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Dry Matter Accumulation, Harvest Index, and Yield of Soybean in Response to Planting Time

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ABSTRACT : Planting date of soybeans [*Glycine max* (L.) Merr.] is one of production components in cultural systems. The objective of the current study was to identify the components of soybean production and cultural practices encompassing planting dates and cultivars that respond to dry matter accumulation, harvest index and yield components. Three determinate soybean cultivars were planted on May 13 (early), June 3 (mid), and June 24 (late). Planting density was 60×15 cm with 2 seeds (222,000 plants per ha). Soybean plants were sampled every 10 days interval from the growth stages of V5 to R8 and separated into leaves including petioles, stems, pods, and seeds. Dry matter accumulations, harvest indices, and yield components were measured. Early planting had taken 55 days from VE to R2 and late planting taken 39 days indicating reduced vegetative growth. Early planting showed higher leaf, stem, pod and seed dry weights than late planting. However, late planting appeared to be higher harvest index and harvesting rate. Vegetative mass including leaf and stem increased to a maximum around R4/R5 and total dry weight increased to a maximum around R5/R6 and then declined slightly at R8. The highest seed yield was obtained with mid planting and no difference was found between early and late plantings. Cultivar differences were found among planting dates on growth characteristics and yield components. The results of this experiment indicated that soybean yield in relation to planting dates examined was mainly associated with harvest index and harvesting rate, and planting date of cultivars would be considered soybean plants to reach the growth stage of R4/R5 after mid August for adequate seed yield.

Keywords : soybean, growth stage, leaf dry weight, stem dry weight, pod dry weight, harvest index, harvesting rate, seed yield.

Planting date is one of production components that can be manipulated to counter the environmental factors and production systems in crop plants. Soybeans [*Glycine max* (L.) Merr.] are grown in Korea as a full season crop or as a second crop in a double cropping system after winter barley or wheat. Full season soybeans are planted in May or early June and double cropped soybeans are planted in mid to late June or early July. Relatively early planting as a full season crop afforded longer vegetative and pod set periods, but had no influence on seed filling period (Wilcox & Frankenberger, 1987). Board & Hall (1984) and Patterson *et al.* (1977) reported higher yield with artificially extended vegetative periods. In contrast, other researchers found little relationship between periods of vegetative or pod set periods and yield, but a stronger relationship between seed filling period and yield (Dunphy *et al.*, 1979; Costa *et al.*, 1980; McBlain & Hume, 1980; Boote, 1981; Kane & Grabau, 1992). In Korea, early planting frequently induced the overgrowth and lodging of soybean plants during the rainy season of July and August in normal years.

Planting soybeans after mid June as a second crop has been shown to decrease seed yield, plant height, and number of nodes and branches in both determinate and indeterminate cultivars (Carter & Boerma, 1979). Yield reduction in late planted determinate soybeans has been attributed to reduced vegetative growth. Late planting reduced number of days to maturity (Board, 1985), reduced number of days to flowering, and decreased the length of vegetative and reproductive periods of development (Parker *et al.*, 1981; Raymer & Bernard, 1988a, b). These reductions are due to a shorter photoperiod encountered by soybean plants in late planted environments (Board & Hall, 1984).

Soybean yield is the product of total dry matter and harvest index, and can therefore be affected by either change in harvest index or a change in dry matter accumulation, or both (Kumudini *et al.*, 2001). Total dry weight of soybean plants increased to a maximum around R5/R6 and subsequently declined during the seed filling period as pod development increased and leaf senescence began. In earlier tests on soybeans of different growth habits and yield potential, no evidence was found that harvest index and improved yield potential were correlated (Schapaugh & Wilcox, 1980; Cregan & Yaklich, 1986). In more recent studies, however, harvest index has been reported to be a significant contributor to yield improvement (Frederick *et al.*, 1991; Shiraiwa & Hashikawa, 1995; Morrison *et al.*, 1999). Also, harvest index of soybean plants was significantly increased in late planting

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as compared to early planting (Park *et al.*, 2000).

