Influences of Different Planting Times on Harvest Index and Yield Determination Factors in Soybean

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ABSTRACT : This experiment was conducted to investigate the changes of harvest index and the relationship between harvest index and yield determination factors by different planting times in the determinate soybean cultivars, Shinpaldal and Danbaeg. Optimum planting were 23 May in 1995 and 1996. Late planting were 13 June in 1995 and 6 June in 1996. Growth period from planting to physiological maturity (R7) was shortened as planting time was delayed in two cultivars due to shortening of reproductive growth period in Shinpaldal, and of vegetative growth period in Danbaeg. Stem weight was distinctly decreased in late planting compared to optimum planting, but seed weight of both cultivars was not different between planting times. Also, seed number per pod and harvest index were significantly increased in late planting and the high correlation was found between two factors. It was suggested that increase of harvest index in late planting would be related with high assimilate use efficiency due to increase of sink capacity. The results of correlation and principal component analysis for yield determination factors showed that main factor on yield determination was pod number per plant at R5 stage associated with dry matter accumulation during early reproductive growth period, seed number per pod and harvest index were the second factor, and one hundred seed weight was the third factor. The result of this experiment indicated that yield determination in soybean was dependent mainly on pod number per plant related to dry matter accumulation by early reproductive growth period, and the increase of seed number per pod and harvest index could compensate for yield decrease by shortening of vegetative growth period in late planting. Such result suggests that optimum planting date can be delayed from mid May to early June in improved soybean cultivars in Korea.

Keywords : planting time, yield determination factor, harvest index, soybean.

Soybean is typically susceptible crop on photoperiodic response, thus planting time is mainly determinated by the day-length of its grown regions (Chang, 1963). In Korea, optimum planting time is known in mid May. Delay of planting time of soybean resulted in decrease of seed yield (Hong *et al.*, 1988; Lee *et al.*, 1989). Several studies have shown that the decreases of canopy establishment and photosynthesis by shortening growth period from planting to beginning seed stage (R5) in late planting were direct causes of reduction of pod setting and seed number (Board, 1985; Boquet, 1990). Therefore, vegetative growth, crop growth rate, and canopy photosynthesis during the early reproductive growth period from flowering (R1) to beginning seed (R5) were important on determination of pod and seed number per unit area in soybean (Board & Tan, 1995; Board *et al.*, 1995; Board *et al.*, 1996; Jiang & Egli, 1995). Egli & Yu (1991) described the relationship between seeds per area, canopy photosynthesis and assimilate requirement of an individual seed in soybean, and supported Charles-Edwards model (1984).

With the exception of yield difference, the increase of harvest index has been observed at late planting of planting time experiment. Several studies were shown that partitioning coefficient and harvest index were increased at late planting or by delay of planting time (Egli *et al.*, 1985; Johnson & Major, 1979). It was thought that the increase of harvest index at late planting would be related with the increase of sink demand to source in natural environment condition and these changes would be influenced on yield determination factors.

Therefore, on the hypothesis that other factors except of vegetative growth during the early reproductive growth period were related to yield determination at late planting, this experiment was investigated the changes of harvest index and the relationship between harvest index and yield determination factors by different planting times.

MATERIALS AND METHODS

This experiment was conducted at the Research Farm of College of Natural Resources, Korea University from 1995 to 1996. Two determinate soybean cultivars, Shinpaldal and Danbaeg, were planted at optimum and late planting times. Optimum planting were 23 May in 1995 and 1996 and late

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planting were 13 June in 1995 and 6 June in 1996. Planting density was 6015 cm with two seeds in silt-loam soil. Experimental design was a split plot arrangement with three replications. Main plot was planting times and split plot was varieties. Other cultural practices were followed with the standard cultural methods.

