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Effects of Planting Dates on Growth and Yield of Soybean Cultivated in Drained-Paddy Field

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ABSTRACT : This study was carried out to determine adequate planting date, to compare the growth characteristics between early and late maturing cultivars, and to provide the data for the cultivation techniques of soybean [*Glycine max* (L.) Merr.] in double cropping system with winter crops on paddy field in Korea. Cultivars were planted on 26 May, 16 June, and 7 July with a planting density of 70 cm (row width) × 10 cm (planting spacing). Seed yield of soybean planted on June 16 and July 7 was approximately 37% and 53%, respectively, less than that of conventional planting date of May 26 in Pungsan-namulkong, and planted on June 16 and July 7 was about 30% and 37%, respectively, less then that of conventional planting date of May 26 in Hanamkong. The number of pods and seeds per plant decreased as planting date delayed. Seed weight increased in Pungsan-namulkong but decreased in Hannamkong as planting date delayed. The flowering date was late in delayed planting plots, but it was shorted for days from emergence to flowering and from emergence to maturity. The plant height of Hannamkong was greater than Pungsan-namulkong from the emergence to flowering stages, but in contrast, it was greater in Pungsan-namulkong than Hannamkong after flowering stage (50 d after emergence) when it planted on May 26. There were no significant differences between two soybean cultivars at planting dates of June 16 and July 7. Leaf number, leaf area, and dry matter were also reduced by late planting, and Both of them were shown in high reduction at the later planting. There was a high significant difference at the flowering (r = 0.87) and pod formation (r = 0.91**) stages between leaf dry matter and seed yield. Crop growth rate (CGR) was greater at R2~R3 growth stages compared to R3~R4 or R4 ~ R5 growth stages in two soybean cultivars and the greatest CGR was obtained at planting date of May 26 in two soybean cultivars except for R4~R5 growth stage in Pungsan-namulkong. There was a highly significant positive difference between the seed yield and the leaf area index (LAI) across R3 to R4 and R2 to R3 stages. The photosynthetic rate (P_N) of the uppermost leaf position had no significant difference among planting dates and between two soybean cultivars. However, P_N of the 7th leaf position increased as the planting date delayed.**

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Increasing soybean yields at late planting dates (after mid June) is major agronomic objectives in southern Korea where adverse double cropping after winter cereals. In this practice of double cropping, planting dates of soybean are delayed until late June to early July. This delay reduced yield and affected most agronomic characteristics compared with full season soybean (Quattara & Weaver, 1994). Late-planted yields can be improved by correcting environmental stresses that slow down CGR during emergence to R5 stage (Fehr *et al.*, 1971; Board & Harville, 1996) and by narrowing inter-row spacing and increasing plant population (Boquet, 1990).

Delayed planting reduced the number of days to maturity (Board & Harville, 1996), reduced the number of days to flowering, and decreased the length of vegetative and reproductive periods of development. Delayed planting also decreased plant height, stem width, number of branches and number of main stem nodes, perhaps due to a shorter vegetative period (Parker *et al*, 1981; Chu *et al.*, 1996; Seung *et al.*, 1995). This reduction was more pronounced for late maturing cultivars than for early maturing cultivars (Shin *et al.*, 1992). However, although these reports indicated that late maturing cultivars decreased more than early maturing cultivars, others indicated similar with two maturing types or conversely, decrease more early maturing cultivars than late maturing cultivars (Chung, 1988). Also, growth reduction was more pronounced for indeterminate cultivars than determinates (Chu *et al.*, 1996; Quattara & Weaver, 1994)

On the other hand, in order to elevate the self-supply, to increase the yield per unit area and to extend the cultivation area of soybean in Korea, it is necessary to extend the cultivation area to paddy fields. However, in case of soybean cultivation on the paddy field, there was one of the important factors in waterlogged which was caused by heavy rainfall or poor drainage at rainy seasons (late June to August). Also, detrimental effects of prolonged rainfall are usually attributed to an inadequate oxygen supply to sustain root respiration and root availability (Seong *et al.*, 2000).

