Korean J. Crop Sci. 49(2): 105~109(2004)

# Effects of Planting Densities and Maturing Types on Growth and Yield of Soybean in Paddy Field

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**ABSTRACT: Field studies were conducted in the southeastern Korea (36°N) on a commerce silt loam soil at paddy field. Seed were manually planted on 16 July 2003. Plants were planted with plant densities of 70 × 10 cm (row width x plant spacing), 50 × 10 cm, and 30 × 10 cm. Two seedlings per hill were taken prior to V3 stage. Fertilizer was applied prior to plant at a rate of 30-30-34 kg ($N$-$P_2O_5$-$K_2O$) per ha. Experimental design was a randomized complete block in a split plot arrangement with three replications. Yield from different planting densities responded similarly in three soybean cultivars and increased when planting density increased. Somyeongkong showed the highest increasing rate of yield about 26% by 338 g $m^{-2}$ at 30×10 cm compared to yield of conventional planting density (70 × 10 cm). Also, the planting density significantly affected pod and seed number and seed weight, but not seed per pod. The tallest plant appeared at 30 × 10 cm. The change of leaf area according to days after emergence showed differently in soybean cultivars. The highest and lowest total dry matter production per square meter appeared at 30 × 10 cm and at 70 × 10 cm, respectively. Crop growth rate (CGR) showed greater at R3~R4 stages compared with V7~R2 or R2~R3 growth stages and showed the greatest at 30 × 10 cm in three soybean cultivars. As late planted soybean, there was a significant relation between seed yield and CGR, and leaf area index (LAI) according to planting densities at before and after the flowering stage. Relationship between seed yield and CGR in three planting densities showed a highly significant positive relation ($R^2$=0.757) at R3 to R4 stages, and significant relations ($R^2$=0.505, 0.617) at V7 to R2 and V2 to V3. Also, there was a highly significant positive difference between seed yield and LAI during R3 to R4 and R2 to R3 stages.**

***Keywords*:** soybean, planting density, yield, CGR, LAI

In Korea, because of low grain yield per unit area and insufficient commitment of mechanization technology, cultivation area of soybean decreased rapidly from 297,000 ha in 1970 to 87,350 ha in 2000 (Cho *et al.*, 2003). Also, the production of soybean was very low and the self-supply of soybean was not more than 26.8% in 2000. Therefore, in order to elevate the self-supply of soybean production, it is essential to increase the grain yield per unit area and necessary to extend the cultivation area to paddy fields. Also, soybean has been cultured as late planting (after mid-June) which is a common limiting factor for soybean production in the southern Korea due to double cropping after a winter crops.

Double cropped soybean is usually grown in relatively wide (65 cm) row width on the southern Korea. Interest has been concerned to increase usage of narrower row width since canopy closure usually occurs earlier with narrower than with wider row width to make the soybean more competitive with weeds (Frederick *et al.*, 1998; Kim *et al.*, 1993).

Late planting reduced the yield of soybean because of shorter vegetative growth compared to conventional planting for optimal yield (Board & Harville, 1996). Thus, lower yield of soybean in late planting may be compensated with planting density, fertilizer, planting pattern, and plant type (Ikeda, 1992; Ikeda, 2000; Ikeda & Sato, 1990; Lueschen & Hicks, 1977). When planting time is late, increased yield will be resulted by narrow row spacing (Board et al., 1996; Board & Harville, 1996; Egli, 1988; Wells, 1991). Seed yield in narrow row increases tended to be greater at late planting dates compared to optimal planting dates, with early- compared to late-flowering cultivars, and under irrigated compared to non-irrigated conditions (Board *et al.*, 1990). Also, many researches had been conducted to determine the spacing between rows and plants within a row that maximizes yield (Frederick *et al.*, 1998; Kim *et al.*, 1993; Kokubun and Watanabe, 1982; Lee *et al.*, 1991; Moore, 1991).

Yields of soybean have increased by using narrow rows of 18cm or 48cm rather than the conventional 96cm row spacing in North Central U.S. soybean growing areas (Beatty *et al.*, 1982). Ikeda & Sato (1990) reported that the yield tended to increase with higher plant population, and more than 25 plants per $m^2$ and 6.0 LAI were necessary to harvest more than 3000 kg per ha continuously in five indeterminate soybean cultivars grown by single planting per hill. Moore (1991) reported that seed weight and size were the greatest at low plant populations, and there was a 9% difference in

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seed weight between low and high plant populations.