Developmental stage from beginning bloom (R1) to full maturity (R8) of plant was determined as defined by Fehr & Caviness (1977). Six plants per plot were sampled four times at beginning pod (R3), beginning seed (R5), physiological maturity (R7), and full maturity (R8) stages. Samples were separated with stem, leaf, pod, and seed, and then plant height, pod, and seed number, and seed number per pod were measured. Dry weight of each separated part was measured after drying with 75 for 48 hrs. Harvest index at each growth stages was calculated as the ratio of seed weight to biological yield. Biological yield was calculated as the vegetative parts, stem, leaf, and pod weight, plus seed weight. The leaf weight at full maturity (R8) stage was excluded from biological yield. Statistical analysis, GLM (general linear model) and principal component analysis, of collected data were performed with the SAS PC package.

RESULT AND DISCUSSIONS

Growth period

The days required from planting to physiological maturity (R7) in two cultivars were shown in Fig. 1. Growth days to R7 stage of optimum and late planting in Shinpaldal were 122 and 104 days, respectively, and those of Danbaeg were 130 and 117 days, respectively. It appeared that the growth days of two cultivars were shortened by delay of planting time. As total growth period was separated with vegetative

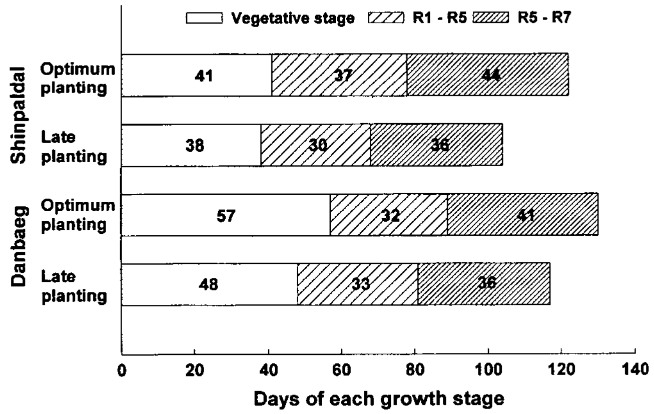

Fig. 1. The mean days required to the indicated growth period of two soybean cultivars at optimum and late planting in1995 and 1996.

growth period, beginning bloom (R1) to beginning seed (R5), and R5 to R7 stage, the percentages of the days required three indicated growth period were compared (data were not shown). The percentages of vegetative growth and reproductive growth period in Shinpaldal were 33~36% and 63~66%, respectively, and those of Danbaeg were 41~44% and 56~59%, respectively. The percentage of reproductive growth period was higher in Shinpaldal than Danbaeg.

The responses of changes in growth day by delay of planting time in each cultivar were different. By the delay of planting time, reproductive growth period was more decreased in Shinpaldal than in Danbaeg. It was resulted from the more shortening of reproductive growth day in Shinpaldal belong to medium maturity group and the more shortening of vegetative growth day in Danbaeg belong to late maturity group by delay of planting time as shown Fig. 1. Therefore, the responses of growth day by delay of planting time were appeared more sensitive on the reproductive growth period in medium maturity group and on the vegetative growth period in late maturity group.

Seed weight and harvest index

Seed yield and yield components were compared in Table 1. On the difference between years, seed number per pod, and 100-seed weight were shown significant different. Seed weight and seed number per plant were not different but they tended to be high in 1996. It was thought that the differences between years on yield components were caused by precipitation during the growth period (data were not shown). The precipitation during the whole growth period was higher in 1995 than 1996. However, by the comparison with each growth stage, the higher precipitation during the R1R5 stage in 1995 resulted in decrease of pod setting and seed number. In 1996 the proper precipitation at each growth stage was advantageous on growth and seed yield.

In the difference by planting time treatment, stem weight, seed number per pod, 100-seed weight, and harvest index were appeared significantly different. Stem weight was distinctly decreased to 5.9 g per plant at late planting from 10.4 g per plant at optimum planting. However, seed number and seed weight were not different. It was shown that no difference in seed number and weight per plant in spite of the decrease of stem weight at late planting were compensated with pod number and the increase in seed number per pod at late planting. These results suggest that delay of optimum planting date from mid May to early June is possible in improved soybean cultivars in Korea. Also, optimum planting date of Shinpaldal, which belongs to medium maturity group, was appeared earlier than that of Danbaeg.

