

Varietal Differences in Germination Rate, Storability, and Flooding Tolerance of Soybean Seeds Produced from Different Cultural Seasons and Locations

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Abstract : Seed germination rate, storability, and flooding tolerance are important factors involved in soybean production in high-temperature and excessive-moisture areas. To evaluate the effects of environmental factors on the germination rate, flooding tolerance, and storability, seeds were produced in three locations and in two seasons. The seed germination rate and flooding tolerance varied significantly by season and location. In general, seeds produced from the cool and dry fall season in southern Taiwan possessed good quality, which was reflected in their high germination rate and flooding tolerance. Storability differed significantly among varieties and was considered to be a genetically determined character. Positive correlations between storability and seed flooding tolerance before and after storage suggested that selection among hybrid progenies for seed flooding tolerance and storability may be carried out by cross breeding.

Key words : Cultural season, Germination, Locality, Seed flooding tolerance, Soybean, Storability, Varietal difference.

作季および地域を異にするダイズ種子の発芽率、貯蔵能力および冠水抵抗性の品種間変異：曾富生・侯福分・呉詩都（中興大学農学院）

要 旨：高温多湿地域におけるダイズ作では種子の発芽率、貯蔵能力および冠水抵抗性が問題となる。そこで異なる作季と地域にダイズ品種を栽培し、生産された種子の発芽率、貯蔵能力および冠水抵抗性の差異を調査した。種子の発芽率と冠水抵抗性は作季と地域によって有意に異なり、台湾南部の低温乾燥な秋作で生産された種子は発芽率が高く、冠水抵抗性も強い傾向を示した。種子の貯蔵能力は品種間に有意差が認められ、遺伝的な形質と推定された。また、種子の貯蔵能力と冠水抵抗性（貯蔵前および貯蔵後）との間には有意な正の相関が認められたので、交配により冠水抵抗性が強く貯蔵能力が高い系統の選抜が可能とみられる。

キーワード：冠水抵抗性、作季、ダイズ、地域性、貯蔵能力、発芽率、品種間差異。

Although soybean is mainly produced in temperate areas, it is also considered a major crop in some tropical and subtropical countries. In the latter areas, deterioration of seed quality and poor field germination under excessive moisture are the limiting factors in soybean production. Some researchers reported that seed storability^{2,3,11,13,17} and seed flooding tolerance⁵ varied among varieties. Furthermore, seed quality was reported to be affected by planting date, maturing stage, and cultural environment^{4,12,14}.

In Taiwan, soybean can be cultivated in spring, summer, and fall. However, reports indicated that there were interactions among varieties, seasons, and locations in seed yield^{8,9,10,16}. Therefore, understanding the variation in seed quality and seed flooding tolerance in different locations and seasons is important in a soybean production and breeding program.

This experiment was conducted to study the variation in seed flooding tolerance and germination

in different seasons and locations. Moreover, the relationship between seed storability and seed flooding tolerance was evaluated.

Materials and Methods

1. Sample collection

Twelve soybean varieties (Table 2) were planted in the experimental farm of Taichung National Chung Hsing University in spring (March–June) and fall (September–December) 1990. In addition, 19 soybean varieties (Table 1) were planted at the Hualien District Agricultural Improvement Station (DAIS), Kaohsiung DAIS, and Taichung National Chung Hsing University in fall 1991. Seeds harvested from each variety were dried to 10% moisture content. Subsequently, seed germination rate and flooding tolerance were tested.

Forty-six soybean varieties (Table 3) were planted at the Seed Improvement and Propagation Station experimental farm, Taichung

Table 1. Location effects on germination and flooding tolerance of seed of different varieties (Fall season).