Therefore, this study conducted to investigate effects of high planting densities on the growth and yield of soybean according to different maturing growth types and to provide the data for the cultivation techniques in late planted soybean with double cropping system of winter crops at 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 using early (cv. Sunamkong), middle (cv. Doremikong) and late (cv. Somyeongkong) maturing types in soybean (*Glycine max* (L.) Merr.). Seed were hand planted on 16 July, 2003. Plants were planted at a high seeding rate and thinned to a plant density of 70 × 10 cm (row width x plant spacing), 50 × 10 cm, and 30 × 10 cm. Seedlings per hill were taken with two plants prior to V3 stage. Based on soil test recommendations, fertilizer was applied prior to planting at a rate of 30-30-34 kg (N-$P_2O_5$-$K_2O$) per ha. Weeds, diseases, and insects were controlled by recommended pesticides.

Experimental design was a randomized complete block in a split plot arrangement with three replications. The plant samples for plant height, leaf area, and dry matter were obtained at 20, 30, 40, 50, 60, 70 and 80 days after emergence. Dry matter was measured after the samples were dried at 80°C for 72 hr in a dry oven. Leaf area was determined by placing the leaf blades through a leaf area meter (LI-COR Li-3100, USA).

CGR was determined by the following equations (Hunt, 1978): Where W and T represents weight (g) and time (day), respectively, and leaf area ($m^2$).

$$CGR\ (g\ m^2\ d^{-1}) = \partial W / \partial T$$

## RESULTS AND DISCUSSION

### Yield and yield components

Table 1 showed yield and yield components of three soybeans with different plant density. Generally, conventional plant population of soybean has planted about 22~33 plants (65 × 10 cm or 70 × 10 cm) per square meter in Korea because single cropping of soybean planted by mid-late in May. Thus, it was needed to cultivate more population in late planting than conventional planting dates because late planting soybean (middle June or thereafter) could severely reduce yields (Beatty *et al.,* 1982; Board *et al.,* 1996). Yield was significantly affected by planting density and cultivars (Table 1). Yield from different planting density responded similarly in three soybean cultivars and yield increased when planting density increased. Doremikong showed the highest yield of 263 g $m^{-2}$ and Sunamkong showed the lowest yield of 218 g $m^{-2}$ in conventional planting density. Also, Somyeongkong showed the highest increasing rate of yield about 26% by 338 g $m^{-2}$ in 30 × 10 cm planting density compared to yield of conventional planting density (70 × 10 cm). On the other hand, planting density significantly affected pod and seed number, and seed weight but not number of seed per pod (Table 1).

### Plant height and leaf area

The beginning of flowering was on July 30 in Sunamkong, on August 2 in Doremikong, and August 6 in Somy-

**Table 1.** Yield and yield components as affected planting densities in three soybean cultivars.

| Cultivars | Plant density (cm) | Pod Number plant$^{-1}$ | Seed number plant$^{-1}$ | Seed number pod$^{-1}$ | 100-seed weight (g) | Yield (g m$^{-2}$) |
|---|---|---|---|---|---|---|
| Sunamkong | 70×10 | 45.7 | 82.3 | 1.80 | 10.5 | 239 |
| | 50×10 | 44.4 | 83.5 | 1.88 | 10.5 | 281 |
| | 30×10 | 35.0 | 61.5 | 1.76 | 10.1 | 302 |
| Doremikong | 70×10 | 45.1 | 95.1 | 2.09 | 13.4 | 263 |
| | 50×10 | 34.1 | 74.0 | 2.17 | 12.9 | 315 |
| | 30×10 | 33.9 | 68.8 | 2.03 | 12.9 | 342 |
| Somyeongkong | 70×10 | 57.2 | 108.6 | 1.83 | 9.0 | 248 |
| | 50×10 | 49.3 | 100.2 | 2.03 | 8.4 | 280 |
| | 30×10 | 46.4 | 97.1 | 2.09 | 8.4 | 338 |
| Plant density (A) | | ** | ** | Ns | * | ** |
| Cultivars (B) | | ** | * | ns | ** | ** |
| A×B | | ns | ns | ns | * | ns |
| CV (%) | | 18.6 | 34.2 | 22.0 | 5.2 | 22.3 |