Therefore, this study was carried out to determine adequate planting dates, to compare growth characters between early and late maturing cultivars, and to provide the data for the cultivation techniques in double cropping system with winter crops on paddy field in Korea

MATERIALS AND METHODS

Field studies were conducted at the Honam Agricultural Research Institute on Junbuk Province in the southwestern Korea (36° N) on a commerce silt loam soil at paddy field.

The early maturing cultivar (cv. Hannamkong; semi-determinate growth habit) and the late maturing cultivar (cv. Pungsan-namulkong; determinate growth habit) were chosen for study (Shin *et al.*, 1995; Suh *et al.*, 1997). Cultivars were planted on May 26, June 16, and July 7, using a planting density of 70 cm (row width) × 10 cm (planting spacing). Plants were sowed with a high seeding rate and thinned with two plants prior to V3 stage. Based on soil test recommendations, fertilizer was applied prior to planting at a rate of 1.5-1.5-1.7 g (N-P-K) per m^2. Weeds, diseases, and insects were controlled by recommended pesticides.

Main plots were cultivars and split-plots were planting dates in a split plot design with each split plot replicated three times in randomized complete blocks. The plant samples for measuring plant height, leaf numbers per plant, number of main stem nodes, main stem width, and dry matter were obtained at 20, 30, 40, 50, 60, 70, and 80 d after emergence. The number of leaves was counted. Leaf area was determined by leaf area meter (LI-COR Li-3100, USA).

The photosynthetic rate (P_N) of the uppermost leaf position and 7th leaves of main stem was measured using a portable photosynthesis instrument measuring device (LCA-4, UK) at the flowering (R2 by Fehr *et al.*, 1971) and the seed development stage (R5). Measurements of six replications per each cultivar were taken from 9 : 30 in the morning to 2 : 30 in the afternoon. The light intensity used to measure the photosynthesis was in the range of 1700 ~ 2000 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR) The CO_2 concentration was 330 ~ 370 ppm and the flow rate of the air was 400 ml min^{-1}.

Net assimilation rate (NAR), leaf area ratio (LAR), crop growth rate (CGR), and specific leaf area (SLA) were derived by following equations (Hunt 1982) where W, T and L_A represented weight (g), time (day) and leaf area (m^2), respectively.

$$\mathrm{CGR}\ (g\ m^2\ d^{-1}) = \partial W/\partial T$$
$$\mathrm{NAR}\ (g\ cm^2\ d^{-1}) = 1/L_A \times \partial W/\partial T$$
$$\mathrm{LAR}\ (cm^2\ g^{-1}) = L_A/W$$
$$\mathrm{SLA}\ (cm^2\ g^{-1}) = 1/2(L_{A2}/W_2 + L_{A1}/W_1)$$

RESULTS AND DISCUSSION

Yield and yield components

Delayed planting dates from May 26 to July 7 had a large effect on the seed yield of two soybean cultivars (Table 1). The seed yield of Pungsan-namulkong planted on June 16 and July 7 was approximately 37% and 53%, respectively, less than that of conventional planting date (May 26). Also, the seed yield of Hanamkong planted on June 16 and July 7 decreased about 30% and 37%, respectively, compared to the seed yield of soybean planted on May 26. According to planting dates, the yield reduction of Pungsan-namulkong was greater than Hannamkong.