Variety	Germination (%)					Flooding tolerance (%)				
	HL	TC	KS	\bar{x}	CV(%)	HL	TC	KS	\bar{x}	CV(%)
PI 088502	99	99	99	99	0	89	90	94	91	2
PI 186195	99	100	98	99	1	82	91	95	89	6
PI 222549	88	99	94	94	5	87	93	87	88	3
PI 232989	96	99	98	98	1	79	83	84	82	3
AGS 2120	97	99	99	98	1	10	39	42	30	48
PI 070466-3	88	97	88	91	5	5	47	43	31	61
PI 079872	91	97	99	96	4	10	41	84	45	67
PI 080470	78	99	99	92	11	53	80	78	70	17
PI 084679	81	90	98	90	8	46	46	47	46	1
PI 086103	69	72	94	78	14	50	64	63	59	11
PI 088508	72	73	64	70	6	16	49	56	40	44
PI 189963	92	97	94	94	2	10	43	30	28	48
PI 196172	70	94	97	87	14	8	10	10	9	11
PI 208430-1	88	97	88	91	7	67	73	69	69	4
PI 230201	93	99	92	95	3	45	57	62	54	13
AGS 66	78	97	99	91	10	0	0	0	0	0
PI 087011	92	90	97	93	3	0	0	0	0	0
PI 200548	92	97	80	90	8	0	0	0	0	0
PI 204336	79	85	98	87	9	0	0	0	0	0
\bar{x}	86.4	93.7	93.4			34.6	47.7	49.7		
LSD(0.05)	2.0	1.9	1.9			7.3	7.1	7.5		

HL: Hualien, TC: Taichung, KS: Kaohsiung.

county, in fall 1988. Seeds were harvested and dried to 10% moisture content. After drying, seeds were packed in polyethylene bags and stored for 18 months in the laboratory (about 25–30°C). Two replications of each variety were stored. Seed germination rate and seed flooding tolerance were tested at harvest and after 18-month storage period.

2. Data collection

Germination rate was calculated for each variety using the standard rolled towel germination test²⁾ with four replications and 50 seeds for each replicate. For seed flooding tolerance, the procedure described by Hou and Thseng⁶⁾ was adopted; 50 seeds (before storage and after 18-month storage) of each variety with four replications were sterilized and soaked in distilled water for 4 days at 25 °C and then germinated in the incubator (dark condition) at 25 °C. Seed storability was represented at the percentage of germination after 18-month storage period divided by the percentage of germination before storage.

Results

1. Environmental effects on variations of the germination rate and flooding tolerance

Tables 1 and 2 show significant differences in the germination rate among varieties, locations, and seasons. Among 19 varieties tested, 4, 13, and 11 varieties showed higher germination rate (>95%) in Hualien, Taichung, and Kaohsiung, respectively. The average germination rates of 19 varieties were 86.4%, 93.7%, and 93.4% in Hualien, Taichung, and Kaohsiung, respectively (Table 1). Table 2 shows that among 12 varieties tested, 3 and 9 varieties had higher germination rate in spring and fall, respectively. The average germination rate of 12 varieties tested was better in fall (95%) than in spring (80%). This indicated that the seeds produced from fall have better quality than those from spring.

Seed flooding tolerance for each variety produced from Hualien, Taichung, and Kaoh-

Table 2. Seasonal effects on germination and flooding tolerance of seeds of different varieties (Taichung).

Variety	Germination (%)					Flooding tolerance (%)				
	Spring	t-test	Fall	\bar{x}	CV(%)	Spring	t-test	Fall	\bar{x}	CV(%)
PI 070197	85	**	95	90	6	35	**	75	55	36
PI 086002	96	ns	98	97	1	96	ns	98	97	1
PI 088508	38	**	85	62	38	16	**	41	29	44
PI 165957	100	ns	100	100	0	98	ns	98	98	0
PI 181697	89	**	96	93	4	49	**	80	65	24
PI 186195	98	ns	99	99	1	90	*	98	94	4
PI 196172	39	**	90	65	40	8	ns	9	9	6
PI 205915	92	*	98	95	3	88	**	98	93	5
PI 222549	94	ns	95	95	1	89	**	96	93	4
PI 222550	90	*	96	93	3	87	**	96	93	5
PI 232989	83	**	98	91	8	39	**	84	62	37
Tarbeel	55	**	94	75	26	10	**	42	26	62
\bar{x}	80		95			59		76		
LSD(0.05)	6.1		1.2			9.8		8.1		
r1	0.875**		0.798**							
r2		0.894**								
r3						0.898**				

