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Varietal Differences and Diallel Analysis of Pre-germination Flooding Tolerance in Soybean Seed

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Seven hundred and thirty varieties of soybean from different sources were evaluated for seed flooding tolerance by the seed germination test after a 4-day soaking at 25°C. The inheritance of seed flooding tolerance was also analyzed with a 6 x 6 diallel cross. A large variation in seed flooding tolerance existed in the soybean germplasm as reflected in the germination rate which ranged from 0 to 100%. Most of the varieties tested were sensitive to seed flooding, and only 4% of the tested varieties showed a high tolerance (germination rate >90%).

Seed flooding tolerance was controlled by both additive and dominance genes and a small number of effective factors and high narrow sense heritability in diallel analysis indicate that the selection for tolerance can effectively be done in early generations.

Key words : *Glycine max*, Seed flooding tolerance, Diallel analysis, Germination, Varietal difference

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the major protein crops in the world, used as food and animal feed. Although soybean is mainly grown in temperate climate areas, it is also widely cultivated in tropical and subtropical regions. In humid tropical and subtropical regions, poor establishment of plants which lowers the seed yield was frequently observed when soybean was subjected to excessive water or heavy rainfall during the period of germination.

Improving varieties with seed flooding tolerance is the most effective way

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to overcome the problem of low germination under excessive water[6]. Varietal differences in seed flooding tolerance were found in some upland crops such as barley[7),8)], soybean[4)], sorghum[9)] and wheat[10)], and the genetic parameters of barley[7)] and sorghum[9)] were also estimated.

The objective of this study was to evaluate the varietal differences and the genetic nature of seed flooding tolerance in soybean.

MATERIALS AND METHODS

1 . *Varietal variation*

Seven hundred and thirty varieties from germplasm collections of the Taiwan Agricultural Research Institute were multiplied at Chung Hsing University, Taichung, in the summer crop (July to October) of 1991. Seeds were harvested at maturity and were dried to 10% moisture content, then stored at 5°C. Seed viability was evaluated by its germination rate as in the standard germination test procedure[1)]. The varieties with more than 95% germination rate were used in the experiments.

Fifty seeds of each variety were tested for germination after being soaked at 25°C for 4 days[5)]. The germination rate was used as the parameter for determining the flooding tolerance of the seed[4)].

2 . *Genetic analysis*

Six strains, PI92683, PI68741, PI087630, PI90575-1, PI89940 and PI186195, were crossed in all possible combinations including reciprocals and obtained 30 F_1 hybrids. The F_1 and their parents were grown to produce seeds in the field at Chung Hsing University, Taichung, in the summer crop of 1991. Seeds were harvested and dried to 10% moisture content, then stored at 5°C. Flooding tolerance for F_1 (F_2 seeds) was evaluated with the same procedures as the varietal test above. The experiment was designed as a randomized complete block with 4 replications. The diallel data of germination were arc sine transformed and then were analyzed after the methods by Hayman's[2),3)].

RESULTS AND DISCUSSION

1 . *Varietal variation*

There were significant differences among varieties in germination rate after 4 days soaking as shown in Table 1. The germination rate ranged from 0 to 100%. Most varieties were sensitive to the flooding of seeds. About 85% of tested varieties were found quite sensitive to submerged stress of seeds as reflected by the reduction of germination rate (<60%). However, there were

Table 1. Frequency distribution for germination of seeds in soybean germplasm when seeds were soaked at 25°C for 4 days

Germination (%)	Number	Frequency (%)
0-9	484	66.3
10-19	39	5.3
20-29	30	4.1
30-39	23	3.2
40-49	21	2.9
50-59	27	3.7
60-69	21	2.9
70-79	24	3.2
80-89	32	4.4
90-100	29	4.0
Total	730	100.0

4% of the tested varieties which showed high flooding tolerance (germination rate >90%). The results indicated that the genetic resources for flooding resistance existed in the soybean germplasm.

2 . *Genetic analysis*

Table 2 shows the germination rates for six parents and their F_1 hybrids ranging from 47 to 99%. The parent PI186195 (P_6) showed a high flooding tolerance with 99% germination, and parent strains, PI90575-1 (P_4) and PI92683 (P_1), were poor in flooding tolerance with a germination rate of 47 and 60%, respectively. The germination rate of F_1 hybrids differed greatly from cross to cross (40-72%).