Lee *et al.* (1989) reported the effect of planting date in yield of soybean cultivars. The yield decreased more in late maturing cultivars than in early or middle maturing cultivars. This result indicated that the reduction of seed yield according to delayed planting resulted from insufficiency of seed development due to shorter vegetative periods which affected reproductive stages with sensitive response against

Table 1. Yield and yield component of two soybean cultivars with different planting dates

Cultivar	Planting date	Number of pods (no. $plant^{-1}$)	Number of seeds (no. $plant^{-1}$)	Seeds per pod (no.)	Seed weight (g 100 $seed^{-1}$)	Yield (g m^{-2})
Pungsan Namulkong	May 26	60.0	119.7	2.00	10.9	362
	June 16	30.7	55.9	1.82	12.3	228
	July 7	27.0	46.9	1.74	13.2	170
Hannamkong	May 26	40.0	71.5	1.80	12.3	260
	June 16	30.6	55.3	1.81	11.8	181
	July 7	28.8	52.3	1.81	11.1	163
Cultivar (A)		ns	*	*	*	**
Planting date (B)		**	**	**	*	**
A×B		*	**	ns	**	*
CV (%)		17.5	19.4	5.2	2.9	11.4

Table 2. Date of flowering, days from emergence to flowering and days from emergence to maturity of two soybean cultivars in different planting dates.

Cultivars	Planting Date	Flowering Date	Emergence to Flowering (Day)	Emergence to Maturity (Day)
Pungsan namulkong	May 26	July 30	58	129
	June 16	August 11	41	119
	July 7	August 15	35	106
Hannamkong	May 26	July 21	49	114
	June 16	August 4	35	110
	July 7	August 12	32	101

a short daytime and high temperature (Table 2) The number of pods and seeds per plant also decreased with delayed planting dates. The reduction was more in Pungsan-namulkong than in Hannamkong with delayed planting date

The seed weight of Pungsan-namulkong increased with delayed planting dates but which of Hannamkong decreased. Although the seed weight, number of pods, and number of seeds were reduced by delayed planting dates, increase of seed weight of Pungsan-namulkong showed relatively fewer seeds per pod in delayed planting date than that of conventional planting dates. However, there was no significant difference in delayed planting dates in seeds per pod and seed weight of Hannamkong which was an early maturing cultivar

On the other hand, the flowering date was late in delayed planting dates, but days from emergence to flowering were shorted and days from emergence to maturity (Table 2). When soybean was planted on May 26, the flowering date was earlier about 7 days in Hannamkong by July 21 compared to that of Pungsan-namulkong by July 30. Also, when planted on June 16 and July 7, the flowering date was August 4 and 12, respectively, in Hannamkong, and August 11 and 15, respectively, in Pungsan-numkong. Days from emergence to flowering and days from emergence to maturity also were shorter in Hannamkong than in Pungsan-namulkong with delayed planting dates.

The plant height of Hannamkong was greater than Pungsan-namulkong across the emergence to flowering stages but, in contrast, the plant height of Pungsan-namulkong was greater than Hannamkong after the flowering stage (50 d after emergence) when planted on May 26 There were no differences, however, between two soybean cultivars planted on June 16 and July 7 (Fig. 1). The plant height of soybeans was measured at 80 days, 70 days, and 60 days after the emergence once these were planted on May 26, June 16, and July 7, respectively.

The plant heights of Pungsan-namulkong and Hannamkong planted on May 26 were 59.5 cm and 49.0 cm, respectively, at R1 growth stage, but they were reduced as 31.4 cm and 28.3 cm at the late planting date of June 16, and as 25 3 cm

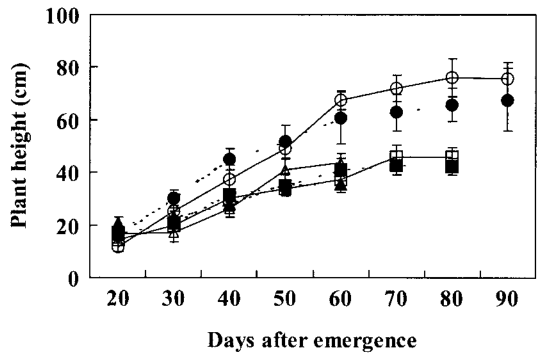

Fig. 1. Plant height of two soybean cultivars in different planting dates Light symbol indicates Pungsan-namulkong and dark symbol indicates Hannamkong ● and ○ were planted on May 26, ■ and □ was planted on June 16, and △ and ▲ were planted on July 7. Means are ±SE, n=9.

and 18.3 cm at the late planting date of July 7, respectively.