*, **: germination or flooding tolerance in spring and fall differ significantly at the 5 and 1% levels, respectively.

ns : non-significant.

r1 : correlation between germination and flooding tolerance for the same season.

r2 : correlation between spring and fall for germination.

r3 : correlation between spring and fall for flooding tolerance.

siung are presented in Table 1. Among 19 varieties tested, four varieties, PI 088502, PI 186195, PI 222549, and PI 232989, gave a seed flooding tolerance of 85% (some of them even >95%) regardless of location. On the contrary, four varieties, AGS 66, PI 087011, PI 200548, and PI 204336, were sensitive to seed flooding treatment, and the seed of those varieties produced from all three locations exhibited the same worst seed flooding tolerance. Average seed flooding tolerance of 19 varieties tested from Hualien, Taichung, and Kaohsiung were 34.6%, 47.7%, and 49.7%, respectively. A difference in the coefficient of variation (CV) was also found. The better the average seed flooding tolerance, the lower the CV value. In the varieties with low average seed flooding tolerance, the CV was high and the variation among locations was large.

As shown in Table 2, seed flooding tolerance varied from 8% to 98% and significantly differed among varieties. In both spring and fall, the values of PI 196172 were 8% and 9%,

respectively, whereas those of PI 165957 and PI 086002 were between 96% and 98%. There were no significant differences between the two seasons. The other nine varieties showed significant differences in seed flooding tolerance among seasons; seed flooding tolerance was better in fall (76%) than in spring (59%).

2. The relationship between seed flooding tolerance and storability

Flooding tolerance of seed just after harvest and after the 18-month storage period and their storability are presented in Table 3. All three germination characters differed significantly among varieties. The ranges of seed flooding tolerance before storage, after storage, and storability were 0–98%, 0–92%, and 12–98%, respectively.

The seed flooding tolerance value before and after storage of 46 varieties tested indicated that these varieties can be classified into three groups. The first group included 26 varieties (code number 1–26); although high

Table 3. Flooding tolerance before and after storage and storability of seeds of different varieties.

Code no.	Variety	Flooding tolerance before storage	Seed storability	Flooding tolerance after storage for 18 months
		—%—		
1	PI 032204	98	45	11
2	PI 186195	97	98	85
3	PI 165957	95	89	59
4	PI 088502	95	92	67
5	PI 086002	94	98	54
6	PI 222550	94	92	58
7	PI 174860	94	95	75
8	PI 232989	92	92	92
9	PI 079691	92	90	36
10	PI 194773	89	79	46
11	PI 153292	88	80	36
12	PI 181697	88	84	64
13	PI 205913	88	83	20
14	PI 079872	83	71	23
15	PI 081037-4	70	97	59
16	PI 194638	43	60	13
17	PI 205915	43	84	43
18	PI 092654	42	80	17
19	PI 079710	42	52	10
20	Tarbeel	42	85	34
21	PI 088508	41	92	41
22	PI 221714	30	63	19
23	PI 194645	28	58	8
24	C110	10	75	5
25	PI 183485	10	67	6
26	PI 100899	8	17	2
27	PI 205906	79	50	0
28	PI 054834	59	35	0
29	PI 086741	34	28	0
30	PI 180519	15	23	0
31	Aksarben	13	12	0
32	Hardome	7	24	0
33	PI 089013	4	56	0
34	PI 092748	0	38	0
35	PI 170889	0	66	0
36	PI 170892	0	20	0
37	PI 194630	0	47	0
38	PI 205087	0	28	0
39	PI 215690	0	23	0
40	PI 215691	0	50	0
41	PI 219652	0	35	0
42	PI 222547	0	30	0
43	PI 222548	0	36	0
44	C6	0	24	0
45	C202	0	70	0
46	C364	0	58	0

variation in seed flooding tolerance among these varieties was found, some were tolerant to flooding before (83–98%) and after storage (58–92%). This was especially obvious in PI 186195 (code number 2), PI 174860 (code number 7), and PI 232989 (code number 8). The second group included six varieties (code numbers 27–33); the seed of these varieties showed lower tolerance to flooding before storage but lost all flooding tolerance after storage. The third group included 13 varieties (code numbers 34–46); seeds of these varieties were very sensitive to flooding. This was reflected in the performance of no flooding tolerance both before and after storage.

