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Variability and Its Factors in Ratio of Seed Weight to Pod-Shell Weight in Soybean

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New soybean cultivars have improved not only in seed quality but also in seed yield per unit area[4]. It is considered that this seed yield increase is not only due to the improvement of assimilation rate but also due to the improvement of distribution rate of assimilation products to seeds.

A shoot of soybean plant is composed of seeds, pod-shells, stems, and leaves (including petiols). These organs are formed as a result of distribution of assimilation products. Generally, in case of Kyushu area, the ratio of dry matter weight of seeds, pod-shells, stems and leaves of soybeans are 3 : 1 : 1 : 3, respectively[6]. So pod-shell weight and stem weight occupy a considerable part of total dry matter weight and can not be disregarded.

There are three characteristics which indicate distribution rate of assimilation products to seed. They are harvest index[9], seed weight rate (Appearent Harvest Index)[2,8] and seed stem ratio[3]. Because the former two characteristics include seed weight in denominator, it is very difficult to improve distribution rate of assimilation products to seed. Meanwhile, the latter one is the ratio of seed weight to stem weight, so there is a trouble of lodging in improving distribution rate by decreasing stem weight. Because stem must support seeds.

On the other hand, pod-shell weight occupies large part of pod weight. So the ratio of seed weight to pod-shell weight (used abbreviated word of S/P ratio here) is defined as a characteristic which indicates the distribution rate of assimilation products to seed.

The objective of this study was to discuss factors of the variability in S/P ratio and factors of varietal difference in the ratio by surveying the ratio among pods on individual plant and the ratio of soybean cultivars.

Materials and Methods

Experiment I :

Five cultivars whose S/P ratios are already known were planted at Kyushu National Agricultural Experiment Station farm in Kumamoto on July 20, 1984. The cultivars were approximately same in maturing stage and in 100 seeds weight. Seeds were planted in 3-row plot, 3 m long with 0.6 m row and 0.15 m hill spacing with two replications. Cultivation was carried out according to the conventional way in this area. Three plants of the same growth were picked up from each plot. Their seed weight and pod-shell weight at each pod were measured. In this survey, the S/P ratio was figured out by dividing seed weight by pod-shell weight. These were obtained by measuring air dry weight of sound 2-seeds pods which had about 15% of water content.

Experiment II :

Cultivars used here included groups from early maturing stage to late maturing stage. These materials were planted on the same field as in the experiment I. Seeds were planted in 1-row plot, 2.25 m long with 0.6 m row and 0.15 m hill spacing.

Three plants of the same growth were picked up from each plot. Their seed weight and pod-shell weight were measured at each individual plant. Calculation method was the same as in the experiment I. This investigation, using one hundred and forty-two cultivars, was conducted from 1982 to 1984.

Additionaly, one was selected at randam from among these three plants, and each pod-shell thickness of twenty pods on the

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Table 1. Variability of S/P ratio among pods on individual plants.

Cultivar	Number of pod	S/P ratio	CV (%)		
			Two seeds weight	One pod-shell weight	S/P ratio
Chiyohime	43.1	3.83	11.9	12.7	9.9
Hyuga	43.7	3.90	11.1	12.5	9.7
Akishirome	29.2	3.35	11.1	11.5	9.3
Shin No. 4	28.5	2.45	13.9	12.7	8.6
Udadaizu	46.9	2.69	9.7	12.3	8.9
Mean			11.5	12.3	9.3
F value				13.70**	

** ; Signiffcant at the 1% level, analysis of variance for difference among CVs of three characteristics.

Table 2. Cross correlation coefficients among three characteristics of pods on individual plants (Chiyohime).

Block	Plant no.	Number of pod	S/P ratio		Seed weight
			Seed weight	Pod-shell weight	Pod-shell weight
I	1	45	0.06	−0.64**	0.72**
	2	35	0.24	−0.62**	0.60**
	3	48	0.57**	−0.47**	0.46**
II	1	32	0.26	−0.38*	0.80**
	2	48	0.17	−0.34*	0.87**
	3	51	0.19	−0.51**	0.74**
Mean			0.25	−0.49	0.74

*,** ; Significant at the 5% and 1% levels, respectively.

individual was measured. This investigation, using one hundred and four from the preceeding 142 cultivars, was conducted from 1983 to 1984.

