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Studies on the Flooding Tolerance and Water Uptake of Seed and Elongation Force of Seedling in Soybeans

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Abstract : Twenty-four soybean (*Glycine max* (L.) Merr.) varieties were used to investigate the relationship between flooding tolerance, water uptake of seed and elongation force in the period of seed germination. The germination rates after 4 days soaking at 25°C under flooding stress are regarded as the index of seed flooding tolerance. Flooding tolerance differed significantly from 0～100% among soybean varieties. Water uptake types of soybean seed were able to be divided into quick absorption and slow absorption types. The relationship between water uptake and flooding tolerance was not significant under seed flooding stress. Elongation force of seedling (maximun weight displacement of seedings) differed greatly among varieties. The relationship between flooding tolerance and elongation force of seedlings was not significant.
Key words : Elongation force, Emergence, Flooding tolerance, Soybean seedling, Uptake, Water.

ダイズ種子の冠水抵抗性・吸水性および芽ばえの抽出力について : 曾 富 生・侯 福 分・武田和義* (台湾中興大学農学院・*岡山大学資源生物科学研究所)

要　旨 : 湿潤地域におけるダイズ作の阻害要因としては生育期における湿害とともに，播種から出芽に至る期間の過湿条件によって種子が死滅する問題がある．そこでダイズ種子の冠水抵抗性（25°Cで4日間水浸した後における発芽率），吸水性および芽ばえの抽出力の品種間差と，それらの特性間の相互関係を検討した．ダイズ種子の冠水抵抗性は0（死滅）から100（無被害）までの大きな品種変異があり，特に黒粒の抵抗性が強かった．種子の吸水速度は品種間変異が認められ，吸水速度と種子の冠水抵抗性の間に有意な関係はなかった．種子の芽ばえの抽出力には品種間変異があったが，抽出力と種子の冠水抵抗性の間に有意な関係はなかった．したがって，種子の冠水抵抗性が高く，かつ抽出力が大きい品種を育成することは可能であると考えられる．
キーワード : 種子の冠水抵抗性，種子の吸水性，出芽，ダイズ，抽出力．

Imbibition is an essential and primary process during seed germination. Seeds enzyme activity and metabolism were induced by a proper imbibition. In general, the process of imbibition includes an initial wetting of seed tissues, followed by the continued swellin of the seed. The germination was operated by 50% of seed moisture content[4]. Some reports have shown that different solutes and other materials rapidly leak from soybean seeds during imbibition. This leakage is decreased by undamaged seed coat and proper imbibition rate[8,9].

Injury of seeds by excessive water may be due to the rapid absorption of water which disrupts the cell membranes, resulting in the leakage of important cellular organelles[11]. Varietal difference of soybean seed flooding tolerance was evaluated by a screening method by soaking seeds at 25°C for 4 days[1,2].

There is a large variation in seed flooding tolerance among soybean varieties. The maximum elongation force differed significantly among species and among cultivars within species[3,5,6]. Seedling emergence of soybean seed is inhibited by high soil moisture content. The causes of decrease in germination rate under flooding stress are : 1) the seeds are injured and the germination ability is lost, 2) the seeds germinate normally but seedling do not break through soil surface.

The objective of this study was to investigate the relationship among seed imbibition, flooding tolerance, and elongation ability and to provide the information for the future selection program about soybean flloding tolerance.

Materials and Methods

Experiment I. Soybean seed imbibition and flooding tolerance

Twenty-four soybean varieties (or strains), sampling from the 730 varieties tested[1], harvested at the fall of 1991 in Taiwan were used (Table 1). Harvested seeds were air dried until moisture content fell below 11% and then kept in storage at 5°C. To determine the change in seed moisture content with time under flooding stress, it was performed by placing 10 seeds in Petri dish and soaking the seeds in distilled water. After 1～2 hours (hrs) soaking, the seed moisture content was measured every 4 hrs for 22 hrs. The experiment was replicated 6 times with 10 seeds per replicate. Furthermore, the method developed by Hou and Thseng[2] was used to measure the flooding tolerance.

Experiment II. Elongation force of soybean seedling

Soybean varieties used in this expriment are listed in Table 1, but only the seeds within the normal range in each variety were chosen. Soybean seedling elongation ability was evaluated by using the procedures described by Howle and Caviness[3]. The method was modified as follows : a case of test tube composed of inner and outer tubes was used in this experiment (Fig. 1.). The size of inner tube is 15 cm in length and 1.8 cm in diameter and size of outer tube is 19 cm in length and 1.9 cm in diameter. All outer tubes were filled with fine sand (sieved through 1.2 mm mesh) of 10 cm in depth. Each of the tubes was sowed with seeds and then the seeds were covered with fine sand of 1.3 cm in depth. Five ml of distilled water were dripped into these tubes and then put the inner tubes which had a small lead ball of 65 g inside each of the outer tubes. The bottom of inner tube was contiguous to the surface of sand in the outer tube, and kept this test tube at 25°C in an incubator for germination. For each variety there were four replications of 10 test tubes each. The elongation length of seedling was measured every day for ten days. When the seedling had extended to the maximum, the height of inner tube lifted by the seedling length was measured and this was regarded as maximum weight displacement of seedling (elongation force). Days to maximum weight displacement were also recorded. All seedlings were removed and cleaned in order to measure the hypocotyl length, root length and fresh weight.

