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Yield Stability of some Soybean Genotypes across Diverse Environments

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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 (*Glycine max* L.) using a completely randomized block design. The partitioning of (environment + genotype × environment) mean squares showed that environments (linear) differed significantly and were quite diverse with regards to their effects on the performance of genotypes for fodder yield and the majority of yield components. 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 suitable for favorable environments while genotypes 'Pusa-16', 'Pusa-40', 'MACS-2', 'MACS-450' and 'JS-325' resulted in low seed yield in poor environments.

Keywords: G × E interaction, stability analysis, seed yield, soybean

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill], designated as the "miracle bean" (Kumar and Badiyala 2005), 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 t/ha based on the amount of light energy available in the field (Specht *et al.* 1999). However, world productivity during 2007 was 2.81 t/ha. Even this level has not been achieved in tropical countries like India, where low productivity is mainly due to a short growing period available in subtropical conditions, limited varietial stability and narrow genetic base of soybean cultivars (Singh and Hymowitz 2001). Crop yield fluctuates due to the 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.

Al-Assily *et al.* (2002) evaluated five soybean genotypes at different locations in two seasons. Three genotypes ('Giza 35', 'H2L12', 'Giza 111') had a high seed yield with a high degree of stability and could be grown over a wide range of environments.

Bakheit (2000) evaluated 15 soybean genotypes during three seasons under three sowing dates. Data confirmed the fact that high yielding genotypes were more likely to have lower stability and *vice versa*, i.e., low yielding genotypes tend to have high stability, in different environments. According to Gebeyehu and Assefa (2003) selection based on the highest yielding genotypes appeared less stable than the average of all lines, and selection solely for seed yield could result in several stable genotypes being discarding. In soybean crops, yield variation of cultivars across locations and years has been associated with changes in number of seeds per unit area (Egli 1998). Hence, the yield component is largely determined during a period that begins in flowering and extends through pod setting (Jiang and Egli 1995).

In fact, crop performance is strongly influenced by weather conditions. So, vulnerability of cultivars to environmental variation can be also viewed as a barrier to imposing yield potential. This is apparent when considering the fact that any breeding program, no matter how localized, must create lines which are adapted to a range of environments, at the very least those representing yearly weather fluctuations as well as those imposed by varying farmers practices (Weaver *et al.* 1991; Alghamdi 2004). If soybean yield potential is to meet future demands, targeting the underlying physiological causes of genotype × environment interactions for genetic improvement would be worthwhile investment.

Therefore, in the present investigation an attempt has been made to evaluate soybean genotypes for yield and their 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 (**Table 1**) during the spring and rainy seasons of 2005 and 2006 at the experimental Farm of Kisan (PG) College, Simbhaoli (28°N, 51°E) UP, India. The soil of the experimental field was sandy loam with low available nitrogen, potas-

Table 1 List of genotypes used in this study.

Indigenous genotypes	Exotic genotypes
'Pusa-2', 'Pusa-37', 'JS-80-81', 'PS-1029', 'PK-1045', 'PK-1347', 'JS-7105', 'MACS-124', 'Pusa-40', 'Pusa-20', 'SL-96', 'SL-637', 'PK-416', 'MACS-2', 'Birsa Soya', 'MACS-450', 'Alankar', 'PK-472', 'JS-22', 'Indra Soya-9', 'Sl-295', 'MACS-58', 'MACS-47', 'JS-335', 'MACS-61-20', 'GS-2', 'Pusa-16', 'Ankur', 'NARC-2', 'MACS-58', 'Shilajeet', 'ADT-1', 'MACS-2', 'Pusa-22', 'Punjab-1' , 'PK-308', 'Gourav'	'Lee', 'Bragg'

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sium and medium available phosphorus with neutral pH. In each of the eight environments (2 seasons × 2 sowing dates × 2 years) each genotype were planted in a completely randomized block design with three replications, in plots of 4 rows, each 3 m long and spaced 30 × 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 condition i.e., irrigation was provided at all the critical stages. Observations were recorded on 10 randomly selected plants from each genotype in all the three replications for days to 50% flowering, days to maturity, plant height (cm), number of pods/plant, biological yield/plant (g), seed yield/plant (g), 100-seed weight (g) and harvest index (%).