Seed number per pod and harvest index were significantly

Table 1. Yield components and the related factors of two soybean cultivars at full maturity (R8) of optimum and late planting in 1995 and 1996.

Year	Treatment	Cultivar	Stem weight	Seed weight	Pod number per plant	Seed numberper plant	Seed number per pod	100-seed weight	Harvest index†	Seed yield
			- g/plant -					- g -		-ton/ha-
1995	Optimum	Shinpaldal	10.3	17.3	68	95	1.3	18.2	0.47	3201
		Danbaeg	11.6	10.8	71	83	1.2	13.1	0.36	1998
	Late	Shinpaldal	3.6	12.4	52	85	1.6	14.6	0.60	2294
		Danbaeg	5.2	10.7	56	86	1.6	12.5	0.52	1980
1996	Optimum	Shinpaldal	7.5	17.3	43	80	1.9	21.6	0.56	3201
		Danbaeg	12.3	20.1	81	142	1.8	14.0	0.49	3719
	Late	Shinpaldal	7.4	20.5	53	102	1.9	20.0	0.59	3793
		Danbaeg	7.4	21.1	75	141	1.9	14.8	0.56	3904
1995			7.7	12.8	62	87	1.4	14.6	0.49	2368
1996			8.7	19.8	63	116	1.9	17.6	0.55	3654
	Optimum		10.4	16.4	66	100	1.5	16.7	0.47	3030
	Late		5.9	16.2	59	103	1.8	15.5	0.57	2993
		Shinpaldal	7.2	16.9	54	91	1.7	18.6	0.56	3122
		Danbaeg	9.1	15.7	71	113	1.6	13.6	0.47	2900
$LSD_{0.05}$ between		Year (Y)	ns‡	ns	ns	ns	0.12	2.36	ns	ns
		Treatment (T)	1.31	ns	ns	ns	0.12	0.84	0.038	ns
		T*Y	1.85	ns	ns	ns	ns	ns	ns	ns
		Cultivar (C)	1.48	ns	11.8	ns	ns	0.97	0.042	ns
		C*Y	ns	ns	16.7	37.0	ns	1.37	ns	ns
		C*T	ns	ns	ns	ns	ns	1.19	0.053	ns
		C*T*Y	ns	ns	ns	ns	ns	ns	ns	ns

†Harvest index = seed weight/(stem+pod+seed weight)
‡ns : nonsignificance

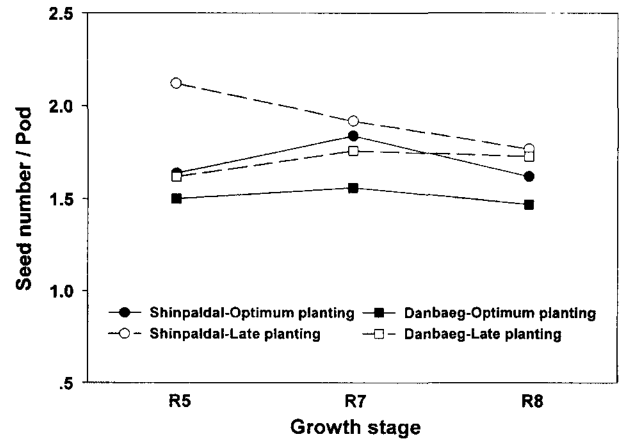

Fig. 2. Seed number per pod at three growth stages of two soybean cultivars at optimum and late planting in 1995 and 1996.

increased at late planting in two cultivars. Harvest index was not direct factor for yield determination. However, in this experiment, increase of harvest index seemed to related with yield determination by the increase of seed number per pod at late planting and the two factors were influenced by the planting time. As shown Fig. 2, seed number per pod was higher in each growth stage after R5 stage at late planting in two cultivars. It was thought that the increase of seed number per pod in late planting resulted from the increasing of assimilate partitioning to pod by the decrease of vegetative growth. On the hypothesis that short distance translocation of photo-assimilates in soybean was limited to the first or second node on assimilating leaf (Heitholt *et al.*, 1986; Thrower, 1962), the increase of harvest index means the increase of sink demand to source. Therefore, it was thought that the increase of seed number per pod improved the harvest index by the increase of sink demand on each node, and the assimilate use efficiency was improved at late planting.

