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Genetic Analysis of Field Germination in Soybean (*Glycine max.* (L) Merill.)

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Summary. Genetic analysis for germination percentage was carried out in the F_3 and F_4 generations of a diallel cross involving six promising genotypes of soybean. Results indicated a high amount of genetic variability and a moderately high heritability together with genetic advance, suggesting a possible improvement for this character through hybridization and selection. Correlations at different levels revealed a strong negative association of germination with only one seed character: seed weight. This observation was further confirmed from path coefficient analysis. These findings strongly suggest that to base selection on seed weight which may not influence the seed quality of soybean.

Key words: Soybean – *Glycine max.* – Germination – Genetic variability – Seed characters

Introduction

Genetic studies on germination percentage in soybean have been very limited. There are only a few reports on the heritability estimates of germination (Green and Pinnel 1968a, b) or on the influence of yield and seed quality characters on germination (Green et al. 1965, Singh et al. 1977). It was, therefore, felt necessary to study the genetic control of germination and the nature of the association of yield and seed quality components to germination. This would be useful in breeding for high field germination in soybean. In this report, the results observed in the F_3 and F_4 generations obtained from a diallel cross involving six promising soybean varieties are presented and discussed.

Materials and Method

Six varieties of soybean ('Punjab-1', 'Bragg', 'JS-2', 'Lee', 'Semmes', 'Improved pelican') were crossed in all combinations. Fifteen F_3's and 15 F_4's, obtained from bulked seeds of randomly selected plants from the F_2 and F_3 generations respectively, were grown in a randomized block design (RBD) with four replications and six parents. Data on the yield per plant and seed quality characters, including 100 seed weight, protein and oil content were recorded from 20 randomly selected plants of each replication. Protein content was determined using the microkjeldahl technique and oil content was extracted and estimated following the usual procedure.

For field germination, a composite sample of 50 seeds was drawn from a bulked lot of each treatment. Seeds were sown under field conditions in two replicates in a RBD. Germination was recorded on the basis of emergence from the 5th to the 7th day after sowing.

Mean, range of variation, coefficient of variation, heritability estimates in both the broad sense and expected genetic advance were calculated. Correlations at both the genotypic and phenotypic levels were calculated on the basis of overall population (F_3, F_4 and parental populations). Predicted means were determined by additing the population means and genetic advance (Shannon *et al.* 1972). Coheritability was estimated according to Bedard *et al.* (1971). For path coefficient analysis, the method of Dewey and Lu (1959) was followed.

Experimental Results

An analysis of variance for germination (Table 1) revealed significant difference due to treatments. Mean squares for treatments were further partitioned into F_3 F_4 F_3 vs F_4 and crosses vs parents. Variances for the F_3 and F_4 crosses were found significant whereas, for the parents vs crosses, they were non-significant.

The data presented in Table 2 indicated a wide range of variation for germination. There was a relatively high genotypic coefficient of variation for germination and heritability estimates were moderately high, not differing significantly between populations. On the basis of the heritability estimates, the expected genetic advance was computed from individuals of the top 5 per cent (Table 3). High estimates of genetic advance were recorded for this character.

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Correlations at different levels were calculated between the germination and seed quality characters (Table 4). One hundred seed weight exhibited a significant negative association with germination at the genotypic and phenotypic levels while yield per plant and protein and oil content did not show any significant association with germination. Coheritability values estimated for germination (Table 5) failed to indicate a positive coheritability with any of the seed quality characters. In general, the magnitude of coheritability was of a low order except in the case of oil and protein content.

The predicted changes in various selected and unselected characters are presented in Table 6. The results indicated that progress can be achieved indirectly by practising selection on correlated characters in contrast to direct selection. Selection for 100 seed weight resulted in a considerable reduction in germination percentage.

A multiple regression equation which indicates the contributions of various seed characters towards variation in germination is presented in Table 7. One hundred seed weight alone contributed the maximum towards germination and showed a coefficient of determination as high as 47.7 per cent. However, the best combination was that of seed weight with protein content, accounting for 59.5 per cent variation. This contribution is greater than all the other seed characters taken together. The further effects of direct and indirect influence of various factors were calculated in two sets using path coefficient analysis. The contributive variables were yield per plant and seed quality characters in the first set, while in second set yield was dropped. All the characters, except 100 seed weight, had shown low negative direct effects on germination (Table 8). The indirect effect of 100 seed weight and oil content on germination was positive via protein content. The direct and indirect effect of yield on germination was negligible.