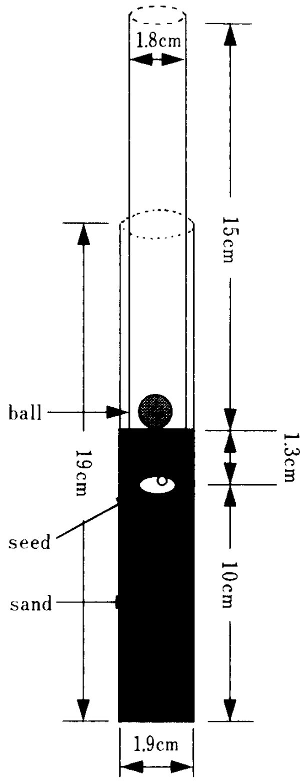

Fig. 1. Germination bed for test the elongation force of seedling.

Results and Discussion

The results of experiment on flooding tolerance of 24 varieties are shown in Table 1. The germination rate of 10 varieties (i.e. C162, C364, PI085420-1, PI087011, PI89006-2, PI91164, PI157450, PI170899, PI200548 and PI215691) was 0 and were regarded as nontolerance varieties. The germination rates of 6 varieties (i.e. PI54873, PI230201, PI070466-3, PI092654, PI79710 and PI209334) were 38～58% and the tolerance of these varieties were classified as middle-class. The germination rate of 8 varieties (i.e., PI165957, PI186195, PI222550, PI232989, PI088502, PI080470, PI205906 and PI208430-1) were 74～100% and were regarded as high-tolerance varieties. All high-tolerance varieties had black seed coats except PI205906 with yellow seed coat. This result indicates that flooding tolerance of soybean seed may be highly related to black seed coat color[1].

Under flooding stress, variation of water uptake of seed during 22 hrs soaking are shown in Table 2. After 1 hr soaking, seed moisture content of 7 and 8 varieties increased to 18～48% and 50～69% of dry weight,

Table 1. Characteristis of varieties in the experiment.

Variety	Flooding toeance	Weight of 100 seeds (g)	Seed coat color
PI165957	100	9.8	B
PI186195	97	7.8	B
PI222550	94	10.5	B
PI232989	93	12.2	B
PI088502	90	11.1	B
PI080470	85	8.2	B
PI205906	80	9.8	Y
PI208430-1	74	13.1	B
PI54873	58	14.3	B
PI230201	50	8.2	Y
PI070466-3	47	15.3	Y
PI092654	42	13.8	B
PI79710	42	17.5	B
PI209334	38	15.2	B
C162	0	14.9	Y
C364	0	12.6	Y
PI085420-1	0	21.1	Y
PI087011	0	18.2	Y
PI89006-2	0	15.5	Y
PII91164	0	24.6	Y
PI157450	0	24.8	Y
PI170899	0	14.5	Y
PI200548	0	19.9	Y
PI215691	0	17.6	Y

Flooding tolerance ; gemiation percentage tested after 4 days soaking of seeds at 25°C.
Seed coat color ; B : black, Y : yellow.

respectively. The moisture content of seed continued to increase to 111～165% of dry weight at 10 hrs. There was no significant difference of increasing of moisture content after 10 hrs soaking. To germinate the soybean seed, moisture content need to be increased to about 50% of dry weight of seed[4]. In this experiment, soybean seed had reached 50% moisture content after 1～2 hrs soaking (except PI54873 and PI186195) and continued to increase after some hours. It also did not find hard seed in the varieties used.

The relationship between seed water uptake and flooding tolerance was not significant under flooding stress (Table 2). In our previous study[1] it was found that all high-tolerance varieties had a black seed coat. The mechanism of flooding tolerance of seed may not be due to the seed coat color or seed water uptake rate, but seed imbibition rate and enzyme activity may affect the water absorption and seed mechanism or the change of metabolic pathway or avoidance of flooding damage[11]. Further studies are needed to understand the biochemical characters of seed during flooding.