Yield determination factors

Correlations among the yield components at full maturity (R8) were shown in Table 2. Seed weight was positively correlated with seed number per plant which was positively

Table 2. Correlation coefficients of yield components and the related factors at three growth stage of two soybean cultivars at optimum and late planting in 1995 and 1996.

Growth stage	Variable	ST	PN	SN	SPP	HSW	HI (Harvest index)
R5	Total weight (TW)		0.789**	0.638**	-0.231	-0.295	-0.536**
	Pod number per plant (PN)			0.889**	-0.041	-0.130	-0.196
	Seed number per plant (SN)				0.409*	-0.161	-0.062
	Seed number per pod (SPP)					-0.038	0.341
	100-seed weight (HSW)						0.861**
R7	TW		0.852**	0.794**	0.019	0.179	-0.203
	PN			0.912**	-0.064	-0.188	-0.087
	SN				0.332	0.053	0.260
	SPP					0.612**	0.850**
	HSW						0.488*
R8	Seed weight (SW)	0.412	0.516**	0.826**	0.639**	0.465*	0.353
	Stem weight (ST)		0.680**	0.435*	-0.227	0.042	-0.666**
	PN			0.796**	-0.107	-0.361*	-0.323
	SN				0.500*	-0.101	0.186
	SPP					0.384	0.772**
	HSW						0.330

*, **significant at the 0.05 and 0.01 levels, respectively.

Table 3. Eigenvalues and contribution rates of three principal components obtained from principle component analysis of yield component and the related factors.

	Eigenvalue	Difference	Proportion	Cumulative
Prin 1	3.908	1.144	0.434	0.434
Prin 2	2.764	1.496	0.307	0.741
Prin 3	1.268	0.473	0.140	0.882

Table 4. Eigenvectors of 7 variables of each principal component.

Variable	Prin 1	Prin 2	Prin 3
Seed weight	0.472	0.199	0.052
Stem weight	0.328	-0.369	0.336
Pod number per plant	0.382	-0.323	-0.203
Seed number per plant	0.462	0.002	-0.335
Seed number per pod	0.224	0.470	-0.241
Harvest index	0.033	0.553	-0.284
100 seed weight	0.108	0.355	0.600
Main variables affecting eigenvectors of princomponents	Seed number per plant, Pod number per plant	Seed number per pod, Harvest index	100-seed weight

correlated with pod number per plant and seed number per pod. Also, it was appeared that pod number per plant was highly correlated with stem weight and seed number per pod was highly correlated with harvest index. These results were similar with the result of principle component analysis in Table 3 and 4. Table 4 showed that the principal component 1 (prin1) was contributed with the factors related with dry matter accumulation such as seed number per plant, pod number per plant, and stem weight, and the principal component 2 (prin2) was contributed with the factors such as seed number per pod and harvest index, and the principal component 3 (prin3) was contributed with 100-seed weight. Therefore, these data indicated that main factor of yield determination was pod number per plant associated with dry weight accumulation, seed number per pod and harvest index influenced by planting time were second factor, and one hundred seed weight was the third factor.

To understand relationships between pod number per plant and vegetative growth, and between seed number per pod and harvest index, correlations between the factors by the growth stage were analyzed in Table 2. Pod number per plant was highly correlated with the total dry weight at R5 and R7 stage. It was thought that pod number per plant was mainly dependent on the total weight at R5 stage rather than at R7 stage, because the total weight at R7 stage was included with pod weight. The linear regression equations between two factors at R5 stage were shown in Table 5 and Fig. 3. This result was agreed with other studies that vegetative growth during the early reproductive growth periods, from beginning bloom (R1) to beginning seed (R5), were important on determination of yield (Board & Tan, 1995; Board *et al.*, 1995; Board *et al.*, 1996; Jiang & Egli, 1995).