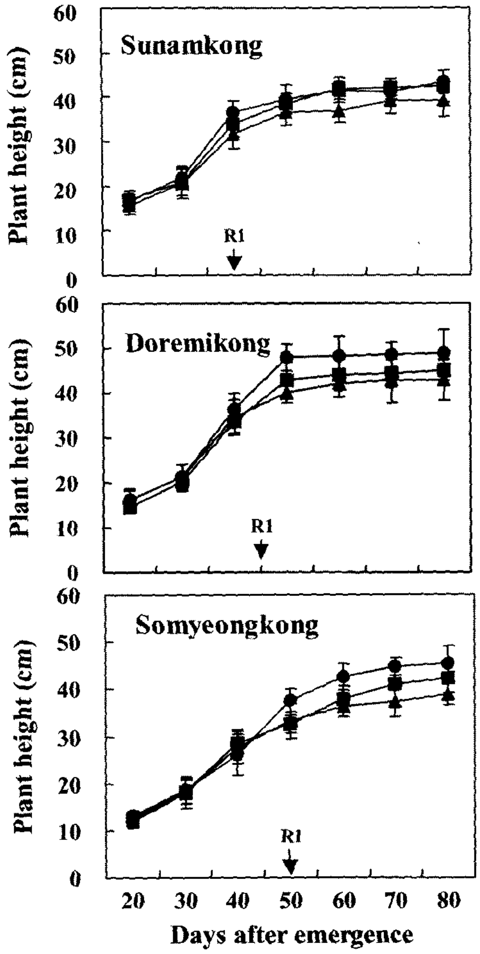


**Fig. 1.** Change in plant height as affected planting densities in three soybean cultivars. ● ; 30×10 cm, ■ ; 50×10 cm, ▲ ; 70×10 cm. All data showed in ±SE. R1 shows the flowering time according to Fehr *et al.* (1977).

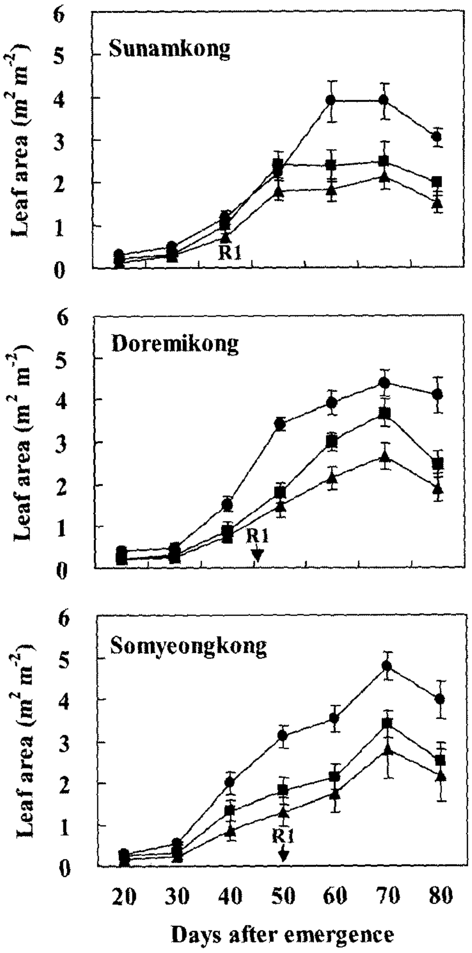


**Fig. 2.** Change in leaf area as affected planting densities in three soybean cultivars. ● ; 30×10 cm, ■ ; 50×10 cm, ▲ ; 70×10 cm. All data showed in ±SE. R1 shows the flowering time according to Fehr *et al.* (1977).

eongkong, respectively. Fig. 1 showed plant height after emergence of three soybean cultivars in different planting densities. The tallest plant height of soybeans in three planting densities appeared at planting density of 30 × 10 cm. Sunamkong, which was an early maturing cultivar, showed no significant difference between 50 × 10 cm and 30 × 10 cm but showed significant difference between 30 × 10 cm and 70 × 10 cm (since R1). However, Doremikong, which was a medium maturing cultivar, showed significant difference between 30 × 10 cm and 50 × 10 cm at the same time. Also, Somyeongkong, which was a late maturing cultivar, showed significant difference in each planting density of 30 × 10 cm, 50 × 10 cm, and 70 × 10 cm.