Discussion

Reports on the nature of the genetic control of germination are very limited. Green and Pinnel (1968[a]) recorded low heritabilities ranging from 3 per cent to 29 per cent and 15 per cent to 60 per cent under different conditions. In another study, Green and Pinnel (1968[b]) estimated heritability with a range of 8 per cent to 30 per cent for wrinkled seed coat, 15 to 38 per cent for shrivelled cotyledons and 10 per cent to 29 per cent for green cotyledons. It is obvious that seed characteristics have considerable influence on germination. Further, Green *et al.* (1971) reported heritability estimates for field germination rang-

Table 1. Analysis of Variance for Germination

Source of variation	D.F.	Mean square
Replication	1	2069.39
Treatments	35	505.23**
Parents	5	621.93
F_3 crosses	14	476.13
F_4 crosses	14	545.10
F_3 vs F_4	1	2.40
$F_3 + F_4$ crosses vs parent	1	273.87
Error	35	120.70

** $P < 0.01$

Table 2. Estimates of Parameters of Variation in Germination

Population	Range		Variance		Heritability	Coefficient of variation	
	Min.	Max.	Genotypic	Phenotypic	Broad sense	Genotypic	Phenotypic
F_3, F_4 and parents	16	87	192.26	252.61	76.10	26.79	30.67
F_3	16	66	177.71	238.06	74.64	26.27	30.41
F_4	26	73	212.20	272.55	77.85	28.46	32.29
Parents	38	87	250.61	310.96	80.59	26.18	31.41

Table 3. Mean, Genetic Advance and Predicted Mean for Germination

	Mean	Genetic advance (GA)	GA as percent mean	Predicted population mean
F_3, F_4 and parents	51.80	24.92	48.10	76.72
F_3	50.73	23.72	46.77	74.45
F_4	51.13	26.47	51.76	77.60
Parents	56.16	29.26	52.10	

Table 4. Genotypic (G), Phenotypic (P) and Environmental (E) Correlations for Different Combination of Characters involving Yield and Seed Characteristics

		Yield	Seed weight	Oil	Protein	Germination
Yield	G	–	0.1218	0.5214**	–0.3629*	–0.1901
	P		0.3366*	0.3881*	–0.3873*	–0.0899
	E		0.2746	0.1068	–0.5241**	0.1749
Seed weight	G		–	–0.0710	–0.2162	–0.4880**
	P			–0.9135**	–0.1964	–0.5200**
	E			+0.734**	–0.0025	–0.9600**
Oil	G			–	–0.6489**	–0.0441
	P				–0.5798**	–0.0024
	E				0.0286	0.2076
Protein	G				–	–0.0258
	P					–0.0132
	E					0.0668
Germination	G					–
	P					
	E					

* $P < 0.05$
** $P < 0.01$

Table 5. Coheritability Values in Per cent for Different Combinations of Characters involving Yield and Seed Characteristics

	Yield	Hundred seed weight	Oil	Protein	Germination
Yield	–	9.84	40.75	–28.00	–13.82
100-seed weight		–	6.52	–19.62	–35.31
Oil			–	–56.96	– 3.63
Protein				–	– 2.09

Table 6. Predicted Changes in Various Selected Characters (underlined) and Unselected Characters (off-diagonal figures) from Selecting Superior 5% of the Population on the basis indicated

Basis of selection	Seed weight (g/100)	Germination %	Protein %	Oil %
100-Seed weight	+<u>3.03</u>	–13.54 (–11.55)	–0.57 (–0.56)	–0.10 (–0.10)
Germination %	–1.79 (–1.11)	+<u>24.92</u>	–0.06 (–0.00)	–0.06 (–0.05)
Protein %	–0.68 (–0.60)	–0.69 (–0.63)	+<u>2.53</u>	–0.95 (–0.94)
Oil %	–0.05 (–0.19)	–1.18 (–1.11)	–1.65 (–1.65)	+<u>1.47</u>

Table 7. Regression Equation, Multiple Correlation Coefficient and Contribution of Different Characters to Variation in Germination (Y_1)