Highly positive correlation between seed number per pod and harvest index was shown after R7 stage in Table 2. It was thought that seed number per pod influenced on harvest

Table 5. Linear regression relationships between total dry weight and pod number per plant at R5 and R7 stage and between seed number per pod and harvest index at R7 and R8 stage of two soybean cultivars at optimum and late planting in 1995 and 1996.

Dependent value	Independent value	Growth stage	Cultivar	Treatment	Slope	Intercept	R^2
Pod number per plant	Total dry weight	R5	Shinpaldal		0.445	36.692 ± 7.054	ns
			Danbaeg		1.715	12.554 ± 12.646	0.706**
				Optimum	2.151	-12.193 ± 11.072	0.803**
				Late	1.444	22.809 ± 8.602	0.723**
		R7	Shinpaldal		0.711	27.773 ± 6.860	0.532**
			Danbaeg		1.604	12.874 ± 6.707	0.908**
				Optimum	2.323	-27.192 ± 10.543	0.895**
				Late	1.125	25.336 ± 6.701	0.744**
Harvest index	Seed number per pod	R7	Shinpaldal		0.520	-0.451 ± 0.474	ns
			Danbaeg		0.420	-0.255 ± 0.069	0.911**
				Optimum	0.422	-0.293 ± 0.130	0.754**
				Late	0.271	0.045 ± 0.111	0.673**
		R8	Shinpaldal		0.176	0.257 ± 0.089	0.532**
			Danbaeg		0.224	0.128 ± 0.073	0.709**
				Optimum	0.211	0.147 ± 0.060	0.752**
				Late	0.062	0.462 ± 0.113	ns

*, **significant at the 0.05 and 0.01 levels, respectively.

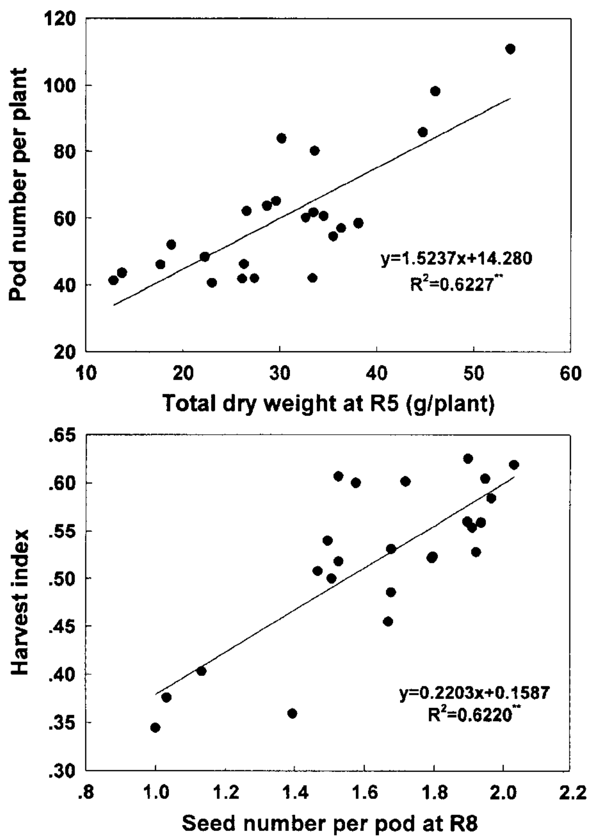

Fig. 3. Linear regressions between total dry weight and pod number per plant at R5 stage and between seed number per pod and harvest index at R8 stage of two soybean cultivars at optimum and late planting in 1995 and 1996.

index during the late reproductive growth period. In this experiment, seed number per pod was indicated as an important second factor of yield determination, and the improving factor of assimilates use efficiency by increase of harvest index. The linear regression equations between two factors at R8 stage were shown in Table 5 and Fig. 3.

Therefore, data from this experiment indicated that yield determination in soybean was dependent mainly on pod number per plant related to dry matter accumulation during early reproductive growth period. The increases of seed number per pod and harvest index were appeared as another important factors could compensate for yield decrease by the decrease of vegetative growth in late planting. Such result suggests that optimum planting date can be delayed from mid May to early June in improved soybean cultivars in Korea.

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