Genotype x environment interaction and stability analysis for yield and its components in soybean [(*Glycine max* L.) Merrill]

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Abstract

The present investigation was carried out to study stability performance over eight environments for seed yield and its components in 40 genetically diverse genotypes (37 indigenous + 3 exotic) of soybean using a randomized complete block design. The partitioning of (environment + genotype x environment) mean squares showed that environments (linear) differed significantly and were quite diverse with regards to their effects on the performance of genotypes for seed yield and majority of yield components. Stable genotypes were identified for wider environments and specific environments with high per se performance (over general mean) for seed yield per plant. The investigation revealed that the genotype MACS-47 was desirable and stable across the environments. Other genotypes PK-308, Bisra Soya, Indra Soya-9, Alankar, and IS-22 were found to be suitable for favorable situations, while genotypes Pusa-16, Pusa-40, MACS-2, MACS-450, and JS-325 were responsible to poor environments for seed yield.

Key words: G X E interaction, stability analysis, seed yield, soybean

Introduction

Soybean [(Glycine max. L.) Merrill] designated as the "miracle bean" has established its potential as an industrially vital and viable oil seed crop in many areas of India. The theoretical limit of soybean productivity was suggested to be 8 tonnes/ha based on the amount of light energy available in the field (Specht, et al., 1999). However, world productivity during 2007 was 2.81 tonnes/ha. Even this level has not been achieved in tropical countries like India, where low productivity is mainly due to the short growing periods available in subtropical conditions, limited varietal stability, and narrow genetic base of soybean cultivars (Singh and Hymowitz, 2001). Crop yield fluctuates due to suitability of varieties to different growing seasons or conditions. A specific genotype does not always exhibit the same phenotypic characteristics under all environments and different genotypes respond differently to a specific environment.

Gene expression is subject to modification by the environment; therefore, genotypic expression of the phenotype is environmentally dependent (Kang, 1998). The development of new cultivars involves breeding of cultivars with desired characteristics such as high economic yield, tolerance or resistance to biotic and abiotic stresses, traits that add value to the product, and the stability of these traits in target environments. Inconsistent genotypic responses to environmental factors such as temperature, soil moisture, soil type, or fertility level from location to location and year to year are a function of genotype x environment (GE) interactions. Genotype x environment interactions have been defined as the failure of genotypes to achieve the same relative performance in different environments (Baker, 1988). Identification of yield-contributing traits and knowledge of GE interactions and yield stability are important for breeding new cultivars with improved adaptation to the environmental constraints prevailing in the target environments. Currently, there is a need for increasing soybean genetic diversity in India so that new cultivars suitable for manufacturing soyfoods can be developed. To avoid genetic vulnerability associated with the narrowing of the genetic base of any crop, the GE interactions of the germplasm are important (Kang, 1998). Therefore, in the present investigation an attempt has been made to evaluate soybean genotypes for yield and its component characters under different environments to identify genotypes with suitable performance in variable environments.

Materials and Methods

The experiment was conducted with 40 indigenous and exotic genotypes of soybean during spring and rainy season of 2005 and 2006 at experimental Farm of Kisan (PG) College, Simbhaoli (28^0N, 51^0E) UP, India. The soil of the experimental field was sandy loam with low available nitrogen, potassium, and medium available phosphorus with neutral pH. In each of the eight environments (2 seasons x 2 sowing dates x 2 years) each genotype was planted in a randomized complete block design with three replications, in plots of 4 rows, each 3m long and spaced 30 x 15 cm. between rows and plants, respectively. At planting, fertilizers were applied at rates equivalent to 20:60:40 kg/ha NPK, respectively.

The crop was raised in irrigated conditions. Observations were recorded on ten randomly selected plants from each genotype in all the three replications for days to 50% flowering, days to maturity, plant height (cm), pods per plant, biological yield per plant (g), seed yield per plant (g), 100-seed weight (g), and harvest index (%). The data were statistically analyzed and the genotypes were assessed for their stability of performance across environments following the method described by Eberhart and Russell (1966).

Results and Discussion

The stability analysis (Table 1) indicated the presence of significant G x E interactions for all the characters studied. Higher magnitude of mean squares due to environments indicates considerable differences between environments for all the characters and that these characters were greatly influenced by environments; thereby suggesting the large differences between environments along with greater part of genotypic response was a linear function of environments i.e., the environments created by season, sowing dates over years was justified and had linear effects. These results are in agreement with the earlier findings of Dillion *et al.* (2009) and Jai Dev *et al* (2009).