Results

Experiment I :

1. *Variability of S/P ratio among pods in individual plant*

Coefficients of variation of seed weight, pod-shell weight and S/P ratio were 11.5%, 12.3%, 9.3%, respectively on average of five cultivars (Table 1). The CV of the S/P ratio was significantly the smallest. The S/P ratio was found to be a stable characteristic.

Coefficients of cross correlation among these three characteristics in each plant were calculated. The coefficient of correlation between seed weight and pod-shell weight was positive and was the highest among the three coefficients. As the five cultivars showed the same tendency in correlation among these three characteristics, the example of Chiyohime was shown in Table 2 on behalf of the five. It was revealed that the more pod-shell weight increased, the more seed weight did.

2. *Variability of the S/P ratio among pods on different pod set situation of an individual plant*

Coefficient of variation of S/P ratio was 7.3% in pods on main stem, and that of pods on branch was 9.3% (Table 3). The CV of pods on branch was significantly higher than that of pods on main stem. It was clarified that the S/P ratio of pods on branch was more variable than that of pods on main stem.

These S/P ratios were divided into three groups; those from upper node, those from middle node and those from lower node. The S/P ratio of pods on lower node was significantly higher compared with that of

Table 3. S/P ratio of pods on different pod set situations of individual plants.

	Main stem			Branch			F value[1)]
CV (%)	7.31			9.31			5.17*
S/P ratio	3.23			3.29			1.48^{NS}
	Node			Node			
	Lower	Middle	Upper	Lower	Middle	Upper	
S/P ratio	3.30	3.22	3.12	3.34	3.23	3.14	
F value[2)]	8.01**			7.18**			

*,** ; Significant at the 5% and 1% levels, respectively.
1) Analysis of variance for difference between main stem and branch.
2) Analysis of variance for difference among pod set situations.

Table 4. Seed weight and pod-shell weight per pod on different pod set situations of individual plants.

	Situation of pod set node			
	Lower	Middle	Upper	F value[1)]
Two-seeds weight (mg)	547	548	539	—
One pod-shell weight (mg)	170	175	176	2.33^{NS}

1) Analysis of variance for difference among pod set situations.

Table 5. S/P ratio and pod-shell thickness of soybean cultivars.

Year	Number[1)] of pod	S/P ratio[2)] Minimum	Mean	Maximum	CV (%)	Number of pod	Pod-shell thickness[3)] Minimum (μm)	Mean (μm)	Maximum (μm)	CV (%)
1982	40	1.77	2.77	3.81	14.2	—	—	—	—	—
1983	33	1.82	2.91	3.64	11.7	20	72	130	189	15.4
1984	39	1.89	2.94	3.79	12.8	20	102	133	178	12.8
Mean	37	1.83	2.87	3.75	12.9	20	87	132	184	14.0

1) Average of pod number surveyed per a cultivar.
2) Numbers of cultivar were one hundred and forty-two.
3) Numbers of cultivar were one hundred and four.

upper node both in main stem and in branch.

The seed weight of two-seed-pods on lower node and upper node were 547 mg and 539 mg respectively and the pod-shell weight of pods on those two situations were 170 mg and 176 mg, respectively (Table 4). Though not significantly, a tendency was seen that, compared with pods of on upper node, those on lower node had larger seed weight and smaller pod-shell weight.

Experiment II :

1. *Varietal difference in S/P ratio*

The first half of Table 5 shows the average of S/P ratio of one hundred and forty-two soybean cultivars. The average of S/P ratio of all cultivars and its CV were 2.87 and 12.9% respectively on the average of three years. The highest S/P ratio was twice as big as the lowest ratio. Varietal difference in the ratio was recognized significantly among soybean cultivars (Table 6).

2. *Relationship between pod-shell thickness and the S/P ratio*

The latter half of Table 5 shows the average of pod-shell thickness of one hundred and four cultivars. Minimum, mean and maximum of pod-shell thickness were 87 μm, 132 μm and 184 μm, respectively. Significant varietal difference in pod-shell thickness was recognized among cultivars (Table 6). It was shown that there were cultivars with thick pod-shell and cultivars with thin one.