Table 3 shows the estimates of different genetic parameters for germination rate. The additive genetic variance (D) and the two components of dominance effect (H_1, H_2) were significant, indicating that both additive and dominance effects are important in the inheritance of seed flooding tolerance. The average degree of dominance at each locus was within the range

Table 2. Germination (%) in a 6×6 diallel cross

Parent	PI92683	PI68741	PI087630	PI90575-1	PI189940	PI186195
PI92683	(60)	51	48	60	59	44
PI68741	63	(76)	72	57	67	62
PI087630	40	62	(80)	62	55	60
PI90575-1	56	67	52	(47)	50	72
PI189940	55	53	59	56	(70)	53
PI186195	52	54	66	60	69	(99)

( ): Parental value

of over dominance ($(H_1 / D)^{1/2}=1.22$). The ratio of $H_2 / 4H_1$ (0.18) suggested unequal frequencies of positive and negative alleles at the loci influencing seed flooding tolerance. Furthermore, the large magnitude of F value indicated that there were higher frequencies of recessive alleles than dominant alleles in parents, which was also estimated by the high value of kd / kr value. The proportional value for the number of effective factors exhibiting dominance was about two effective factors. The narrow sense heritability value of 0.47 indicated that selection for the high flooding tolerance could effectively be done in early segregating generations.

Table 3. Estimate of genetic parameters for germination (%) in a 6×6 diallel cross

Genetic parameter	Estimated value
D	9.89**±1.6
H_1	14.61**±4.1
H_2	10.54**±3.7
h	17.64**±2.5
F	11.84**±4.0
E	0.24±0.06
$(D-H_1)$	−4.71±3.6
$(H_1 / D)^{1/2}$	1.22
$H_2 / 4H_1$	0.98
kd / kr	2.94
h / H_2	1.67
$h^2(n)$	0.47

** : Significant at 1% level

The variance and covariance graph of the seed germination shown in Fig. 1 provides information about the genetic relationship among the parents. The linear regression of Wr on Vr has a slope nearly equal to 1 suggesting the absence of epistasis and independent distribution of genes among the parents. The position of the Vr and Wr values on the line reveals the proportions of the dominant and recessive genes in the parents. The magnitude and sign of the Wr value at the intercept of the regression line also show the level of dominance. The P_1 (PI92683), P_2 (PI68741) and P_5 (PI89940) are located near the origin. This indicates that they carry dominant genes exclusively. On the other hand, P_6 (PI186195) located away from the origin, indicating a relative abundance of recessive genes in this parent. The regression line intercepted the Wr axis above the origin suggesting that seed flooding tolerance is controlled by over-dominant gene(s).

The discontinuity between the points of the high germination group

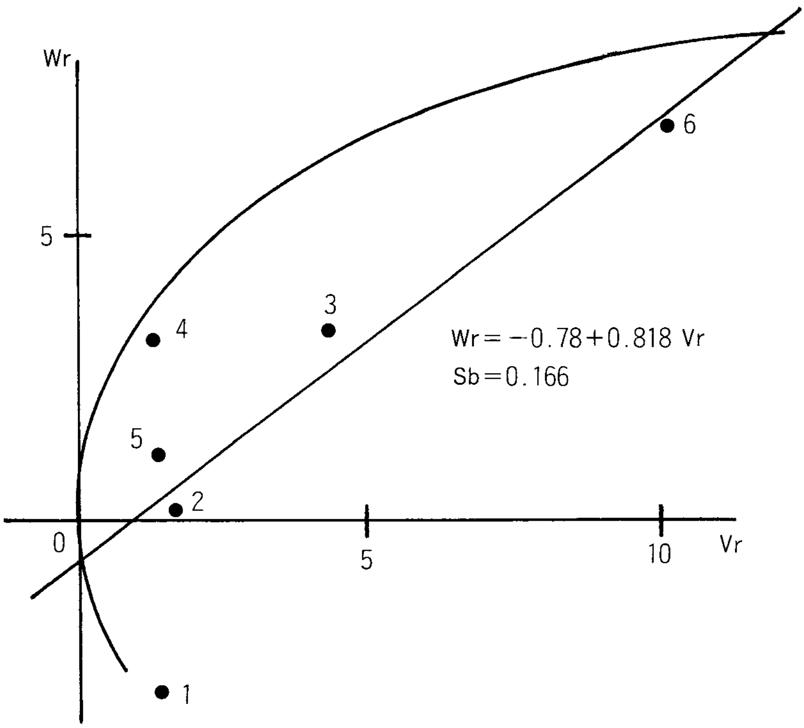

Fig. 1. Wr / Vr graph for germination in a 6×6 diallel cross.
1 : PI92683 2 : PI68741 3 : PI087630
4 : PI90575-1 5 : PI89940 6 : PI186195

against the low germination group revealed the possible involvement of a major gene as well as polygenes in the inheritance of the flooding tolerance among parents. This indicates that selection for high germination segregants from the cross of high / low seed germination parents would be effective because of the possible major genic control of the character.

