	26.92	6.53	26.92	6.53	26.92	6.53	1.54	– 10.65
ICG 11386	**33.05**	26.01	8.53	26.01	8.53	26.01	8.53	1.91	– 5.31
ICG 10352	26.63	**29.32**	2.4	**29.32**	2.4	**29.32**	2.4	0.71	– 0.36
ICG 1416	13.36	27.99	10.46	27.99	10.46	27.99	10.46	4.41**	54.63**
Average mean	26.14	27.56		27.56		27.56			

Table 5 (Cont.)

Genotypes	Pod yield per plant			Kernel yield per plant		
	Mean	b_i	S^2di	Mean	b_i	S^2di
ICG 50	26.57	0.28**	– 26.99	14.44	0.24**	– 9.78
K-134	52.73	1.07	– 25.76	28.99	0.77*	– 10.15
ICG 3542	61.45	1.47**	– 17.47	34.02	1.43**	– 2.99
ICG 3245	53.74	1.43**	– 25.79	33.32	1.80**	– 8.66
M-13	55.89	1.83**	– 24.28	30.82	1.88**	– 10.15
TG-42	56.5	– 0.51**	– 20.86	32.29	– 0.63**	– 10.19
TPT-4	**66.48**	1.50**	– 26.89	32.62	0.93	– 10.11
ICGV-86564	61.08	– 0.36**	– 26.39	**38.48**	0.11**	– 7.54
ICG 7633	64.62	1.77**	– 18.97	36.68	1.77**	– 6.39
ICG 1326	53.52	1.80**	– 26.48	35.08	2.05**	– 9.12
ICG 2184	46.83	1.30**	– 26.79	28.57	1.55**	– 7.61
ICG 7332	58.3	0.12**	– 15.85	32.68	0.21**	– 8.18
ICG 3509	62.18	1.98**	– 20.97	30.07	1.84**	– 9.48
ICG 7749	48.23	0.91	– 26.71	32.92	1.82**	– 8.13
JL 24	**65.3**	1.63**	– 16.80	**37.29**	1.63**	– 1.80
BAU 13	55.37	0.26**	– 25.96	31.31	0.39**	– 9.36
TCGS 29	52.79	0.58**	– 26.98	28.32	0.45**	– 8.03

Table 5 (Cont.)

Genotypes	Pod yield per plant			Kernel yield per plant		
	Mean	b_i	S^2di	Mean	b_i	S^2di
ICGV 89214	65.12	0.29**	4.8	35.21	0.08**	1.28
ICGV 86584	61.91	1.12	– 10.64	33.91	0.96	0.68
ICG 11386	**76.86**	1.22**	–16.03	**38.41**	0.76*	– 9.08
ICG 10352	55.77	1.63**	– 12.54	31.56	1.85**	– 4.33
ICG 1416	38.51	0.67**	– 26.38	18.49	0.10**	– 7.95
Average mean	56.35			31.61		

* Significant at 5%; ** Significant at 1%

Table 6 Performance of genotypes in the environments.

Characters	Stable environment	Favourable environment	Poor environment
Harvest index	ICG-3542, ICGV-86584, ICG-11386	ICG-3245, ICG-7633	–
Shelling %	ICG-2184, JL-24	K-134, ICG-7633, ICG-1326	–
SMK %	TPT-4, ICGV-86584, ICG-11386	ICG-3542, ICG-3245, M-13, ICG-7633, ICG-1326, ICG-7749, JL-24, ICG-10352	TG-42, ICGV-86564, ICG-7332
Protein content	ICG-7749	TG-42, ICG-1326	–
Protein yield/plant	K-134	ICG-3542, TPT-4, ICG-7633	BAU-13, TCGS-29, ICGV-89214, ICG-1416
Pod yield/plant	ICG-3542, TPT-4, ICGV-86584, ICG-11386	ICG-7633, ICG-3509, JL-24	TG-42, ICGV-86564, ICG-7332, ICGV-89214
Kernel yield/plant	ICG-3542, TPT-4, ICGV-86584, ICG-11386	ICG-3245, ICG-7633, ICG-1326, ICG-7749, JL-24	TG-42, ICGV-86564, ICG-7332, ICGV-89214

Protein yield/plant

The environments, in which protein yield/plant was estimated, showed varying effects for the expression of the character as indicated by significant environment (linear). However, the performance of the genotypes for the character in E III was superior. Pooled deviation was non-significant against pooled error and the linear component of genotype × environment interaction was higher than the non-linear component. This indicated the possibility of prediction of performance of genotypes across the environments (Senapathi *et al*. 2004). As genotypes mean squares were significant against pooled deviation, the genotypes differed significantly in their response to environments indicating genetic control of response to environments and independent nature of genetic systems in controlling stability parameters (Yadava *et al*. 1980).