The leaf number, leaf area, and dry matter were also reduced by late planting. However, although the growth of main stem was stopped at the flowering stage in determinate soybean cultivars, the main stem was progressively growing after flowering stages in paddy field. The plant heights of Pungsan-namulkong reduced by 59.5, 31.4, and 25.3 cm, and of Hannamkong reduced by 49.0, 28.3, and 18.3 cm at R1 growth stages when planted on May 26, June 16, and July 7, respectively. The leaf number, leaf area and dry matter were reduced by delayed planting in Hannamkong than in Pungsan-namulkong (Table 3).

Reduction of the number of leaf with the late planting was 17% and 38% on June 16 and on July 7, respectively, in Pungsan-namulkong, and was 31% and 43% on June 16 and July 7, respectively, in Hannamkong compared to on May 26.

Also, the leaf area reduced with the late planting about 17 to 24% on June 16, and 33 to 36% on July 7 compared to on May 26. Dry matter of leaves and roots also reduced similar to the leaf number and leaf area with the late planting. On the other hand, there was a high significant relationship between leaf dry matter and seed yield at the flowering (r = 0.87**) and pod formation (r = 0 91**) stages, but no significant relationship at seed development stages (Fig. 2).

Table 3. Growth traits of two soybeans at R1 and R5 growth stages in different planting dates.

Cultivar	Planting date	Number of leaves (no m^{-2})		Leaf area (m^2 m^{-2})		Dry matter (g m^{-2})			
						Leaf		Stem	
		R1	R5	R1	R5	R1	R5	R1	R5
Pungsan namulkong	May 26	459	713	2 06	4.20	131	237	297	550
	June 16	322	589	1.31	3 22	87	168	191	355
	July 7	284	439	1.14	2 82	75	144	173	304
Hannamkong	May 26	376	750	1.81	3.52	89	226	167	434
	June 16	236	521	1 07	2.67	52	143	105	267
	July 7	189	425	0 90	2.26	47	129	96	222
Cultivar (A)		*	ns	*	*	*	ns	**	**
Planting date (B)		**	**	**	**	**	**	**	**
A x B		*	*	**	*	**	ns	**	*
CV (%)		15 7	15 1	14 7	16.2	13 9	13 1	15.9	13 3

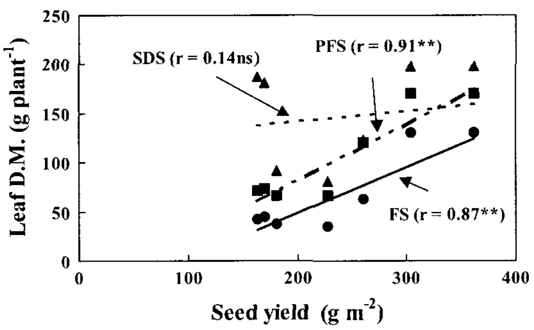

Fig. 2. Relationship between seed yield and leaf dry matter with different planting dates in two soybean cultivars ● : flowering stage (FS), ■ pod formation stage (PFS), ▲ seed development stage (SDS).

Results from this study were similar to results from Ookawa *et al* (1999). They carried out the study to compare yields of two soybean cultivars, and stated that soybean cultivar of higher dry matter after flowering could attain a higher seed yield Therefore, in order to obtain the most seed yield, the most leaf dry matter production at R1 ~ R4 growth stages was very important during reproductive growth stages of soybean.