Statistical procedures

The combined analysis of variance was carried out according to Steel and Torrie (1984), to estimate the main effects of the different sources of variation and their interactions. The phenotypic stability analysis was conducted using the model suggested by Eberhart and Russell (1966) where genotypes were considered fixed, while years and sowing dates were random variables. The model provides two stability parameters; the first estimate was the linear regression coefficient (b) of genotype mean on the average of all genotypes in each environment; the second estimate was the mean squares of deviation from regression (S^2d) for each genotype. However, the ideal variety is one with a high mean performance, unit regression coefficient (b=l) and the deviation from regression approaching zero as possible as $S^2d = 0$.

Evaluation of crop adaptability to yielding capacity of particular years was conducted by linear regression analysis. This method uses the regression coefficient slope of each cultivar on the average yield of all cultivars evaluated in different environments (sowing dates) as a measure of cultivars yield responsiveness, and conceptually a reciprocal of yield stability, interpreted as: a) slope < l indicating higher stability, low responsiveness. b) Slope = 1, average stability, average responsiveness, c) Slope > l lower stability, higher responsiveness, adapted to high yielding environments.

The regression coefficient (Bi) and genotype mean yield were used together as a measure of adaptation according to Bilbro and Ray (1976). Genotype with b = l.0 was considered adapted for all environments; while genotype with b < 1.0 was considered adapted for low yielding environments and genotype with b > 1.0 was considered better adapted for high yielding environments, depending upon the genotype mean yield.

RESULTS AND DISCUSSION

The stability analysis (**Table 2**) indicated the presence of a significant G × E interaction for all the characters under study. 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 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) (**Table 3**).

The partitioning of mean squares (environments + genotype × environments) (**Table 2**) showed that environments (linear) differed significantly and were quite diverse with respect to their effects on the performance of genotypes for seed yield and the majority of yield components. Further, the higher magnitude of mean squares due to environments (linear) as compared to genotype × environment (linear) exhibited a linear response of environments that accounted for the major part of total variation for the majority of 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 × 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 under study suggested that the deviation from linear regression also contributed substantially towards the differences in stability of genotypes. Thus, both linear (predictable) and non-linear (unpredictable) components significantly contributed to genotype × 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) (**Table 3**).

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 4**. Characters like days to 50% flowering, days to maturity, number of pods/plant and harvest index showed higher number of predictable genotypes, while for plant height, biological yield, seed yield and 100-seed weight had fewer predictable genotypes. Further, the stable genotypes identified for wider environments and specific (either favourable or poor) environments with high *per se* performance (over general mean) for seed yield/plant are presented in **Table 4**. It is evident from the table that one genotype viz., 'MACS-47' was 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/plant was also stable for other yield-contributing traits (**Table 5**) 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 suitable for favourable situations with predictable performance as they possessed high seed yield/plant with below average responsiveness (bi > 1) and non-significant deviation from the regression line. Five other genotypes viz., 'Pusa-16', 'Pusa-40', 'MACS-450' and 'IS-335' were suitable for poor environments with predictable performance as they exhibited high *per se* performance for seed yield/plant with above-average responsiveness (bi < 1) and non-significant deviation from the regression line. Two other high-yielding genotypes, 'Pusa-20' and 'MACS-58', had regres-

Table 2 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/plant	Biological yield/plant (g)	Seed yield/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 × E	273	4.93*	7.78*	10.07**	19.85**	9.17**	1.97**	0.24**	6.41**
Environment + (G × E)	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 × 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 3 Comparison of findings of our study and that of other studies on soybean.