As there was significant negative correlation between the S/P ratio and the pod-shell thick-

Table 6. Analysis of variance for varietal difference in S/P ratio and pod-shell thickness among soybean cultivars.

S/P ratio				Pod-shell thickness			
Factor	D.f.	Mean square	F	Factor	D.f.	Mean square	F
Year	2	12.57	41.37**	Year	1	462.00	6.65**
Cultivar	141	3.53	11.61**	Cultivar	103	619.91	8.92**
Error	282	0.30		Error	103	69.50	

** ; Significant at the 1% level.

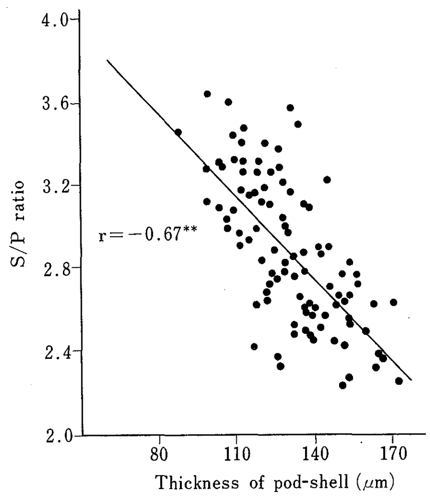

Fig. 1. Relationship between S/P ratio and thickness of pod-shell of soybean cultivars.

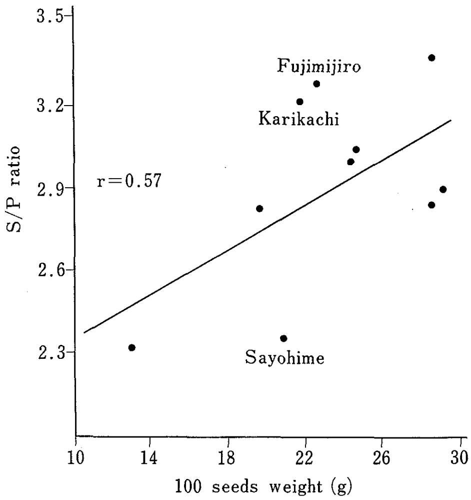

Fig. 2. Relationship between 100 seeds weight and S/P ratio in cultivars with same thickness of pod-shell (126 μm —130 μm)

Table 7. Varietal difference in S/P ratio among soybean cultivars with same pod-shell thickness.

Thickness (μm)	Number of cultivar	S/P ratio			F value[1]
		Minimum	Mean	Maximum	
106∼110	5	2.98	3.22	3.60	7.98**
116∼120	9	2.42	3.02	3.32	11.72**
126∼130	9	2.32	2.89	3.37	20.30**
136∼140	10	2.44	2.71	3.10	7.12**
146∼150	5	2.45	2.66	2.89	5.24*

*,** ; Significant at the 5% and 1% levels, respectively.

1) Analysis of variance for difference among cultivars with same pod-shell thickness.

ness, the cultivar with thin pod-shell was high in the S/P ratio (Fig. 1). However, the figure showed that varietal difference existed even among those with same pod-shell thickness. Therefore, analysis of variance for varietal difference was conducted among S/P ratio of cultivars with same pod shell thickness. As the result, it was recognized that there were varietal differences in the ratio not only among cultivars with thick pod-shell but also among those with thin pod-shell (Table 7).

3. *Pod-shell size and seed weight to S/P ratio*

Fig. 2 shows correlation between S/P ratio and 100 seeds weight of cultivars whose pod-

Table 8. Difference of pod-shell weight among soybean cultivars with same pod-shell thickness and same 100 seeds weight.