The parental value is related with the number of positive alleles possessed by the parent, and the order of dominance of parents is related to the number of recessive alleles. Fig. 2 shows the relative position for the order of dominance (Wr+Vr) and parent measurement (Yr).

A significant positive correlation (at 5% level) between Yr and (Wr+Vr) indicated that dominant genes for germination generally acted toward decreasing the value. High germination parents such as PI186195 (P_6) possessed more recessive genes, while low germination parents such as PI92683 (P_1) had more dominant genes.

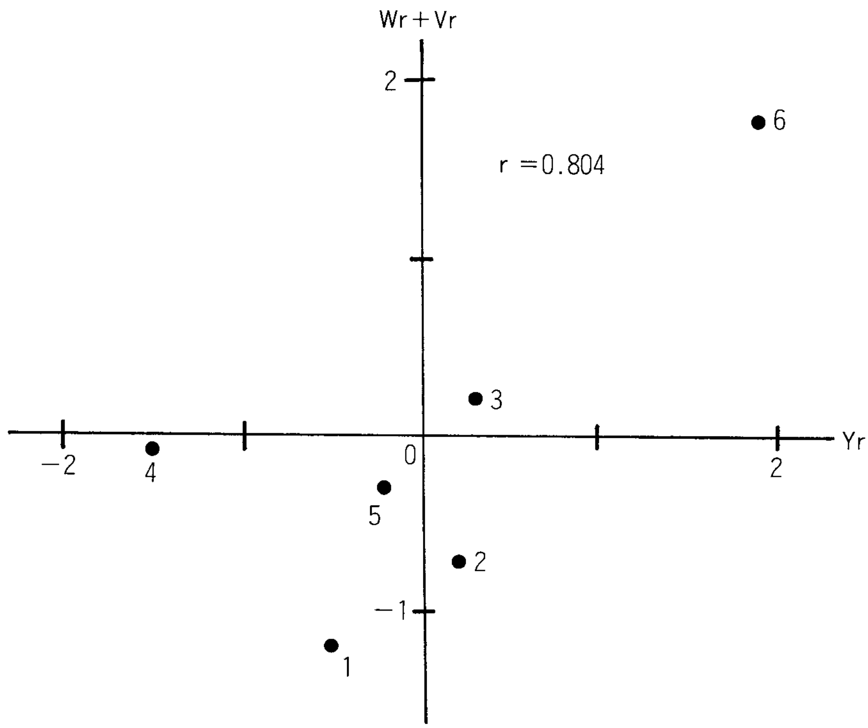

Fig. 2. Scatter plot showing the relationship between standardized values of Yr and (Wr+Vr).
1 : PI92683 2 : PI68741 3 : PI087630
4 : PI90575-1 5 : PI89940 6 : PI186195

The large variations in seed germination controlled by both additive and dominance genes and small number of effective factors and high narrow sense heritability suggest that flooding tolerance can be effectively improved through breeding.

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ダイズ種子の冠水抵抗性の品種間差とダイアレル分析

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起源の異なる730品種の大豆種子を25℃，4日間浸漬処理し，その後の発芽率で種子の冠水抵抗性を評価した．また，種子の冠水抵抗性の遺伝様式を6×6のダイアレル分析で調査した．

供試した品種の冠水処理後の発芽率は0～100％まで分布し，種子の冠水抵抗性には大きな変異が認められた．大部分の品種は冠水条件に感受性であり，供試品種の4％のみが高度の抵抗性（発芽率90％以上）を示した．

ダイアレル分析の結果，種子の冠水抵抗性は，相加的効果と優性効果が有意であり，優性効果の方が相加的効果よりも重要であった．種子の冠水抵抗性を支配する遺伝子は2対，狭義の遺伝率は0.47と推定され，抵抗性の強い方が劣性なので，初期世代における選抜効果が期待できる．

キーワード：*Giycine max*，種子冠水抵抗性，ダイアレル分析，発芽，品種間差