On the other hand, leaf area of three soybeans in three planting densities was shown in Fig. 2. The change of leaf area according to days after emergence appeared differently in soybean cultivars. Significant difference of leaf area in each planting density occurred at 55 days after emergence in Sunamkong, at 45 days after emergence in Doremikong, and at 35 days after emergence in Somyeongkong. Board & Harville (1996) stated that significant difference in LAI between narrow and wide rows of late-planted soybean (maturing group VI) showed at 26 days after emergence. These researchers also stated the source strength during emergence to R1 affecting final yield in late plantings was decreased by row width. Somyeongkong showed the highest increasing rate of yield about 26% by 338 g $m^{-2}$ in planting density of 30 × 10 cm compared to the yield of planting density of 70 × 10 cm (Table 1). The most yield increment at late maturing cultivar in higher planting density originated from significant increase of leaf area at faster stage (before R1) instead of reproductive growth stages. Previous study indicated that source alternation during vegetative period had little effect on yield (Jiang & Egli, 1995). This study was, however, conducted at optimal planting dates, in which the vegetative periods were longer than the late planting.

### Dry matter and growth characteristics

The change of total dry matter according to days after emergence of three soybean cultivars in three planting densities is shown in Fig. 3. The highest and the lowest total dry matter production per square meter among three planting densities was in planting density of 30 × 10 cm and in 70 × 10 cm, respectively, for three soybean cultivars. Total dry matter showed merely significant difference each other planting density of 30 × 10 cm, 50 × 10 cm, and 70 × 10 cm in Sunamkong, but showed no significant difference between planting density of 50 × 10 cm and 70 × 10 cm. However, there was a significant difference of the total dry matter among all plant densities of Doremikong and Somyeongkong after 50 days and 60 days after emergence.

Also, previous studies reported that the total dry matter level of 700 to 800 g $m^{-2}$ at R5 was considered to be an optimal for pod and seed production (Egli, 1988; Board & Harville, 1996; Board, 2000). From our results, the total dry matter was 600 g, 700 g, and 800 g in Sunamkong, Doremikong, and Somyeongkong, respectively, with the planting density of 30 × 10 cm at R5 stages. Cho *et al.* (2003) reported soybean yield was primarily determined during the vegetative and early reproductive periods. Therefore, to gain optimal seed yield, it may use the higher plant population when soybeans are planted at planting seasons considered as late (at mid-June) compared to conventional plant density.

CGR were obtained across V7~R4 growth stages when soybeans were planted with three planting densities (Table 2). CGR generally was greater during R3~R4 stages compared to V7~R2 or R2~R3 growth stages, and the greatest CGR was obtained at planting density of 30 × 10 cm across all planting densities in three soybean cultivars. However, Kokubun & Watanabe (1982) reported that the CGR associated with the planting density and the CGR was greater in high density (22 plant $m^{-2}$) before the flowering, but the CGR was greater in low density (11 plant $m^{-2}$) after the flowering. From this report, since the greater CGR was obtained from relative lower planting density and earlier planting time, it was different with our results. 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