Present study	Previous studies
The analysis of variance revealed significant G × E interaction for all the characters under study. Partitioning of mean squares into its components 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. Among the cultivars used in this study, 'MACS-47' showed high mean seed yield and was found to be stable over the environments. Five other genotypes viz., 'Pusa-16', 'Pusa-40', 'MACS-450' and 'IS-335' were found suitable for poor environments. On the other hand, five genotypes viz., 'PK-308', 'Bisra Soya', 'Indra Soya-9', 'Alankar' and 'IS-22' were found suitable for favourable situations with predictable performance.	Mehla *et al.* (2000) observed significant difference for all traits in genotype, environment and genotype x environment (G×E) interaction. The linear and non-linear components significantly contributed to total G×E interaction for the expression of characters. The genotypes 'HK89-112', 'HK91-163', 'HK92-105', 'HK92-110', 'HK92-121', 'HK92-124', 'HK92-201', 'HK93-96' and 'GNG 827' were found stable and desirable for cooking time. 'HK92-105', 'HK92-110', 'HK92-121' and 'HK92-124' were promising genotypes for stability of almost all characters.
	Popalghat *et al.* (2001) found significant genotype × environment (G×E) interaction. Both linear and non-linear components of G×E interaction were significant, but linear components were predominant. Cultivars 'PhuleG-12' and 'Vishal' were suitable for wide cultivation on the basis of their stability parameters. Cultivar Vijay showed above average stability for seed quality, while 'Vishal' showed average stability for germination percentage and seedling vigour index.
	Sood *et al.* (2001) found three promising genotypes namely, 'HPG 27', 'HPG 33' and 'HPG 81' for seed yield. 'HPG 72', aside from being stable for pods per plant and 100-seed weight, also recorded significantly higher yield than the control while, genotype 'C 235', was suitable only for favourable environments.
	Rao *et al.* (2002) studied G×E interaction and yield stability of 12 soybean genotypes and reported that location × year and location x year x genotype interactions were significant.
	Muhammad *et al.* (2003) used interaction between the genotypes and environments (G x E interaction) as an index to determine the yield stability of genotypes under all the environments. The G×E interaction was highly significant and both linear as well as non-linear components were equally important for determining the yield stability. The genotypes '96051' and '98280' gave the highest grain yield but their high deviation from regression showed fluctuation in the performance under different environments. The genotypes 'C44', 'NCS950183' and '93009' exhibited above average yield but their low deviation from regression revealed more stable performance compared to others.
	Alghamdi (2004) reported significant G×E interaction for seed weight per plant (g) and seed yield (t ha^{-1}). The tested genotypes ranked differently across diverse environments. The response of seed weight and seed yield varied from genotype to genotype across different environmental conditions. This may offer raw material for improving soybean performance under the investigated conditions. 'Giza 111' and 'Clark' showed high mean values for yield and yield attributes while, 'Giza 82' and 'Giza 35' resulted low mean values over all environments and were poorly adapted.
	Akande *et al.* (2009) observed significant main effects of year, location, variety and their interactions on all the characters except pod length and number of seeds per pod. Among other traits number of days to50% flowering, number of seeds per pod and 100 seed weight showed average values of 45.29, 2.31 and 13.07, respectively.
	Dillion *et al*. (2009) reported that pooled analysis of variance exhibited significant genotypic differences in respect of all the characters except pod yield. The variation due to environments was also significant for days to maturity, plant height and 100 seed weight indicating their sensitivity to variation in environment. Contrary to this pod yield and its most important component trait, number of pods per plant appeared to be less affected by change in the environment. It is interesting to note that the pod yield and two of its important component traits, pods per plant and 100 seed weight showed a major proportion of non-linear G×E variation. However days to maturity, plant height showed significant linear component of G×E interaction. For 100-seed weight, pods per plant and pod yield, the deviation from regression values were significant for most of the genotypes.
	Gurmu *et al.* (2009) reported significant environment, genotype and GEI effects of which environment and GEI captured larger portion of the total sum of squares. Three genotypes with medium yield performance i.e., 'IPB-144-81(p)', 'Braxton' and 'Awassa-95' were identified as stable genotypes for grain yield. 'Haddee-1' and 'Braxton' genotypes with high oil content showed stable performance across the environments. 'Clarck-63k' showed high crude protein content with stable performance.
	Ram *et al.* (2009), while working with black gram reported that the analysis of variance for stability as well as environment was highly significant for all the characters except protein content. The G×E interaction was highly significant for seed yield/plant and water absorption (g/g seeds). The environment linear components were significant for all the characters.

