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Stability of Soybean Genotypes in Central Plain Thailand

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ABSTRACT

Genotype x environment interactions and stability estimates for yield and yield components of soybean genotypes were carried out at Khao Hin Son Research Station, Chachoengsao Province during July 1996 and December 1996. The experiment consisted of ten soybean genotypes (IAC–2, VX4.16.12, CPAC 150–76, CPAC 359–76, CPAC 639–76, TGX1447–3D, Santa Maria, KUSL 20004, CM 60 and SJ 4) in twelve environments (3 plant densities, 200,000 300,000 and 400,000 pl/ha and 4 planting dates, July 8, 1996, August 30, 1996, October 22, 1996 and December 14, 1996). Despite variation between environments, most soybean genotypes did not give significant response. Significant mean squares of genotypes for yield and yield components indicated the existence of genetic variability in these characters. Although changes in yield and yield components of some genotypes were linear functions of the invironments, genotypes appeared to be the most important factor contributing to the variation in yield and yield components. Yield improvement through selection is, therefore, possible across these environments.

The results of stability estimates suggested that the top four genotypes with good adaptability were VX4.16.12 (1,372 kg/ha), Santa Maria (1,381 kg/ha), KUSL 20004 (1,732 kg/ha) and CM 60(1,468 kg/ha).

Key words : genotype x environment interaction, stability, soybean

INTRODUCTION

Soybean (*Glycine max* L.) is considered an economic field crop of Thailand. It has a potential to become an important crop on poor-grade paddy lands in the central plain of the country. Yearly imports of the raw and finished products of soybean are worth billions of baht (Srisomboon *et al*., 1988a, 1988b). One of the soybean production constraints is lack of genotypes suitable for growing in the central plain conditions of Thailand (Srisomboon *et al*., 1992). Therefore, availability of the soybean genotypes which are environmentally adapted is essential.

The soybean genotypes derived from Brazil, with long-juvenile genes, that are capable of extending their vegetative growth period for about ten days without altering their original maturity dates (Kiihl and Garcia, 1989) could be one source of the germplasms which may alleviate the problems of adaptability. In addition, some Thai genotypes were also used for comparison in the present study. Nevertheless, photoperiod sensitivity and light intensity are not the only factors affecting soybean yield. Soil conditions, weeds, pests and diseases should also be taken into consideration in soybean

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production (Kaewmeechai *et al*., 1992).

In the present experiment, a measure of relative performance of genotypes under different environments could provide information for the adaptability and stability patterns of the genotypes (Finlay and Wilkinson, 1963).

MATERIALS AND METHODS

The experiment was a $10 \times 3 \times 4$ factorial with three replicates arranged in a randomized complete block design. Each plot measured 2 m $\times$ 4 m containing four rows with 50 cm between rows and 20 cm between plants within each row.

The ten genotypes used were seven from Brazil controlled by the long-juvenile genes (IAC–2, CPAC 150–76, CPAC 359–76, CPAC 639–76, TGX 1447–3D, VX 4.16.12 and Santa Maria) and three from Thailand (KUSL 20004, CM 60 and SJ 4). The twelve environments were created with three plant densities (200,000, 300,000 and 400,000 pl/ha) and four planting dates (July 8, 1996, August 30, 1996, October 22, 1996 and December 14, 1996). Basal fertilizer was applied to all plots at the rates of 18.75, 56.25 and 37.50 kg/ha of N, P_2O_5 and K_2O, respectively. The plots were kept free from weeds by hand-weedings. Pests and diseases were kept under control as necessary. Sprinkler irrigation was applied during the dry periods.

The following parameters were recorded from each plot:

1) Soybean yield was obtained randomly from a 1 m^2 quadrat;

2) Number of pods/plant was randomly recorded from 10 plants within a 1 m^2 quadrat;

3) Number of seeds/pod was derived from a random sampling of 50 pods from within the two middle rows of the plot; and

4) Seed size (100 seed weight) was randomly measured from a 1 m^2 quadrat.

To measure the stability patterns of the parameters, regression coefficient (b) between the genotypic mean values and the environmental mean values was used. This could also be applied as a measure of adaptability. Genotypes with $b < 1.0$ were considered above average in stability and specially adapted to unfavorable environments; genotypes with b values > 1.0 were considered below average in stability and specially adapted to favorable environments; and genotypes with $b = 1.0$ were described as average in stability and either poorly or well adapted to all environments depending upon the genotypic mean yield (Finlay and Wilkinson, 1963). In this method, the regression of genotype on test mean yield consists of the following components:

$$b = [\sigma^2 m + \sigma(gm)(m)]/\sigma^2 m,$$

where $\sigma^2 m$ is the variance due to environmental effects and $\sigma(gm)(m)$ is the covariance of genotype x environmental effects with environmental effects.