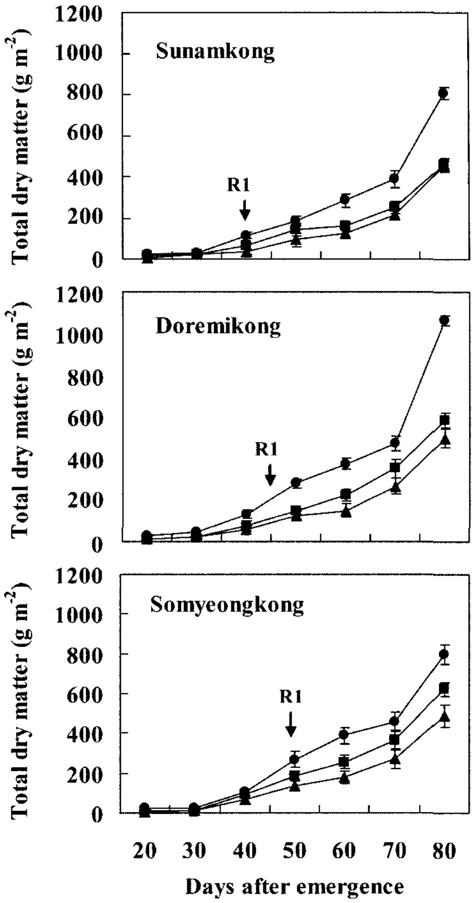


**Fig. 3.** Change in total dry matter as affected planting densities in three soybean cultivars. ● ; 30×10 cm, ■ ; 50×10 cm, ▲ ; 70×10 cm. All data showed in ±SE. R1 shows the flowering time according to Fehr *et al.* (1977).

**Table 2.** Crop growth rate (g $m^{-2}$ $d^{-1}$) of three soybean cultivars in three planting densities at V7 to R4 growth stages.

| Planting density (cm) | Growth stages | Cultivars | | |
|---|---|---|---|---|
| | | Sunamkong | Doremikong | Somyeongkong |
| 70× 10 | V7~R2 | 0.99 | 3.54 | 5.66 |
| | R2~R3 | 5.74 | 6.78 | 6.91 |
| | R3~R4 | 6.12 | 6.54 | 4.41 |
| 50×10 | V7~R2 | 3.79 | 5.21 | 8.06 |
| | R2~R3 | 7.88 | 6.92 | 9.35 |
| | R3~R4 | 6.71 | 10.68 | 6.66 |
| 30×10 | V7~R2 | 8.59 | 8.73 | 7.62 |
| | R2~R3 | 6.75 | 15.18 | 16.51 |
| | R3~R4 | 10.15 | 9.10 | 12.02 |

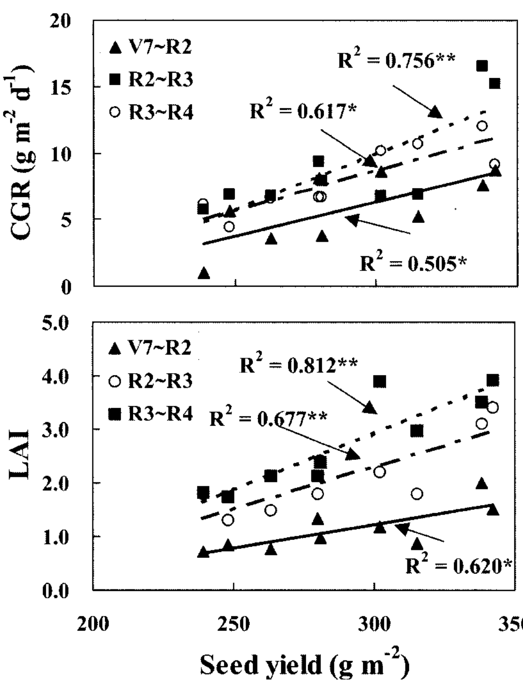


**Fig. 4.** Relationship between the seed yield and CGR, and LAI of three soybean cultivars in three planting densities according to late planting. * and ** are a significant level at 0.05 and 0.01. The solid line, dotted line, and dot-dash-line are regression lines gained at V7~R2, R2~R3, and R3~R4 stage, respectively.

R1 to R5 stages in higher density showed a very important factor in grain yield at RGR with late planting.

For late planted soybean, there was a strong relationship between the CGR and the yield with planting density at before and after the flowering stage. Relationship between the seed yield and the CGR in three planting densities showed a highly significant positive relation ($R^2$=0.757) during R3 to R4 stages and significant relations during V7 to R2 ($R^2$=0.505) and V2 to V3 stages ($R^2$=0.617) (Fig. 4). Also, there was a highly significant positive difference between the seed yield and LAI across R3 to R4 and R2 to R3 stages. Therefore, present results suggest that the high seed yield production of late planting be mainly related to three characteristics; 1) a high CGR at vegetative and early reproductive stage in high planting density, 2) a high capability to expand the leaf area during vegetative period after emergence, and 3) a cultivation of relatively late maturity soybean cultivars planted late.

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