The objective of this study was to identify the components of soybean production and cultural practices encompassing planting dates and cultivars that respond to dry matter accumulation, harvest index, and yield in the field conditions. This information may aid producers in adopting practices that will design a production system to develop better yielding soybean cultivars and planting dates.

MATERIALS AND METHODS

Field experiment was conducted at the research farm of College of Life and Environmental Sciences, Korea University, Namyangju city, Gyeonggi province in 2001. Three determinate cultivars of soybean [*Glycine max* (L.) Merr.] were obtained from the National Crop Experiment Station, RDA. The cultivars, Hwangkeumkong (large seed, broad leaflet, medium branches, released in 1980), Shinpaldalkong 2 (medium seed, broad leaflet, less branches, 1992), and Pungsannamulkong (small seed, narrow leaflet, more branches, 1996) were planted at Baegsan silty loam soil. Planting density was 60×15 cm with 2 seeds in depth of 3 cm. This population of 222,000 plants per ha was consistent with the recommended planting population. Planting date was May 13 (early), June 3 (mid), and June 24 (late). Plot size was 6.5 m length with 4 rows. Fertilizer, N : P_2O_5 : K_2O = 45 : 70 : 60 kg/ha was incorporated in the soil before planting as basal dressing. Experimental design was split plot arrangement which main plot was planting dates and split plot was cultivars with four replications. The irrigation of 30 mm was accompanied by an overhead sprinkler system after seeding at each planting date for uniform seedling establishment.

Data on daily air temperatures and rainfall were recorded at the experimental sites and obtained from the Yangpyeong Meteorological Station (data not shown). Temperatures throughout the growing season showed fairly normal except higher in mid May and early June as compared to normal year. Rainfall was insufficient in August especially late August abnormally and 30 mm irrigation by an overhead sprinkler system was necessitated both early and mid September for the adequate soybean growth without drought stress. Application of insecticides was accompanied for the prevention of beanbugs.

Eight soybean plants were sampled every 10 days interval from the growth stages of V5 to R8 (full maturity) by cutting the cotyledonary nodes. Each growth stage was identified by Fehr & Caviness (1977). Soybean plant samples from the treatment combination plots were separated into leaves including petioles, stems, pods, and seeds. Fresh weight, dry weight, and water content were measured. Plant height, branch number, node number, leaf number, pod number, and seed number of soybean plants were obtained at each samples. Dry weights of the samples were taken at 80°C for 48

Table 1. Growth stage development of three soybean cultivars according to three planting dates.

Planting date	Cultivar	Emergence (P‡-VE)	Full bloom (VE-R2)	Beginning seed (R2-R5)	Physiological maturity (R5-R7)	Growth period (VE-R7)
				----- days -----		
May 13	Hwangkeumkong	8(May 21)	56(Jul. 16)	24(Aug. 9)	37(Sep. 15)	117
	Shinpaldalkong 2	8(May 21)	47(Jul. 7)	34(Aug. 10)	43(Sep. 22)	124
	Pungsannamulkong	8(May 21)	63(Jul. 23)	33(Aug. 25)	37(Oct. 1)	133
	Mean	8a†	55a	30a	39a	125a
June 3	Hwangkeumkong	6(Jun. 9)	46(Jul. 25)	22(Aug. 16)	32(Sep. 17)	100
	Shinpaldalkong 2	6(Jun. 9)	44(Jul. 23)	28(Aug. 20)	35(Sep. 24)	107
	Pungsannamulkong	6(Jun. 9)	55(Aug. 3)	28(Aug. 31)	35(Oct. 5)	118
	Mean	6b	48b	26b	34b	108b
June 24	Hwangkeumkong	5(Jun. 29)	38(Aug. 6)	18(Aug. 24)	34(Sep. 27)	90
	Shinpaldalkong 2	5(Jun. 29)	33(Aug. 1)	25(Aug. 26)	34(Sep. 29)	92
	Pungsannamulkong	5(Jun. 29)	45(Aug.13)	20(Sep. 2)	35(Oct. 7)	100
	Mean	5c	39c	21c	34b	94c
Mean	Hwangkeumkong	6a	47b	21c	34c	102c
	Shinpaldalkong 2	6a	41c	29a	37a	108b
	Pungsannamulkong	6a	54a	27b	36b	117a