Equations	R	Contribution to germination
$Y_1 = 189.233 - 9.\overset{**}{194}X_1$	0.689**	47.699
$Y_1 = 202.455 - 3.848X_2$	0.278	7.751
$Y_1 = 79.678 - 1.345X_3$	0.155	2.395
$Y_1 = 398.825 - 9.\overset{**}{816}X_1 - 5.\overset{**}{133}X_2$	0.772**	59.551
$Y_1 = 185.954 - 9.\overset{**}{282}X_1 - 0.227X_3$	0.669**	44.813
$Y_1 = 246.542 - 4.129X_2 - 1.627X_3$	0.182	3.330
$Y_1 = 399.502 - 9.\overset{**}{803}X_1 - 5.\overset{**}{137}X_2 - 0.039X_3$	0.755**	57.089

X_1 = 100-seed weight (g)
X_2 = Protein percentage
X_3 = Oil percentage
* Significant ($P \leq 0.05$)
** Highly significant ($P \leq 0.01$)

Table 8. Path Coefficient Analysis of Factors Influencing Germination through Direct and Indirect Effect of Variables

Pathways of association	Path coefficient	
	Set-I	Set-II
1. Seed yield vs. germination		–
Direct effect	–0.1174	–
Indirect effect		
via 100-seed weight	–0.0693	–
via percent oil content	–0.1328	–
via percent protein content	–0.1294	–
Total correlation (r_g)	–0.1901	
2. 100-seed weight vs. germination		
Direct effect	–0.5689	–0.5878
Indirect effect		
via seed yield	–0.0143	–
via percent oil	0.0181	0.0225
via percent protein	0.0771	0.0773
Total correlation (r_g)	–0.4880	–0.4880
3. Per cent oil vs. germination		
Direct effect	–0.2547	–0.3179
Indirect effect		
via seed yield	–0.0612	–
via 100-seed weight	0.0404	0.0417
via per cent protein	0.2314	0.2321
Total correlation (r_g)	–0.0441	–0.1441
4. Per cent protein vs. germination		
Direct effect	–0.3567	–0.3588
Indirect effect		
via seed yield	0.0426	–
via 100-seed weight	0.1230	0.1270
via percent oil	0.1653	0.2060
Total correlation (r_g)	–0.0258	–0.0258
Residual effect	0.6796	0.6894

ing from 7 per cent to 59 per cent. In the present study, germination exhibited a high genetic variability and also a high phenotypic coefficient of variation. The latter indicates a masking influence of the environment on the expression of germination, further confirmed with the results of moderately high estimates of heritability. The heritability estimates based on different populations were relatively higher than those reported by Green and Pinnel (1968[a, b]). This is very possible since broad sense heritability estimates would be biased upward by dominance and epistatic effects. The high heritability, together with high genetic advance, is probably due to additive gene effects (Panse 1957). These results strongly support the view that germination is under genetic control and it can be improved through hybridization and selection.

With respect to the relationships of seed characters to germination, seed size has been reported to show negative correlations (Fehr and Probst 1971; Green et al. 1965; Burris *et al.* 1973). Seed coat thickness and 100 seed weight have also shown significant correlations with germination (Singh *et al.* 1977). In the present study, none of the seed characteristics were significantly associated with germination except that of seed weight, which exhibited a strongly negative correlation. By virtue of this negligible association of field germination with quality characters, selection for a high protein or a high oil content in soybean will not prove to be a hurdle when selecting genotypes for high germination. The present studies suggest that selection should be based on the smaller seed size in order to improve germination.

The coheritability estimates was made to measure the joint heritability of a pair of characters which are specifically involved in the prediction formulae for correlated responses to directional selection. In the present report, coheritability estimates of yield and seed characters revealed negative coheritability for oil with protein content and for seed weight with germination. The coheritability of germination with other characters were also negative but low in magnitude. This is expected in the presence of environmental variances. It is interesting to note that selecting for seed weight would have a definite negative influence on germination and protein content.

From the multiple regression equation, seed weight appears to show the maximum contribution towards variation in germination while protein alone did not seem to have any effect. However, its coefficient assumed significance whenever seed weight was included in the equation. This suggests seed weight is important in explaining variations in germination. This observation was further confirmed by path coefficient analysis.

Although correlations are helpful, they do not provide an exact picture of the relative importance of direct and indirect influences of each of the component characters. Path coefficient analysis was carried out to find out the direct and indirect effects of yield and seed characters on germination. The results revealed that a possible improvement in germination could occur by a selection based on small seed size. This was also apparent from the results of correlations between these characters. The low genotypic correlation coefficients of protein and oil content with field germination indicated they had no influence on germination, however path analysis showed that these characters have a high, but negative direct effect on germination.

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