Cultivar	Pod-shell thickness (μm)	100 seeds weight (g)	S/P ratio	100 pod-shells weight (g)
Karikachi	129	22.0	3.21	15.6
Sayohime	126	21.0	2.36	20.6
Fujimijiro	128	22.9	3.28	15.4

shell thickness was constant (from 126 μm to 130 μm). There was a tendency that the more seed weight increased the more S/P ratio did. Though the coefficient of correlation between 100 seeds weight and S/P ratio was not significant, in some cases, there was varietal difference in S/P ratio among cultivars with same 100 seeds weight. Sayohime, Karikachi and Fujimijiro had the same 100 seeds weight but their S/P ratios were different. Among these three cultivars, Sayohime's 100 pod-shells weight was larger than that of another two cultivars (Table 8). That shows seed of Sayohime did not grow fully in comparison with its growth of pod-shell. The degree of seed growth to pod-shell size is one of the factors of varietal difference in S/P ratio.

Discussion

Varietal difference was recognized in S/P ratio of soybean cultivars used in this experiment. The values of this ratio agree with previous report[5,6]. And coefficient of variation of the S/P ratio was significantly less than those of seed weight and pod-shell weight. Generally, 100 seeds weight is a characteristic whose variability is relatively small[1], so we might say that the S/P ratio is a characteristic whose variability is relatively small.

Relationship between seed weight and pod-shell weight was closely possitive. So in case of pod whose pod-shell grows fully, seed also grows fully. Therefore, in order to increase seed weight, a suitable environment for increasing pod-shell weight will be needed.

The S/P ratio of the pod on lower node was larger than that of the pod on upper node significantly. Generally, soybean plants with determinate growth habit bloom from middle part of stem to upper and lower part one after another. In case of main stem. pods on lower node were on the 7th—9th node, and in case of branch, on the 3rd—4th node. Hence, those pods are approximately on the middle part of a plant and they are ripened from flowers bloomed early. As these pods have long ripening period, their seeds grow enough and the S/P ratios increase. On the contrary, as pods on upper node are ripened from flowers bloomed late, their ripening periods are short. As a result, the S/P ratios do not increase. This means that assimilation products are not sometimes translated fully from pod-shell to seed. Therefore, it is conjectured that to get high distribution rate, suitable environment is needed in which assimilation products is translated fully from pod-shell to seed.

There was a significant negative coefficient of correlation between the pod-shell thickness and the S/P ratio. This result agrees with previous report[7]. Generally, a cultivar whose pod-shell is thin has high S/P ratio. However, varietal difference in the S/P ratio was recognized even among cultivars which have the same pod shell thickness. So, it is surmised that the degree of seed growth to pod-shell size is one of the factors of varietal difference in S/P ratio. It will be significant to investigate if this factor of the varietal difference is a genetic factor or an environmental one.

The S/P ratio of Misuzudaizu was 3.68 and that of Karikachi was 1.77. Namely the highest S/P ratio was twice as big as the lowest one. For example, if seed yield of those two cultivars were 300 kg per 10a respectively, the pod-shell weight of Misuzudaizu would be 81.5 kg and that of Karikachi would be 169.5 kg. Therefore, of all the assimilation products of Karikachi, 88.0 kg might be distributed to the pod-shell in vain. If this distribution could be done more effectively, the seed yield of Karikachi would increase 88.0 kg more per 10a. Though this is only a simple calculation using weight of dray matter, we can suggest that improving the S/P ratio is a very important means for getting soybean cultivars having high yield ability.

Summary

1. Ratio of seed weight to pod-shell weight (S/P ratio) is considered as a characteristic which indicates distribution rate of assimilation products to seed in soybean. One of the purposes of this study is to survey variability of the S/P ratio among pods on individual plants of soybean cultivars. The another two purposes are to explain varietal difference among the S/P ratio and to discuss the factors of varietal difference in the ratio by surveying thickness and weight of pod-shell of soybean cultivars.

2. The variability of the S/P ratio among pods on an individual plant was lower than that of seed weight and that of pod-shell weight (Table 1). As significantly positive correlation was recognized between seed weight and pod-shell weight, to increase pod-shell weight means to increase seed weight (Table 2). Therefore. it seems to be important to grow up pod-shell fully for seed to be grown up enough.