sion coefficient < 1, were suitable under poor environments with un-predictable performance due to significant deviation from the regression line. The stability of seed yield and its components in soybean genotypes has also been reported by several groups: Mehla *et al.* (2000), Singh *et al.* (2001), Sood *et al.* (2001), Popalghat *et al.* (2001), Rao *et al.* (2002), Muhammad *et al.* (2003), Alghamdi (2004), Ramana Satyanarayana (2005), Sudaric *et al.* (2006), Pan *et al* (2007), Akande *et al.* (2009), Dillion *et al*. (2009), Gurmu (2009), Jai Dev *et al*. (2009) and Ram *et al.* (2009) (**Table 3**).

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 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 4 Stability parameters for eight characters in 40 genotypes of soybean.

	Genotypes	Days to flowering			Days to maturity			Plant height (cm)			No. pods /plant		
		Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
1.	PK-1347	39.75	1.30	6.36	97.88	1.25	1.84	31.88	1.19	4.44	21.37	1.13	2.86
2.	JS-7015	34.83	0.94	2.89	103.29	0.75	10.43	36.54	1.10	0.92	21.48	1.10	3.29
3.	Lee	39.29	1.30	5.92	105.12	0.70	1.46	32.96	1.12	1.91	19.97	1.10	2.58
4.	MACS-124	35.42	0.55	1.20	101.12	1.51	7.89	41.04	1.13	8.80	19.96	0.60	3.96
5.	MACS-6120	39.42	1.23	4.98	97.88	1.27	20.22	40.33	0.87	8.21	22.81	1.08	8.04
6.	GS-2	37.38	1.00	0.73	102.12	0.78	4.84	43.21	0.92	2.83	30.25	1.43	24.69
7.	Pusa-16	36.12	0.81	1.95	99.12	1.48	17.30	32.08	0.06	1.83	27.42	1.10	82.79
8.	Pusa-24	38.75	1.16	13.41	97.62	1.39	12.63	30.21	0.83	1.69	22.15	1.40	17.12
9.	Pusa-37	35.46	0.99	3.92	92.08	0.88	1.38	33.92	0.91	14.56	30.91	1.33	3.20
10.	Pusa-40	36.21	0.73	6.87	103.50	0.98	0.14	34.58	0.77	9.15	28.44	1.60	4.65
11.	Pusa-20	36.92	1.27	5.39	104.50	0.71	1.72	38.52	0.72	1.07	29.18	0.54	10.40
12.	Pusa-22	44.29	1.76	2.13	105.88	1.02	2.72	43.96	1.10	9.34	30.97	1.58	12.09
13.	Sel. 295	39.79	1.15	2.49	103.62	1.02	14.63	52.96	1.33	1.00	25.90	0.67	4.70
14.	MACS-58	35.96	0.94	1.47	100.50	0.59	-0.68	38.08	0.80	0.83	31.62	1.23	31.47
15.	Bragg	41.96	0.86	8.03	101.50	0.55	5.46	43.33	1.10	12.07	34.45	1.08	15.33
16.	SL-96	35.21	1.18	0.24	105.00	0.99	0.49	42.08	1.00	2.12	35.24	0.78	2.89
17.	SL-637	35.67	1.07	8.13	103.29	0.35	2.49	38.08	0.39	4.74	25.90	1.30	7.12
18.	PK-416	36.92	1.57	7.06	108.12	0.72	-0.99	39.79	0.86	-0.50	37.13	0.40	1.38
19.	MACS-2	35.50	0.31	5.01	103.71	0.42	10.40	40.54	0.66	4.26	26.84	0.56	15.41
20.	Birsa soya	34.38	0.38	-0.27	105.50	0.35	-0.54	39.42	0.79	13.93	32.46	1.02	0.90
21.	Punjab-1	44.50	0.83	2.98	106.12	0.50	5.84	51.67	1.23	21.95	30.93	0.79	16.61
22.	PK-308	43.00	0.23	0.59	103.88	0.74	1.09	51.71	1.17	24.90	29.13	1.02	29.21
23.	Gaurav	53.38	0.73	2.47	109.08	0.78	0.71	53.00	1.10	7.38	30.57	0.90	4.32
24.	Indra soya 9	37.58	0.84	-0.84	107.38	0.99	-0.48	35.33	1.08	5.77	27.30	1.60	1.87
25.	JS 80-21	34.46	0.54	0.85	100.88	1.58	3.96	32.58	0.86	2.74	32.59	1.90	43.25
26.	Ankur	35.50	0.69	13.16	100.00	1.27	1.55	42.83	0.78	0.96	30.90	0.87	6.45
27.	PS-1029	36.71	0.96	2.23	98.88	0.85	-0.37	52.00	1.04	8.14	24.48	0.21	2.59