†Numbers within columns by the same letter do not differ at the 5% level Duncan's multiple range test.
‡P : planting , VE : emergence, R2 : full bloom, R5 : beginning seed, R7 : physiological maturity.

hours. Crop growth rate was calculated from total dry weight on each plant. Apparent harvest index was measured as the ratio of seed yield to biomass (excluding roots and leaves) from the growth stages of R5 to R8. At R8 growth stage, soybean plants from 2 m row length were harvested from the middle two rows of each plot for determining seed yield and yield components. Soybean plants from 2 m row length from the middle two rows of each plot were counted for determining harvesting rate which was the ratio of harvested density to planted density. The collected data were subjected to statistical analyses using SAS package for analyses of variance and correlations.

RESULTS ANDDISCUSSION

Soybean growth stage developments of three cultivars at three planting dates are shown in Table 1. Significant differences of soybean growth stage developments were found among cultivars and planting dates. May 13 planting (early) had taken 55 days from VE to R2, but June 24 planting (late) which delayed 42 days taken 39 days indicating reduced vegetative growth (Carter & Boerma, 1979; Ouattara & Weaver, 1994). The differences between two plantings were 9 days until R5 and 5 days until R7 growth stage. Thus, seed filling periods from R5 to R7 were observed relatively small differences between May 13 and June 24 plantings (Wilcox & Frankenberger, 1987; Weaver *et al.*, 1991; Park *et al.*, 2000). Total growth period was 125 days at May 13 planting and 94 days at June 24 planting. Soybean cultivar differences were found among growth stages measured, and cutivar 'Pungsannamulkong' at May 13 planting took 63 days until R2 and 133 days until R7 which showed the longest growth period among three cultivars.

Leaf dry weights of soybean plants from V5 to R8 growth stages for three cultivars at three planting dates are shown in Fig. 1. The highest leaf dry weight was obtained at May 13 planting. At May 13 planting, cultivar 'Hwangkeumkong'

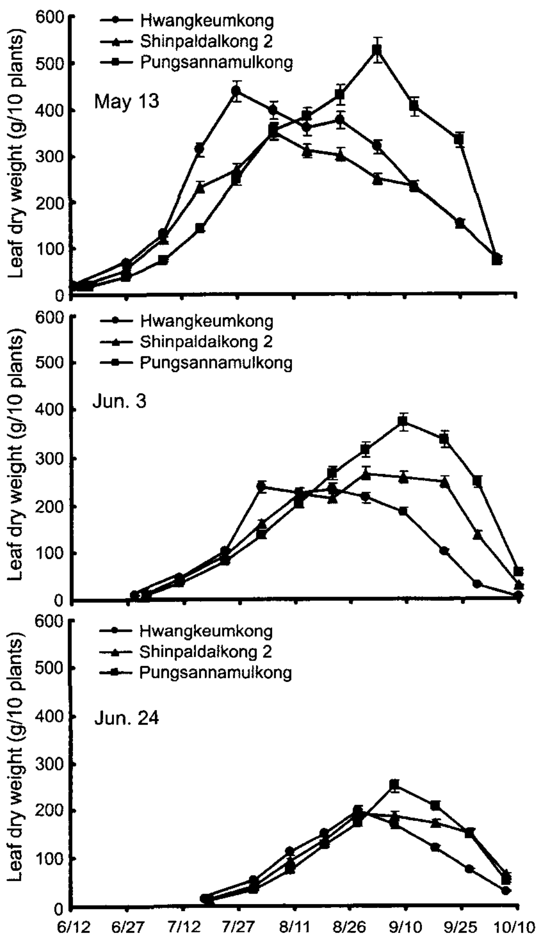

Fig. 1. Leaf dry weight from V5 to R8 growth stages of three soybean cultivars according to three planting dates.