The partitioning of mean squares (environments + genotype x environments) (Table 1) showed that environments (linear) differed significantly and were quite diverse with respect to their effects on the performance of genotypes for seed yield and majority of yield components. Further, the higher magnitude of mean squares due to environments (linear) as compared to genotype x environment (linear) exhibited that linear response of environments accounted for the major part of total variation for majority of the characters studied. Dillion *et al*. (2009) also reported similar results and stated that the mean differences between seasonal effects and the effect of seasons on seed yield and its attributes in soybean were quite real in nature. The significance of mean squares due to genotype x environment (linear) component against pooled deviation for days to maturity, plant height, pods per plant, and harvest index suggested that the genotypes were diverse for their regression response to change with the environmental fluctuations. Similarly, the significant mean squares due to pooled deviation observed for all the characters studied suggested that the deviation from linear regression also contributed substantially towards the differences in stability of genotypes. Thus, both linear (predictable) and non-linear (un-predictable) components significantly contributed to genotype x environment interactions observed for seed yield per plant and yield component characters. This suggested that predictable as well as un-predictable components were involved in the differential response of stability. Similar results were reported by Ramana and Satyanarayana (2005) and Dillion et al. (2009).

The mean values for yield and its components, regression coefficient (bi), and deviation from regression (S^2di) for 40 genotypes over eight environments are presented in Table 2. The characters like days to 50% flowering, days to maturity, pods per plant, and harvest index showed higher number of predictable genotypes, while plant height, biological yield, seed yield, and 100-seed weight had lower numbers of predictable genotypes. Further, the stable genotypes identified for wider environments and specific (either favorable or poor) environments with high per se performance (over general mean) for seed yield per plant are presented in Table 2. It is evident from the table that one genotype viz., MACS-47, was found stable and widely adapted with high mean performance (12.87 g), average responsiveness (bi ~ 1), and non significant deviation from regression line (S^2di ~ 0). This variety for seed yield per plant was also stable for other yield contributing traits (Table 3) and could be utilized for all the environments to achieve higher and stable seed yield increment. On the other hand, five genotypes, PK-308, Bisra Soya, Indra Soya-9, Alankar, and IS-22, were found suitable for favourable situations with predictable performance as they passed high seed yield per plant along with below average responsiveness (bi > 1) and non-significant deviation from regression line. Four other genotypes, viz., Pusa-16, Pusa-40, MACS-450, and IS-335, were found suitable for poor environments with predictable performance as they exhibited high *per se* performance for seed yield per plant along with above average responsiveness (bi < 1) and non-significant deviation from regression line. Other high yielding genotypes, Pusa-20 and MACS-58, having regression coefficients less than one, were found suitable under poor environments with un-predictable performance due to significant deviation from regression the line. The stability of genotypes for seed yield and its components in soybean has also been reported by Singh *et al* (2001), Rao *et al.* (2002), Alghamdi (2004), Ramana Satyanarayana (2005), Sudaric *et al.* (2006), Pan *et al* (2007), Dillion *et al*. (2009), Gurmu (2009), and Jai Dev *et al*. (2009).

Conclusion

In conclusion, this study showed the presence of and the type of GE interactions among the 12 soybean genotypes and their yield components. High-yielding genotypes with broad adaptation and some genotypes with specific adaptation were identified. Further investigations on GE interactions at important crop growth stages for yield components and biochemical profiles would help to develop strategies that integrate traditional plant breeding with modern molecular marker-based selection for tailoring soybean cultivars for high yield and target environments. Among the cultivars used in this study, MACS-47, showed high mean seed yield and was found to be stable over the environments and therefore; could be used in the breeding programme for the development of high yielding stable genotypes over environments for future use.