Fifteen varieties were sampled to evaluate the varietal difference in weight displacement and germination characters. As shown in Table 3, the influence of these germination characters such as maximum weight displacement of seedling was 6.0～28.5 mm, days to maximum weight displacement of seedlings was 6.5～11.0 days, hypocotyl length was 4.5 ～9.1 mm, root length was 0.7～7.1 mm, and fresh weight was 0.8～2.0 mg. As shown in Figure 2, the relationship between seed flooding tolerance and maximum weight displacement of seedling was not significant. The results indicate that some varieties which have

Table 2. Water uptake of seed during 22 hours soaking for different varieties.
(% of dry weight)

Variety	Time after soaking (hrs)						
	1	2	6	10	14	18	22
C364	69	74	120	125	124	124	125
PI91164	56	59	114	144	143	141	143
PI157450	56	81	130	165	160	162	164
PI165957	56	67	113	136	134	123	123
PI205906	53	78	116	125	126	119	118
PI215691	53	73	102	128	128	124	124
PI232989	53	61	129	125	121	124	125
C162	50	59	105	122	121	123	123
PI222550	48	56	97	115	113	115	115
PI092654	43	77	92	124	137	140	143
PI54873	38	29	79	127	131	120	126
PI79710	35	56	79	116	117	116	117
PI170899	35	60	96	113	115	115	115
PI080470	20	56	102	124	128	130	131
PI186195	18	35	86	111	118	122	123
Mean	45 ± 3.9	61 ± 3.7	104 ± 4.1	126 ± 3.4	127 ± 3.2	126 ± 2.9	128 ± 2.9
Correlation between flooding tolerance	−0.444	−0.353	−0.143	−0.337	−0.286	−0.412	−0.444

Table 3. Characteristics of emergence for different varieties.

Variety	Max weight displacement (mm)	Days to max. Weght displacement (day)	Hypcotyl length (mm)	Root length (mm)	Fresh weight (mg)
PI230201	28.5	10.5	5.7	0.8	1.5
PI070466-3	27.2	9.7	5.1	0.7	1.7
PI200548	26.2	8.4	9.1	2.3	1.7
PI157450	25.8	10.7	6.6	1.0	2.0
PI232989	25.8	9.7	6.6	1.7	1.9
PI082011	19.8	7.4	4.3	6.2	1.7
PI085420-1	16.8	6.5	6.7	7.1	1.8
PI088502	16.3	9.4	5.2	2.9	1.2
PI208430-1	15.5	10.3	5.2	2.7	0.8
PI209334	13.8	7.5	6.0	3.1	1.7
PI186195	11.1	7.4	5.0	2.8	1.0
PI89006-2	9.3	8.1	8.6	4.3	1.8
C364	8.6	8.7	5.7	1.0	1.1
PI170899	7.0	10.0	5.1	0.8	1.3
PI165957	6.0	11.0	4.5	1.1	1.1
LSD (0.05)	7.7	1.3	1.9	1.0	0.4

Maximum weight displacement (elongation force) : height of inner tube lifted by the seeding.

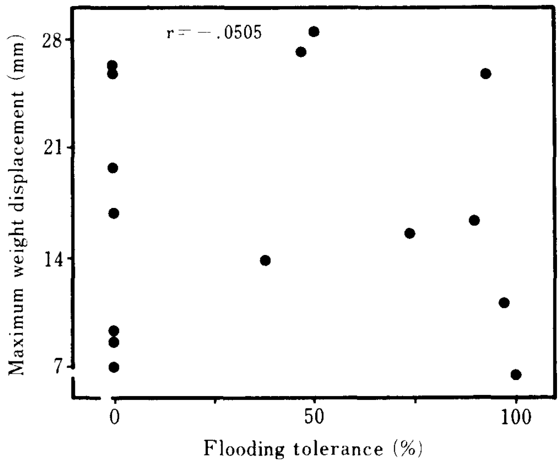

Fig. 2. Relationship between maximum weight displacement and flooding tolerance of seed in different varieties.

larger seeds do not have a greater maximum weight displacement of seedlings and high-tolerance varieties do not always have a smaller maximum weight displacement of seedlings.

Generally, in legumes it is more difficult to obtain a desirable stand than in other crops. This trend appears to be more pronounced when soil physical conditions or management practices are unfavorable, e.g., soil crusting or deep sowing. This may be attributed to the difference in "emergence ability" among soybean varieties. The results of researches in measuring the elongation force of seedlings have been reported[3,7,10]. It has been shown that elongation force of seedling differed among species and the elongation force was positively correlated with seed mass. That is, the large seeded species produce large stems and therefore a stronger elongation force of seedling exists[5,6]. The results of this experiment are in accord with the elongation force of seedlings differing within the same species and the elongation force of seedling was not correlated with seed mass. The results indicate that: 1) there are significant differences in maximum weight displacement of seedlings among soybean varieties, 2) the relationship between seed weight and maximum weight displacement of seedlings is not significant, and 3) the relationship between seed flooding tolerance and seed maximum weight displacement of seedlings is not significant. From the results of this experiment, we may select among the soybean progenies of high seed flooding tolerance and strong elongation force of seedling by cross breeding.

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