Table 3 shows that storability of 46 varieties tested varied from 12 to 98% and that storability was significantly different. Broad sense heritability calculated from those data was 86%, indicating that storability is one of the genetic traits involved.

Among 46 varieties tested, nine (code numbers 2, 4, 5, 6, 7, 8, 9, 15 and 21) showed higher storability (>90%). PI 186195 (code number 2) and PI 232989 (code number 8) especially had higher seed flooding tolerance after storage.

The relationships between seed flooding tolerance before and after storage and storability of 33 varieties (code numbers 1–33 in Table 3) are presented in Figures 1–3. Three characters showed significantly positive corre-

lation with each other $r=0.719$, 0.641 , and 0.810 . The results indicated that the seeds of the varieties which were tolerant to flooding before storage and had high storability still exhibited high seed flooding tolerance after the 18-month storage period.

Discussion

In Taiwan, soybean can be produced in

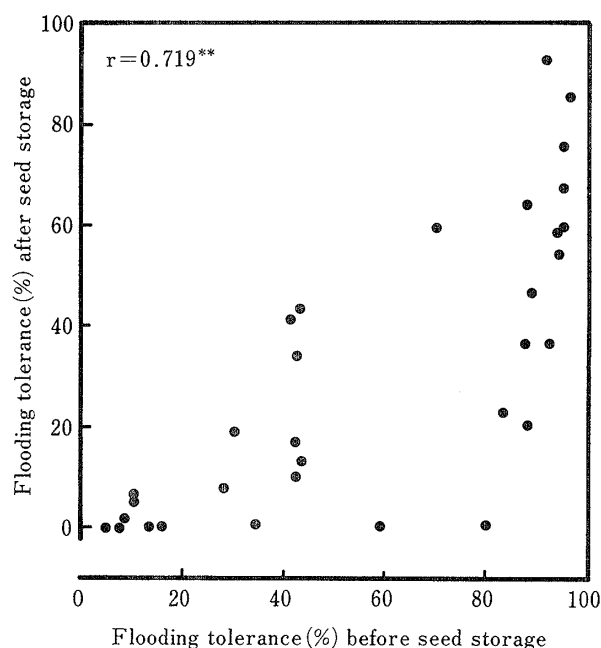


Fig. 2. Relationship between flooding tolerance after storage and flooding tolerance before storage in different varieties.

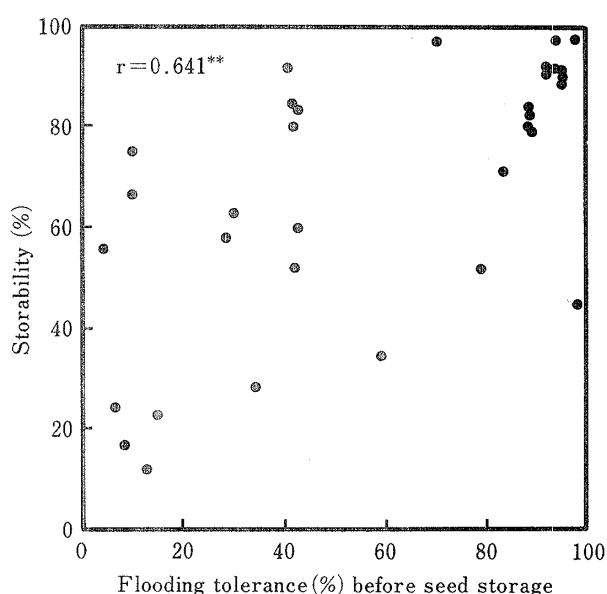


Fig. 1. Relationship between storability and flooding tolerance of seed in different varieties.