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Table 1: Analysis of variance for stability for yield and yield components in soybean

Source of Variation	df	Mean sum of squares for different characters							
		Days to 50% flowering	Days to maturity	Plant height (cm)	Pods per plant	Biological yield per plant (g)	Seed yield per plant (g)	100-seed weight (g)	Harvest index
Genotypes (G)	39	107.36**+	103.57**+	599.65**+	151.79**+	124.77**+	24.54**+	14.22**+	7.57**+
Environment (E)	7	197.60**+	772.14**+	1031.01**+	1672.91**+	507.85**+	118.83**+	11.56**+	148.05**+
G x E	273	4.93*	7.78*	10.07**	19.85**	9.17**	1.97**	0.24**	6.41**
Enviornment+(GxE)	280	40.27**+	50.43**+	30.23**+	61.18**+	21.64**+	4.90**+	0.52**+	9.95**+
E (linear)	1	1383.16**+	5404.85**+	7216.90**+	11710.15**+	3554.76**+	831.89**+	80.97**+	1036.08**+
G x E (linear)	39	4.45	15.09**+	15.15**+	38.20**+	13.41**	1.96**	0.21**	12.63**+
Pooled deviation	240	4.48*	6.39**	8.99**	16.37**	8.25**	1.93**	0.24**	5.24**
Pooled error	624	3.28	4.17	2.45	9.92	1.85	0.46	0.09	3.99

*, ** = significant against pooled error at 1% and 5% level, respectively;
+ = significant against pooled deviations at 5% level