28.	MACS-450	36.67	1.18	0.79	101.12	1.19	0.34	43.67	0.69	20.14	30.56	1.00	29.11
29.	MACS-47	34.79	0.84	2.33	102.88	1.24	1.37	41.17	0.84	7.72	23.04	0.62	2.33
30.	JS-335	39.39	1.51	8.05	103.33	1.07	1.85	74.75	1.40	11.32	26.28	0.60	27.75
31.	Alankar	35.88	1.42	1.11	105.29	1.18	0.97	40.12	1.01	7.15	27.87	0.69	2.30
32.	PK-1042	34.33	0.46	-0.38	94.75	1.24	5.37	50.17	1.16	11.42	27.85	0.52	5.75
33.	VLS-21	36.67	1.31	9.40	101.12	1.23	6.38	46.21	1.29	4.69	32.77	1.40	28.22
34.	NARC-2	36.71	1.23	2.82	103.46	1.13	4.69	49.88	1.14	20.88	36.60	1.06	15.74
35.	PK-472	37.58	1.30	2.35	103.88	1.17	2.47	38.96	0.71	7.36	33.09	1.22	12.25
36.	JS-22	39.21	1.49	2.99	105.75	1.16	1.98	39.83	0.61	36.15	32.91	0.68	23.17
37.	MACS-58	36.75	1.09	8.68	100.25	1.70	25.59	49.72	1.45	6.31	22.49	0.75	-1.04
38.	Shilajeet	41.25	1.19	-0.05	102.12	1.20	3.08	45.21	0.51	10.92	27.80	1.25	1.60
39.	ADT-1	34.00	1.07	-0.36	96.12	1.03	15.90	53.45	1.32	3.31	27.30	1.04	17.25
40.	MACS-21	39.54	0.58	4.25	104.25	1.03	3.88	57.02	1.93	4.88	28.69	1.04	-0.84
Population mean		37.94			102.29			43.07			28.34		
SE mean		0.83			0.95			1.13			1.52		

Table 4 (Cont.)

	Genotypes	Biological yield/plant			Seed yield/plant			100-seed weight			Harvest index		
		Mean	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**
1.	PK-1347	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	22.53	1.37	13.40	10.04	1.90	4.58	12.54	1.20	0.05	44.40	-0.50	0.80
27.	PS-1029	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	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	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	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	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	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	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	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	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	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	15.09	0.60	5.36	6.50	0.67	0.53	9.83	0.90	0.01	43.20	-0.20	2.61
38.	Shilajeet	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	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	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		21.86			9.74			12.50			44.75		
SE mean		1.08			0.52			0.18			0.86		

Table 5 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/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/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/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

* A limit for yield was fixed at 10.81 g/plant. Even though all other genotypes were stable for some characters their yield was below the range and are thus not represented in this table.

Sudaric A, Simic D, Vrataric M (2006) Characterization of genotype by environment interactions in soybean breeding programmes of southeast Europe. *Plant Breeding* **125 (2)**, 191-194

Weaver DB, Akridge RL, Thomas CA (1991) Growth habit, planting date and row-spacing effects on late planted soybean. *Journal of Crop Science* **31**, 805-810