The genotype x envionment interaction results were obtained by the analyses of variance.

RESULTS AND DISCUSSION

Genotypes

Table 1 shows the results of soybean yield and yield components.

1. Yield

Differences between genotypes in soybean yield were statistically significant. The genotypes with high yield were VX4.16.12 (1,372 kg/ha), Santa Maria (1,381 kg/ha), KUSL 20004 (1,732 kg/ha), CM 60 (1,468 kg/ha) and SJ 4 (1,360 kg/ha). IAC-2 had the lowest yield, about 41 % lower than the high yielding genotypes. The highest yielding genotype was KUSL 20004 which is the recently improved genotype from Thailand (Srinives *et al*., 1996).

2. Yield components

2.1 Seed size (100 seed weight)

Significant differences between genotypes in seed size were observed. The genotypes with large seed size were CPAC 150–76 (14.2g), CPAC 539-76 (13.8g), TGX 1447–3D (14.4g), KUSL 20004 (14.9g), CM 60 (13.8g) and SJ 4 (13.7g). Santa Maria had the smallest seed size (11.7g), about 17 % smaller than the large seeded group. The KUSL 20004 gave the largest seed size of all.

2.2 Number of pods/plant

There were significant differences between genotypes in number of pods/plant. The genotypes which produced high number of pods/plant were VX 4.16.12 (62 pods/plant), CM 60 (59 pods/plant), SJ 4 (56 pods/plant) and Santa Maria (65 pods/plant). CPAC 539–76 gave the lowest number of pods/plant (44 pods/plant), about 29 % lower than those with high number of pods/plant.

2.3 Number of seeds/pod

Significant differences between genotypes in number of seeds/pod were recorded. Those genotypes giving high number of seeds/pod were Santa Maria (1.92 seeds/pod), KUSL 20004 (2.01 seeds/pod), SJ 4 (1.85 seeds/pod) and CM 60 (1.95 seeds/pod). The genotype which had the smallest number of seeds/pod was IAC–2 (1.31 seeds/pod), about 32 % smaller than the group with high number of seeds/pod.

These data suggested that a genotype with either high number of pods/plant or high number of seeds/pod with large seed size inclined to produce high yield.

Environments

Table 1 shows the results of soybean mean yield and yield components under each environment when calculated across the ten genotypes.

No significant differences in yield were detected when the soybean genotypes were planted in October with planting density of 200,000 pl/ha, the October planting with plant density of 400,000 pl/ha and the December planting with 200,000 pl/ha. When the planting dates *per se* were taken into account, the yields in October and December plantings (ranging from 1,293 to 1,319 kg/ha) were significantly higher than those planted in July and August (ranging from 1,157 to 1,206 kg/ha).

There were no significant differences between the environments in mean 100 seed weight. The October and December plantings gave significantly higher number of pods/plant (ranging from 60 to 63 pods/plant) than the July and August plantings (ranging from 48 to 52 pods/plant). In contrast, the July and August plantings produced significantly higher number of seeds/pod (ranging from 1.73 to 1.89 seeds/pod) than the October and December plantings (ranging from 1.54 to 1.56 seeds/pod).

The results indicated, in general, that changes in plant density had no significant influence on soybean yield and yield components in the present study.

Genotype x environment interaction

The results of the genotype x environment interactions for soybean yield and yield components revealed that the mean squares of environments and genotype x environment interactions for yield and yield components were not significant (data not shown). On the contrary, the mean square of genotypes was highly significant suggesting that there was a genetic variation. The genotypes were the main factor contributing to the differences in yield and yield components.

Stability estimates for yield

The stability patterns of soybean yield of the ten genotypes are shown in Table 2. Significant regression coefficients indicated by the tests of agreement with b = 0 for VX 4.16.12 (1,372 kg/ha) and SJ 4 (1,360 kg/ha) suggested that changes of the yields of these genotypes were linear functions of the environments (Finlay and Wilkinson, 1963). Soybean yields of Santa Maria (1,381 kg/ha) and

Table 1 Main effects of genotype and environment on yield, 100 seed weight, number of pods/plant and number of seeds/pod.