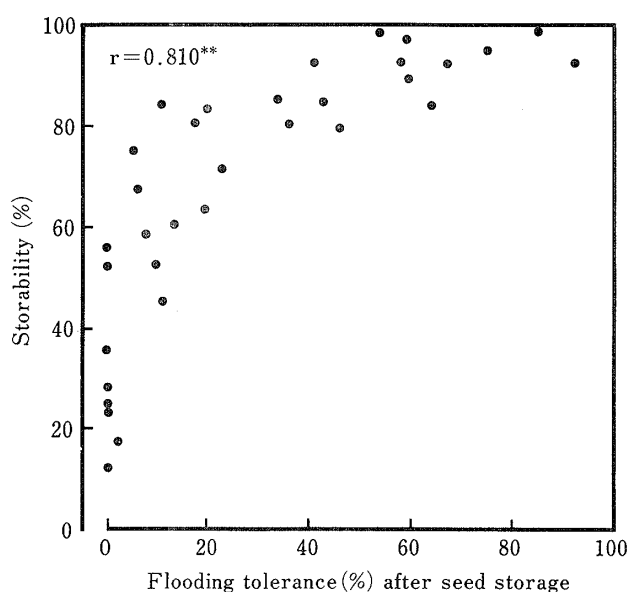


Fig. 3. Relationship between flooding tolerance after storage and storability in different varieties.

spring (February–June), summer (July–October), and fall (September–January). In spring, temperature and moisture are high at seed filling and maturing stages. In summer, high temperature and heavy rainfall often occur in the sowing and early growth periods. In fall, because of the high temperature in the early growth period and cold weather during the maturing stage, soybean could be produced only in central and southern Taiwan.

Since cultivated soybeans have no dormancy, seeds harvested from the previous season could be sown for successive crops. However, in this experiment the seeds produced from fall appeared to have a higher germination rate ($>95\%$) than those from spring (80%). This indicated that the seeds produced in spring may be of low quality. Hence, seed propagation should be done only in summer and fall and seed must be stored for 6–9 months to provide the seed requirement for the succeeding year. Seed storability is thus an important factor in soybean production in Taiwan.

In this experiment, different varieties were grown in three locations (Hualien, Taichung and Kaohsiung) in fall, and seeds harvested from these locations were germinated. The results showed that there was a significant difference in germination rate among the locations. The seeds produced from Hualien showed only 86% average germination rate, whereas, seeds produced from Taichung and Kaohsiung had good germination quality ($>93\%$).

In general, seeds that mature in the cool and dry season are of good quality^{1,4,12,14,15}). In Taiwan, weather conditions in spring and fall are quite different. High temperature and humidity are always recorded during the harvest in spring. In fall, excessive rainfalls at harvest occur in the northeast of Taiwan (Hualien), but the weather is cool and dry in Taichung and Kaohsiung. Therefore, propagation of soybean seems to be better in fall and in central and southern Taiwan.

In humid tropical and subtropical regions, excessive rainfall resulting in water-logged soil is a factor that limits production. In general, excessive water during germination causes the deterioration of seeds and reduces seed emergence in the field. Seed flooding tolerance of

soybean is a genetic character⁷⁾ and varies with varieties⁵⁾. Seed storability differs among varieties as well¹¹⁾. The results of 46 varieties tested in this experiment also showed that both seed flooding tolerance and seed storability varied among varieties, and the broad sense heritability suggested that storability is genetically controlled. Among 46 varieties tested, only two (PI 186195 and PI 232989) had both high seed flooding tolerance ($>92\%$ before and $>85\%$ after storage) and high storability ($>92\%$). Significantly positive correlation was found between storability and flooding tolerance. This indicated that selection among hybrid progenies for seed flooding tolerance and good storability may be achieved by cross breeding.

According to the International Rules for Seed Test²⁾, besides seed purity, the analysis of seed health test and genetic verification of seed, germination rate and seed vigor are the most important parameters for evaluating adaptation in the field. In humid tropical and subtropical regions, since the period of germination is always subject to heavy rainfall after sowing, seed flooding tolerance and storability are additional essential characters for evaluating seed quality.

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