Growth analysis

The CGR was greater at R2 ~ R3 stages compared to R3 ~ R4 or R4 ~ R5 growth stages in two soybean cultivars, and the greatest CGR was obtained at planting date of May 26 in two soybean cultivars except for R4 ~ R5 growth stages in Pungsan-namulkong (Table 4). Kokubun & Watanabe (1982) observed that high-yielding cultivars tended to have higher CGR during the flowering and pod formation stages. Ookawa *et al.* (1999) reported that the CGR during ripening was clearly high in cultivars of high seed yield. The CGR under the conventional planting date of May 26 was higher in Pungsan-namulkong than in Hannamkong, but it was opposite compared to the conventional planting date for relatively late planting of after mid-June. Therefore, present results indicated that the reduction of seed yield in early ripening growth habit types by late planting was smaller than that of other types

Board & Harville (1996) stated that increasing level of CGR across R1 to R5 stages showed a very important factor in seed yield at relative growth rate with late planting. From this report, since the greater CGR was obtained from a relative lower planting density and earlier planting time, our results was different from this report. They also stated that optimal gain was mainly related to a rapid vegetative growth and a high capability to expand the leaf area during the period of flowering at high planting density. Board & Harville (1996) stated that increasing level of CGR across R1 to R5 stages in higher density showed a very important factor in seed yield at relative growth rate with late planting.

NAR of soybeans at conventional planting date of May 26 was greater in Punsan-namulkong than in Hannamkong in general, but the NAR of the later planted soybean was greater in Hannamkong than in Pungsan-namulkong.

The NAR of Pungsan-namulkong was the greatest at R2 ~ R3 stage, thereafter it was slightly decreased. But the greatest NAR of Hannamkong was obtained at the latest planting date of July 7. The LAR showed slightly increasing tendency at the later planting dates during reproductive growth stages (across R2 ~ R5) in the two soybean cultivars. The LAR was lower in Pungsan-namulkong than in Hannamkong planted on May 26, but it was not different in two soybean cultivars at late planting date except for LAR at R4 ~ R5 stages planted on July 7. The SLA also showed similar

Table 4. Growth analysis of two soybean cultivars across flowering and seed development stages in different planting dates.

Growth Stages	Planting date	CGR ($g\ d^{-1}$)		NAR ($g\ m^2 d^{-1}$)		LAR ($cm^2 g^{-1}$)		SLA ($cm^2 g^{-1}$)	
		PSN	HN	PSN	HN	PSN	HN	PSN	HN
R2 ~ R3	May 26	24 2±2 5	22 8±2.6	8.5±0.6	4 5±0 6	57.6±7.0	80 5±7.9	52 7±5.4	79.4±7 7
	June 16	14 3±1 3	16 9±1.9	7.5±0 8	8 3±0.9	102.2±9 1	97 4±8 9	95 1±8.4	89.3±8 1
	July 7	12 3±1 7	12 9±0.6	7.2±0.7	8 4±0.8	107.8±10 1	106.7±9 4	118.3±11.2	114.6±9 1
R3 ~ R4	May 26	21 3±3.1	23 8±3 3	7.5±0.6	3 8±0.4	54.3±6.7	66.5±6 8	55 7±4 8	57 6±4 9
	June 16	15.0±0.8	12 9±1 3	5.4±0.5	5.7±0.5	93.8±8 1	94 5±9 9	92.6±7.8	99 2±8 2
	July 7	14 9±1.1	12 9±1 7	4.6±0 5	7 1±0.9	114.2±9.1	120 8±10 3	110 8±9 4	126 3±10 1
R4 ~ R5	May 26	15 0±0 9	16 7±2 1	3.9±0.4	2 3±0.3	53 9±5 8	62 3±5 7	55.2±4.7	66 9±5 2
	June 16	16 0±1 6	14.8±1 6	4 1±0 4	4.9±0.6	94 1±8 6	97 6±8 2	95.4±7 4	96 3±8 1
	July 7	21 7±3 2	10.8±1.0	4.3±0.3	5.9±0 6	104 7±10 1	114.1±9 6	84.1±7.1	105 6±8 9