Table 2: Stability parameters for eight characters in 40 genotypes of soybean

S.	Genotypes	Days to flowering			Days to maturity			Plant height			Pods / plant			Biological yield			Seed yield/plant			100-seed weight			Harvest index		
N		Mea	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
1.	PK-1347	39.75	1.3	6.36	97.88	1.25	1.84	31.88	1.19	4.44	21.37	1.13	2.86	14.17	0.57	0.04	6.63	0.58	0.23	10.84	0.67	0.09	46.88	2.04	3.08
2.	JS-7015	34.83	0.9	2.89	103.29	0.75	10.43	36.54	1.10	0.92	21.48	1.10	3.29	14.48	0.41	2.59	6.56	0.47	0.86	12.94	0.93	0.45	45.12	0.83	4.43
3.	Lee	39.29	1.3	5.92	105.12	0.70	1.46	32.96	1.12	1.91	19.97	1.10	2.58	15.94	0.58	0.31	7.24	0.63	0.46	11.33	1.05	0.49	45.69	2.16	12.01
4.	MACS-124	35.42	0.5	1.20	101.12	1.51	7.89	41.04	1.13	8.80	19.96	0.60	3.96	16.45	0.73	4.25	7.48	0.79	1.20	13.09	1.29	0.48	45.45	2.70	3.60
5.	MACS-6120	39.42	1.2	4.98	97.88	1.27	20.22	40.33	0.87	8.21	22.81	1.08	8.04	16.26	0.54	0.11	7.41	0.63	0.50	11.63	1.08	0.410	45.50	1.61	10.29
6.	GS-2	37.38	1.0	0.73	102.12	0.78	4.84	43.21	0.92	2.83	30.25	1.43	24.69	22.71	1.16	1.52	9.70	0.99	0.36	11.26	0.76	0.29	42.38	1.28	0.29
7.	Pusa-16	36.12	0.8	1.95	99.12	1.48	17.30	32.08	0.06	1.83	27.42	1.10	82.79	25.48	1.08	5.38	11.27	0.86	0.23	12.89	1.41	0.36	44.53	0.56	9.34
8.	Pusa-24	38.75	1.1	13.4	97.62	1.39	12.63	30.21	0.83	1.69	22.15	1.40	17.12	17.51	0.77	0.65	7.94	0.78	0.76	12.66	1.60	0.62	45.25	1.81	11.53
9.	Pusa-37	35.46	0.9	3.92	92.08	0.88	1.38	33.92	0.91	14.56	30.91	1.33	3.20	21.67	1.26	6.09	9.85	1.20	1.70	12.37	1.29	0.27	45.27	1.24	3.21
10	Pusa-40	36.21	0.7	6.87	103.50	0.98	0.14	34.58	0.77	9.15	28.44	1.60	4.65	23.61	0.54	31.71	10.85	0.77	6.23	13.03	0.88	0.14	45.91	1.48	-0.91
11	Pusa-20	36.92	1.2	5.39	104.50	0.71	1.72	38.52	0.72	1.07	29.18	0.54	10.40	23.69	0.52	29.65	10.81	0.90	5.34	11.37	1.00	0.15	45.04	1.76	3.38
12	Pusa-22	44.29	1.7	2.13	105.88	1.02	2.72	43.96	1.10	9.34	30.97	1.58	12.09	21.95	0.58	23.95	10.13	0.63	5.45	9.81	0.55	0.29	46.00	0.96	-0.04
13	Sel. 295	39.79	1.1	2.49	103.62	1.02	14.63	52.96	1.33	1.00	25.90	0.67	4.70	22.97	0.65	15.10	9.80	0.42	1.31	13.77	2.00	0.14	13.16	0.13	12.53
14	MACS-58	35.96	0.9	1.47	100.50	0.59	-0.68	38.08	0.80	0.83	31.62	1.23	31.47	23.75	0.27	21.69	10.91	0.48	6.75	15.05	1.50	0.00	45.68	1.21	1.50
15	Bragg	41.96	0.8	8.03	101.50	0.55	5.46	43.33	1.10	12.07	34.45	1.08	15.33	23.68	1.44	2.50	10.53	1.37	0.79	12.71	1.03	0.10	44.39	0.99	-0.11
16	SL-96	35.21	1.1	0.24	105.00	0.99	0.49	42.08	1.00	2.12	35.24	0.78	2.89	22.63	1.37	4.42	10.30	1.34	1.10	13.48	1.35	0.27	45.51	1.44	2.07
17	SL-637	35.67	1.0	8.13	103.29	0.35	2.49	38.08	0.39	4.74	25.90	1.30	7.12	22.89	1.10	22.16	10.39	1.21	3.52	13.84	0.99	0.22	45.58	0.71	2.44
18	PK-416	36.92	1.5	7.06	108.12	0.72	-0.99	39.79	0.86	-0.50	37.13	0.40	1.38	23.42	0.88	10.71	10.61	1.03	2.77	12.26	1.05	0.55	44.79	0.92	-0.66
19	MACS-2	35.50	0.3	5.01	103.71	0.42	10.40	40.54	0.66	4.26	26.84	0.56	15.41	24.48	0.88	6.59	11.23	0.92	1.47	13.89	0.55	0.15	45.82	0.92	-0.48
20	Birsa soya	34.38	0.3	-0.27	105.50	0.35	-0.54	39.42	0.79	13.93	32.46	1.02	0.90	26.98	1.33	0.51	12.08	1.28	0.53	13.25	0.70	0.31	44.76	1.53	1.57
21	Punjab-1	44.50	0.8	2.98	106.12	0.50	5.84	51.67	1.23	21.95	30.93	0.79	16.61	23.70	1.34	10.87	10.47	1.28	2.04	14.54	0.15	0.30	44.18	1.21	1.66
22	PK-308	43.00	0.2	0.59	103.88	0.74	1.09	51.71	1.17	24.90	29.13	1.02	29.21	24.25	1.03	3.60	11.10	1.22	0.97	13.78	0.67	0.22	45.52	1.03	2.18
23	Gaurav	53.38	0.7	2.47	109.08	0.78	0.71	53.00	1.10	7.38	30.57	0.90	4.32	23.30	1.80	22.35	10.32	1.48	4.74	11.51	1.32	0.11	44.48	0.35	-0.69