3. The S/P ratio of pods on lower node was significantly higher than that of pods on upper node of each individual plant (Table 3). Pods on lower node are on the middle part of plants and these pods are from flowers bloomed early and have enough ripening period. So it may be suggested that in order to increase the S/P ratio, sufficient ripening period is needed.

4. There was significant correlation between pod-shell thickness and S/P ratio (Fig. 1). It may be suggested that pod-shell thickness is one of the factors of varietal difference in the S/P ratio.

5. There was varietal difference in the S/P ratio among cultivars with same pod-shell thickness (Table. 7). Moreover, the varietal difference in pod-shell weight was recognized among cultivars with same pod-shell thickness and same 100 seeds weight (Table. 8). Therefore, the degree of seed growth to pod-shell size can also be one of the factors of varietal difference in the S/P ratio among soybean cultivars.

References

1. HORIE, M., K. MIKOSHIBA and H. OGIWARA. 1971. Statistical studies on various characters of crop plant. X. Studies on the variation of characters among individual plants of soybean varieties. Proc. Crop Sci. Soc. Japan **40** : 230—236**.
2. KAMIYA, M and H, SANBUICHI 1979. Harvest index in soybean. Report of the Hokkaido Branch, the Crop Sci. Soc. of Japan and Hokkaido Branch, the Japanese Soc. of Breeding. **19** : 41*.
3. KAWASHIMA, R., N. MARUYAMA, S. SUGIYAMA, K. MIKOSHIBA and H. MATUZAWA. 1962. Studies on yield ability in soybean. I. Traits of high yield cultivars by estimating relationship among characters. Bull. Nagano Pref. Agric. Exp. Stn. **5** : 55—62*.
4. NAKAMURA, S., S. MATSUMOTO and I. WATANABE. 1979. Comparison of characters between new and old soybean varieties recommended in Tohoku district. Bull. Tohoku Natl. Agric. Exp. Sth. **60** : 151—160*.
5. ———— 1982. Seed-pod shell ratio in soybean. Report of the Kyushu branch of the Crop Sci. Soc. of Japan **49** : 91—93*.
6. ————, Y. NAKAZAWA and T. OHBA. 1984. Seed pod shell ratio in soybean. ——Varietal differences and its classification of seed-pod shell ratio——. Report of the Kyushu Branch of the Crop Sci. Soc. of Japan **51** : 17—20*.
7. ————, ———— and ———— 1985. Seed-pod shell ratio in soybean. ——Relationship between seed-pod shell ratio and thickness of pod shell——. Report of the Kyushu Branch of the Crop Sci. Soc. of Japan **52** : 49—51*.
8. SCHAPAUGH, W.T. Jr. and J.R. WILCOX. 1980. Relationships between harvest indices and other plant characteristics in soybeans. Crop Sci, **20** : 529—533.
9. SINGH, I.D. and N.C. STOSKOPF. 1971. Harvest index in cereals. Agron. Jour. **63** : 224—226.

* : In Japanese.
** : In Japanese with English summary.

〔和 文 摘 要〕

大豆における粒莢重比の変動とその要因

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1. 粒莢重比（莢がら重に対する粒重の比）を同化産物の子実への分配効率を表わす形質の一つと規定した．個体内部位別の粒莢重比を調査し，この形質の変動を検討するとともに，多数品種の粒莢重比および莢がらの厚さを調査し，粒莢重比の品種間差およびその要因を検討した．

2. 個体内莢間の粒莢重比の変動は，粒重や莢がら重の変動より安定していた．これは粒重と莢がら重が密接な正の相関関係にあるためで，粒の充実のためには莢がらの充実が重要であることが推察された．

3. 下位節莢は上位節莢より粒莢重比が高かった．これは下位節莢が個体の中央周辺にあり，開花の早い莢が多く，したがって，粒の充実期間が比較的長くなるためと推察された．

4. 莢がらの厚さと粒莢重比は密接な関係があり，粒莢重比の品種間差の要因の一つは莢がらの厚さにある．更に，その厚さを一定にしても粒莢重比に品種間差が認められた．これは粒重が等しくとも莢がら重に差があるからで，莢がらの大きさに対する粒の充実程度も品種間差の要因になっていると推察された．