Genotype	Yield (kg/ha)	100 Seed weight (g)	Number of Pods/plant	Number of Seeds/pod
IAC–2	862	13.40	47	1.31
VX 4.16.12	1372	13.53	62	1.66
CPAC 150–76	1178	14.21	52	1.52
CPAC 539–76	964	13.77	44	1.50
CPAC 639–76	1221	13.01	54	1.61
TGX 1447–3D	890	14.44	49	1.43
SANTA MARIA	1381	11.73	65	1.92
KUSL 20004	1732	14.85	68	2.01
CM 60	1468	13.89	59	1.95
SJ 4.	1360	13.69	56	1.85
S.E. (Mean)	33.41	0.19	2.0	0.07
Environment				
El	1206	13.73	49	1.85
E2	1179	13.69	49	1.83
E3	1181	13.68	48	1.89
E4	1191	13.77	51	1.79
E5	1157	13.61	52	1.73
E6	1172	13.56	51	1.75
E7	1319	13.66	63	1.55
E8	1294	13.62	61	1.54
E9	1309	13.54	62	1.56
EIO	1312	13.62	61	1.56
Ell	1293	13.69	60	1.54
E12	1301	13.64	61	1.54
S.E. (Mean)	18.30	0.11	1.0	0.04

El = 8 July 1996, 200,000 plants/ha
E2 = 8 July 1996, 300,000 plants/ha
E3 = 8 July 1996, 400,000 plants/ha
E4 = 30 August 1996, 200,000 plants/ha
E5 = 30 August 1996, 300,000 plants/ha
E6 = 30 August 1996, 400,000 plants/ha
E7 = 22 October 1996, 200,000 plants/ha
E8 = 22 October 1996, 300,000 plants/ha
E9 = 22 October 1996, 400,000 plants/ha
El0 = 14 December 1996, 200,000 plants/ha
Ell = 14 December 1996, 300,000 plants/ha
E12 = 14 December 1996, 400,000 plants/ha

Table 2 Stability estimates across twelve environments among the ten soybean genotypes for yield.

Genotype	Mean yield (kg/ha)	Regression coefficient (b)	b = 0		b = 1		r^2
			t (DF = 10)	P	t (DF = 10)	P	(%)
IAC –2	862	0.110+0.189	0.58	NS	-	-	3
VX 4.16.12	1372	1.564+0.261	6.00	**	2.16	NS	78
CPAC 150–76	1178	1.104+0.072	15.24	**	1.44	NS	96
CPAC 539–76	964	0.292+0.142	2.05	NS	-	-	30
CPAC 639–76	1221	0.941+0.123	7.65	**	0.48	NS	85
TGX 1447–3D	890	0.872+0.163	4.13	**	2.01	NS	63
Santa Maria	1381	2.288+0.175	13.10	**	7.36	**	94
KUSL 20004	1732	2.077+0.230	9.05	**	4.86	**	89
CM 60	1468	0.083+0.136	0.61	NS	-	-	4
SJ 4	1360	0.869+0.176	4.94	**	0.74	NS	71
Grand Mean	1243						

NS = nonsignificant.
* and ** significant at $p < 0.05$ and $p < 0.01$, respectively.

KUSL 20004 (1,732 kg/ha) were more sensitive to favorable environments than any other genotype. These are illustrated by their steeper regression slopes. CM 60 (1,468 kg/ha) was the most stable genotype (b < 1) with above average yield, while the IAC–2 and CPAC 539–76 also gave above average stability but their yields were below average. The TGX 1447–3D (890kg/ha), CPAC 150–76 (1,178 kg/ha) and CPAC 639–76 (1,221 kg/ha) had average stability but below average performance. These results suggested that the genotype such as CM 60 would produce high yield in all environments. On the other hand, the TGX 1447–3D, CPAC 150–76 and CPAC 639–76 would give low yields in all environments. The genotypes Santa Maria and KUSL 20004 gave above average performance and specially adapted to favorable environments.

Stability estimates for yield components

The stability for 100 seed weight of the ten soybean genotypes is given in Table 3. There were significant regressions for all genotypes between genotypic mean 100 seed weight and environmental mean 100 seed weight. The data indicated that the 100 seed weight of all genotypes were above average in stability and specially adapted to unfavorable environments.

Table 4 shows the data on stability pattern for number of pods/plant. The regression coefficients b = 1 between genotypic mean number of pods/plant and environmental mean number of pods/plant for the genotypes CPAC 150–76 and TGX 1447–3D were not significant. Changes in number of pods/plant for these two genotypes were linear functions of the environments. The number of pods/plant for the genotypes IAC–2, CPAC 539–76 and CPAC 639–76 were stable across environments and, therefore, specially adapted to

Table 3 Stability estimates across twelve environments among the ten soybean genotypes for 100 seed weight.