24	Indra soya 9	37.58	0.8	-0.84	107.38	0.99	-0.48	35.33	1.08	5.77	27.30	1.60	1.87	27.31	1.52	9.50	12.24	1.46	1.79	14.42	10.07	0.33	44.83	1.47	6.45
25	JS 80-21	34.46	0.5	0.85	100.88	1.58	3.96	32.58	0.86	2.74	32.59	1.90	43.25	22.15	1.40	3.98	10.07	1.29	1.83	13.72	0.99	0.02	45.32	0.00	0.30
26	Ankur	35.50	0.6	13.1	100.00	1.27	1.55	42.83	0.78	0.96	30.90	0.87	6.45	22.53	1.37	13.40	10.04	1.90	4.58	12.54	1.20	0.05	44.40	-	0.80
27	PS-1029	36.71	0.9	2.23	98.88	0.85	-0.37	52.00	1.04	8.14	24.48	0.21	2.59	15.54	0.74	2.10	6.99	0.87	0.42	10.93	0.70	0.11	44.47	0.97	3.17
28	MACS-450	36.67	1.1	0.79	101.12	1.19	0.34	43.67	0.69	20.14	30.56	1.00	29.11	23.83	0.78	3.60	10.84	0.82	1.12	13.44	0.79	0.14	45.38	1.14	0.41
29	MACS-47	34.79	0.8	2.33	102.88	1.24	1.37	41.17	0.84	7.72	23.04	0.62	2.33	28.93	1.10	6.44	12.87	1.08	0.57	11.19	1.26	0.00	44.61	1.44	0.79
30	JS-335	39.39	1.5	8.05	103.33	1.07	1.85	74.75	1.40	11.32	26.28	0.60	27.75	27.38	1.19	4.60	12.18	0.94	0.85	14.72	0.75	0.27	44.70	0.86	1.09
31	Alankar	35.88	1.4	1.11	105.29	1.18	0.97	40.12	1.01	7.15	27.87	0.69	2.30	25.60	1.64	3.11	11.39	1.43	0.58	13.21	0.78	0.06	44.80	0.50	-0.63
32	PK-1042	34.33	0.4	-0.38	94.75	1.24	5.37	50.17	1.16	11.42	27.85	0.52	5.75	20.52	1.17	-0.28	9.11	1.19	0.77	13.52	1.04	0.10	44.09	0.50	18.37
33	VLS-21	36.67	1.3	9.40	101.12	1.23	6.38	46.21	1.29	4.69	32.77	1.40	28.22	16.17	0.86	-0.20	7.19	0.95	0.07	13.10	0.19	0.04	44.23	2.19	3.16
34	NARC-2	36.71	1.2	2.82	103.46	1.13	4.69	49.88	1.14	20.88	36.60	1.06	15.74	23.83	1.72	20.58	10.42	1.59	5.32	11.29	1.13	0.08	43.57	0.27	4.40
35	PK-472	37.58	1.3	2.35	103.88	1.17	2.47	38.96	0.71	7.36	33.09	1.22	12.25	22.56	0.77	2.73	10.36	1.02	0.56	10.56	0.79	0.47	45.96	0.90	1.13
36	JS-22	39.21	1.4	2.99	105.75	1.16	1.98	39.83	0.61	36.15	32.91	0.68	23.17	27.44	1.38	0.92	11.88	1.27	0.47	11.51	0.73	0.25	43.33	1.04	9.49
37	MACS-58	36.75	1.0	8.68	100.25	1.70	25.59	49.72	1.45	6.31	22.49	0.75	-1.04	15.09	0.60	5.36	6.50	0.67	0.53	9.83	0.90	0.01	43.20	-	2.61
38	Shilajeet	41.25	1.1	-0.05	102.12	1.20	3.08	45.21	0.51	10.92	27.80	1.25	1.60	19.47	0.89	1.34	8.42	0.97	0.83	11.12	0.83	0.04	43.03	0.10	4.83
39	ADT-1	34.00	1.0	-0.36	96.12	1.03	15.90	53.45	1.32	3.31	27.30	1.04	17.25	18.18	0.76	-0.06	8.03	0.77	0.18	12.34	1.19	0.08	44.12	0.32	0.89
40	MACS-21	39.54	0.5	4.25	104.25	1.03	3.88	57.02	1.93	4.88	28.69	1.04	-0.84	22.36	1.30	2.35	9.74	1.23	1.40	11.58	1.05	0.17	43.44	0.07	3.14
Population mean		37.94			102.29			43.07			28.34			21.86			9.74			12.50			44.75		
SE mean		0.83			0.95			1.13			1.52			1.08			0.52			0.18			0.86		

Table 3: Most widely adapted genotypes identified on the basis of seed yield per plant along with their stability for component traits in soybean

Genotypes	Seed yield per plant (g)	Stable yield attributes
Pusa-16	11.27	Days to flowering, plant height, biological yield/plant, seed yield/plant, 100-seed weight and harvest index
Pusa-40	10.85	All characters are stable except pods per plant
Pusa-20	10.81	Days to flowering, days to maturity, plant height, seed yield/plant, 100-seed weight and harvest index
MACS-58	10.91	All characters are stable except pods per plant and biological yield/plant
MACS-2	11.23	All characters are stable except days to maturity and pods per plant
Bisra soya	12.08	All characters are stable except days to maturity
PK-308	11.10	All characters are stable except days to flowering
Indra soya-9	12.24	All characters are stable
MACS-450	10.84	All characters are stable except pods per plant
MACS-47	12.87	All characters are stable
JS-335	12.18	All characters are stable
Alankar	11.39	All characters are stable biological yield/plant
JS-22	11.88	All characters are stable