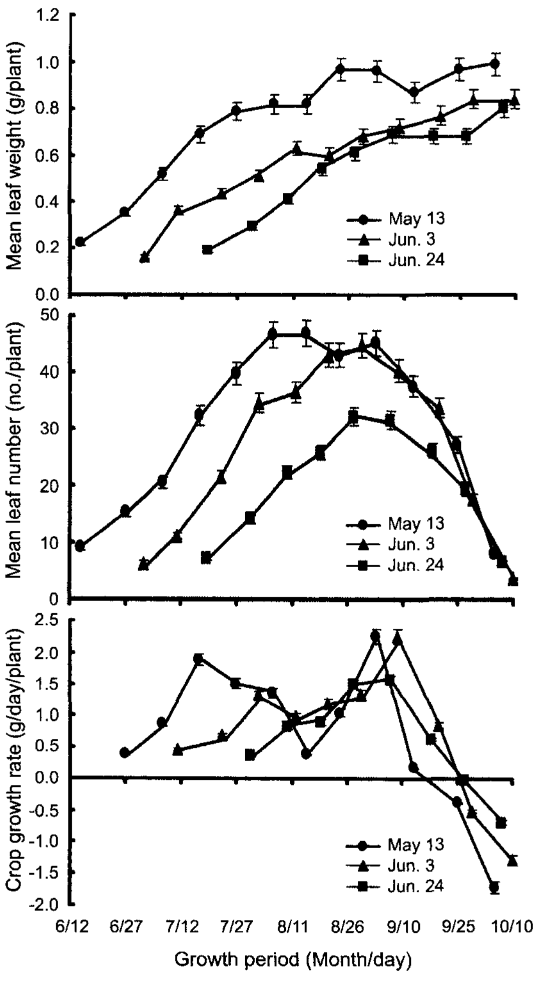

Fig. 2. Mean leaf weight, leaf number, and crop growth rate from V5 to R8 growth stages of three soybean cultivars according to three planting dates.

showed highest leaf dry weight at late July and cultivar 'Pungsannamulkong' showed it at early September which indicated cultivar differences as in Table 1. However, June 3 and June 24 plantings showed the similar trends among three cultivars. Mean leaf weight, mean leaf number, and crop growth rate of soybean plants at three planting dates are appeared in Fig. 2. Mean leaf weight and mean leaf number were highest at May 13 planting. The highest mean leaf number was occurred on early August at May 13 planting and on early September at both June 3 and 24 plantings. Kumudini *et al.* (2001) reported that leaf area index affecting by leaf number rose to a maximum around the R4/R5 stage and then declined in both old and new cultivars. Crop growth rate of soybean plants was generally reduced on August which observed highest temperatures during the growing season and severely reduced at May 13 planting among three planting dates.

Stem dry weights of three soybean cultivars were significantly different among three planting dates (Fig. 3). The highest stem dry weight was found at May 13 planting and the lowest was at June 24 planting. Cultivar 'Pungsannamulkong' having more branches among three cultivars showed the highest stem dry weight during later growth stages of the plants at all three plantings.