The highest mean performance for protein yield/plant was recorded by ICGV-89214 (7.92) followed by TCGS-29 (97.34) and BAU-13 (6.96). Mean performance above the average was shown by six genotypes. The genotypes that showed regression coefficient equal to one were K-134, ICGV-86564 and ICG-2184. The genotypes showed least deviation from regression with an exception to TG-42, ICGV-86564 and ICG-7332.

Pod yield/plant

Genotypes for pod yield/plant showed better performance in E II. Genotypic mean squares were significant which indicated that the genotypes differed significantly in their response to environments indicating genetic control of response to environments. The magnitude of genotype × environment (linear) component was higher than non-linear component. Hence, prediction of performance of genotypes across the environments was possible (Yadava and Kumar 1978; Senapathi *et al*. 2004). Prakash Kumar *et al*. (1984) reported low magnitude of non-linear component of genotype x environment interaction for pod yield.

From **Table 5**, it was concluded that the highest mean performance for pod yield per plant was recorded by the genotype ICG-11386 (76.86). Ten other genotypes showed high mean values above the average. The genotypes which showed regression coefficient equal to unity were K-134, ICG-3542, ICG-3245, TPT-4, ICG-2184, TCGS-29, ICGV-86584, ICG-1416, ICG-7749 and ICGV-89214. All genotypes showed non-significant deviation from regression.

Kernel yield/plant

Genotypes for the character kernel yield/plant showed the best performance in E II. The environments were contrasting and caused differential response on genotypes for producing kernel yield. Genotype mean squares were found to be significant indicated that the genotypes differed significantly in their response to environments and independent nature of genetic systems in controlling stability parameters (Bentur *et al*. 2004). The magnitude of linear component was higher than non-linear component indicating the possibility of prediction of performance of genotypes across the environments (Sinha and Sinha 1993; Kumaresan and Nadarajan 2005; Dushyantha Kumar and Shadakshari 2006).

The genotypes ICGV-86564 (38.48) followed by ICG-11386 (38.41) registered higher mean performance for kernel yield/plant. Eleven other genotypes showed high mean values which were above the average. The genotypes like K-134, ICG-3542, ICG-11386, TPT-4 and ICGV-86584 showed regression coefficient equal to unity. Regarding deviation from regression all genotypes showed the least deviation from regression.

From the studies presented in **Table 6**, the genotypes TG-42, ICGV-86564 and ICG-7332 were suitable to poor environment for SMK percentage, pod yield and kernel yields. TCGS-29 was suitable to bad environment for total biomass/plant and protein yield/plant. For characters like protein yield/plant, pod yield/plant and kernel yield/plant, ICGV-89214 was found to be suitable to unfavourable environments.

The genotype ICG-7633 was suitable for favourable environments for characters like HI, shelling percentage, SMK percentage, protein yield/plant, pod yield/plant and kernel yield/plant. For characters like shelling percentage, SMK percentage, protein content and kernel yield ICG-1326 was observed to be suitable for good environment. JL-24 for SMK percentage, pod yield and kernel yields and ICG-3245 for characters like HI, SMK percentage and kernel yield were suitable to the best environment. The environment Rabi Inceptisols (E II) was highly responsive for the genotypes, ICG-7332, ICG-3245, ICG-7633, ICG-3509, ICG-3542, ICG-1326, ICG-7749 and JL-24. A high protein and kernel yielding variety suitable to intensive input agriculture may be developed by including these genotypes in a breeding programme.

SUMMARY

The genotypes, ICG-11386 and ICGV-86584 exhibited stable performance for four characters viz., HI, SMK percentage, pod yield and kernel yield/plant. ICG-3542 expressed stability for HI, pod yield and kernel yield/plant whereas TPT-4 was stable for SMK percentage, pod yield and kernel yield/plant. For shelling percentage two genotypes, ICG-2184 and JL-24 were found to be stable. The genotype K-134 was stable for protein yield/plant. For total biomass/ plant ICG-3509 was considered as stable whereas genotype ICG-7749 was stable for protein content. The genotypes (ICG-3509, ICG-3542, ICGV-86584, ICG-11386, ICG-2184, JL-24, TPT-4 and K-134) that exhibited stability performance across the environments for these characters may be incorporated in the breeding programme for developing a general adoptable variety with high protein and kernel yield.

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