[J] Pungsan-namulkong, [h]Hannamkong

Table 5. Photosynthetic rate (CO_2 mol $m^{-2}\ s^{-1}$) of the uppermost leaf and 7th leaf positions of two soybean cultivars at the flowering and seed development stages in different planting dates

Cultivar	Planting date	Flowering stage		Seed development stage	
		Uppermost leaf	7th leaf	Uppermost leaf	7th leaf
Pungsan-namulkong	May 26	26 2±4 8	12.2±5.9	32.5±5 0	10.4±6 4
	June 16	31.1±1.8	24.7±4 8	32.8±4 0	17.4±6 8
	July 7	29 0±1 7	22 7±6 2	36.5±4 9	17.7±3 7
Hannamkong	May 26	24.2±4.9	13 0±4 5	30.3±6 9	10.1±5 8
	June 16	29.1±6.7	22.3±3.7	32.6±6.5	13.5±1.5
	July 7	31 7±2 4	28 7±4 0	30.2±4 3	14.4±2 9

trend as LAR.

Photosynthesis

The P_N of the uppermost and the 7th leaf positions at the flowering and seed development stages were shown in Table 5. The P_N of the uppermost leaf position had no significance among planting dates and between two soybean cultivars. However, the P_N of the 7th leaf position increased as the planting date delayed. The P_N at the flowering stage, Pungsan-namulkong was the highest by 24.7 CO_2 µmol $m^{-2}\ s^{-1}$ in planted on June 16 and Hannamkong was the highest by 28 7 µmol $m^{-2}\ s^{-1}$ planted on July 7.

At the seed development stage, the highest P_N of Pungsan-namulkong planted on July 7 was 17.7 CO_2 µmol $m^{-2}\ s^{-1}$ and of Hannamkong planted on July 7 was 14.4 CO_2 µmol $m^{-2}\ s^{-1}$ in. The P_N on the 7th leaf position of Pungsan-namulkong was greater than that of Hannamkong at the seed development stage.

Cho *et al.* (2003) reported that photosynthesis at seed development stages among soybean cultivars showed positive correlation with seed yield in middle and lower leaf position. Sagawa (1998) also showed the positive correlation with yields at seed development stage. From this experiment, higher yield of Pungsan-namulkong compared with that of Hannamkong might cause to increase the P_N at middle and lower leaf as well as the 7th leaf position at the seed development stage planted on June 16 and July 7. Also, there was a positive correlation (r = 0.75*) between P_N of the 7th leaf positions and SLA, but no significance (r = 0 17ns) between P_N of the uppermost leaf positions and SLA (Fig 3)

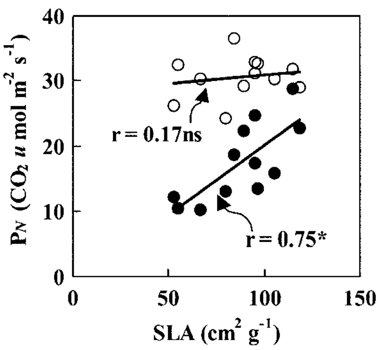

Fig. 3. Relationships between photosynthetic rate (P_N) and leaf specific area (SLA) at the flowering (○) and the seed development (●) stages with different planting dates in two soybean cultivars.

Generally, the P_N of middle and lower leaves had an intimate relationship with the light intensity character of the leaf, the late planted soybeans had less LAI, and the size of individual leaf area was smaller compare to the conventional planted soybeans. So, the late planted soybeans had a good light intensity at middle and lower leaves (Cho *et al.*, 2003; Sagawa, 1998). In this experiment, late planted soybeans showed higher P_N than the conventionally planted soybeans, and Pungsan-namulkong had higher P_N than Hannamkong. Some reporters stated that there was no correlation between the photosynthesis and yield because the photosynthesis was measured with flourished leaves (Ford *et al.*, 1983; Kukubun *et al.*, 1988).

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