Genotype	Mean	Regression coefficient	b = 0		b = 1		r^2
	100 seed weight (g)	(b)	t (DF = 10)	P	t (DF = 10)	P	(%)
IAC–2	13.40	1.339+0.807	1.66	NS	-	-	22
VX 4.16.12	13.53	1.062+0.668	1.59	NS	-	-	20
CPAC 150–76	14.21	1.265+0.597	2.12	NS	-	-	31
CPAC 539–76	13.77	1.933+1.005	1.92	NS	-	-	27
CPAC 639–76	13.01	0.354+1.303	0.27	NS	-	-	1
TGX 1447–3D	14.44	1.317+0.649	2.03	NS	-	-	29
SANTA MARIA	11.73	1.183+0.872	1.36	NS	-	-	16
KUSL 20004	14.85	0.731+0.652	1.12	NS	-	-	11
CM 60	13.89	0.385+0.405	0.95	NS	-	-	8
SJ 4	13.69	0.700+0.864	0.81	NS	-	-	6
Grand Mean	13.65						

NS = nonsignificant.
* and ** significant at $p < 0.05$ and $p < 0.01$, respectively.

Table 4 Stability estimates across twelve environments among the ten soybean genotypes for number of pods/plant.

Genotype	Mean number of	Regression coefficient	b = 0		b = 1		r^2
	pods/plant	(b)	t (DF = 10)	P	t (DF = 10)	P	(%)
IAC–2	47	0.529+0.252	2.10	NS	-	-	31
VX 4.16.12	62	1.493+0.112	13.28	**	4.40	**	95
CPAC 150–76	52	1.242+0.313	3.96	**	0.77	NS	61
CPAC 539–76	44	0.190+0.105	1.80	NS	-	-	25
CPAC 639–76	54	0.431+0.132	3.28	NS	-	-	52
TGX 1447–3D	49	0.747+0.271	2.75	*	0.93	NS	43
SANTA MARIA	65	1.682+0.083	20.33	**	8.22	**	98
KUSL 20004	68	3.005+0.347	8.67	**	5.78	**	88
CM 60	59	1.962+0.112	17.55	**	8.59	**	97
SJ 4	56	1.791+0.114	15.69	**	6.94	**	96
Grand Mean	56						

NS = nonsignificant.
* and ** significant at p.< 0.05 and $p < 0.01$, respectively.

unfavorable environments. The SJ 4, CM 60, KUSL 20004, Santa Maria and VX 4.16.12 were below average in stability for their number of pods/plant. They were specially adapted to favorable environments.

The stability for number of seeds/pod of the ten soybean genotypes is shown in Table 5. The regressions of the genotypic mean number of seeds/pod on the environment mean number of seeds/pod for VX 4.16.12, CPAC 150–76, CPAC 539–76, CPAC 639–76 and TGX 1447–3D were highly significantly different from zero. These results suggested that changes in this character were linear functions of the environments. The number of seeds/pod for IAC–2, Santa Maria and KUSL 20004 gave above average stability patterns as illustrated by b < 1. Santa Maria and KUSL 20004 were considered the most stable genotypes with, particularly, above average number of seeds/pod. The two genotypes were, therefore, specially adapted to unfavorable environments in this character. CM 60 and SJ 4 had below average stability and specially adapted to favorable environments.

CONCLUSION

Results of the experiment on ten soybean genotypes planted in twelve environments consisted of various plant densities and planting dates led to the following conclusions:

1. The genotypes with above average yield were VX 4.16.12, Santa Maria, KUSL 20004, CM 60 and SJ 4.

2. Although genotype x environment interaction study showed that genotype was the most important factor contributing to the variation in yield and yield components, stability patterns

Table 5 Stability estimates across twelve environments among the ten soybean genotypes for nwnber of seeds/pod.

Genotype	Mean number of seeds/pod	Regression coefficient (b)	b = 0		b = 1		r^2
			t (DF = 10)	P	t (DF = 10)	P	(%)
IAC–2	1.31	0.243+0.244	1.00	NS	-	-	9
VX 4.16.12	1.66	1.064+0.105	10.11	**	0.61	NS	91
CPAC 150–76	1.52	0.859+0.735	11.69	**	0.19	NS	93
CPAC 539–76	1.50	0.843+0.122	6.90	**	1.29	NS	83
CPAC 639–76	1.61	1.300+0.136	9.54	**	2.21	NS	90
TGX 1447–3D	1.43	1.109+.0.261	4.25	**	0.42	NS	64
SANTA MARIA	1.92	0.251+0.142	1.77	NS	-	-	24
KUSL 20004	2.01	0.693+0.409	1.69	NS	-	-	22
CM 60	1.95	1.647+0.278	5.93	**	2.33	*	78
SJ 4	1.85	1.794+0.215	8.34	**	3.69	**	87
Grand Mean	1.68						

NS = nonsignificant.
* and ** significant at p < 0.05 and p < 0.01, respectively.

suggested that changes in these characters of some genotypes were linear functions of the environments;

3. The high yielding genotypes such as Santa Maria, CM 60, KUSL 20004 did not respond to changes in environment. Their variation in yield and yield components were mainly genotypic in nature;

4. The four high yielding genotypes selected for further evaluations on various environments were the VX 4.16.12, Santa Maria, CM 60 and KUSL 20004.

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