Pod dry weights excluding seeds of three soybean cultivars at three planting dates are obtained as shown in Fig. 4. Although pod dry weights were similar between May 13 and June 3 plantings, cultivar differences were clear primarily due to seed size and maturity differences. Cultivar 'Hwangkeumkong' having large seed showed higher pod dry weight at earlier pod growth at three planting dates. Cultivar 'Poongsananmulkong' having small seed and more pod numbers showed higher pod dry weight at later pod growth. Pod dry weights increased during the seed filling period to reach a maximum value and then declined slightly at harvest maturity (Kumudini *et al.*, 2001). At May 13 planting, all the three cultivars showed reducing pod number by pod dropping during the middle of September (data not

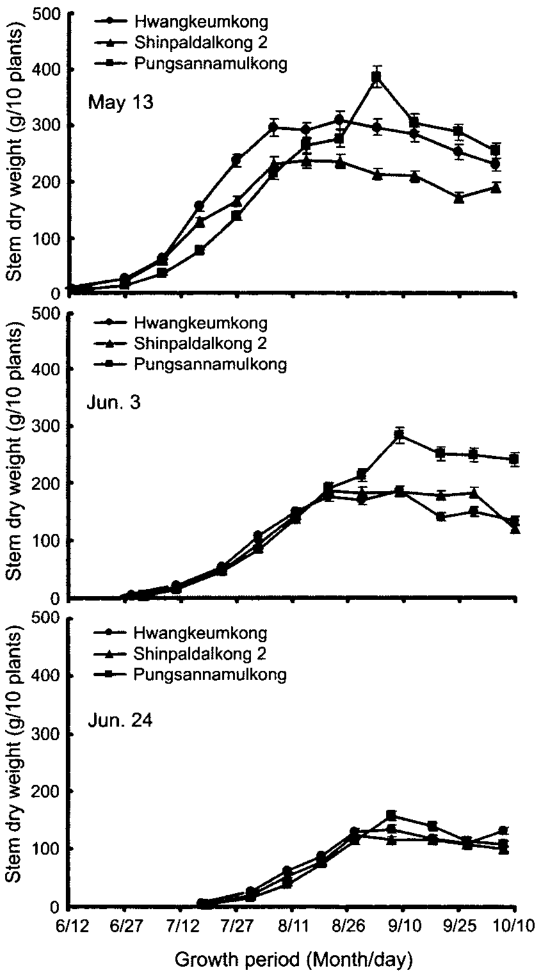

Fig. 3. Stem dry weight from V5 to R8 growth stages of three soybean cultivars according to three planting dates.

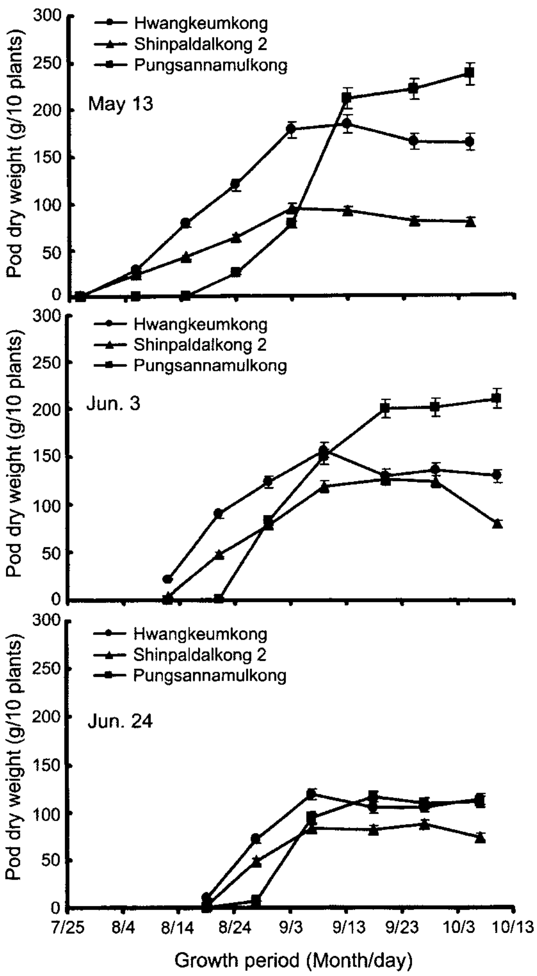

Fig. 4. Pod dry weight from R3 to R8 growth stages of three soybean cultivars according to three planting dates.

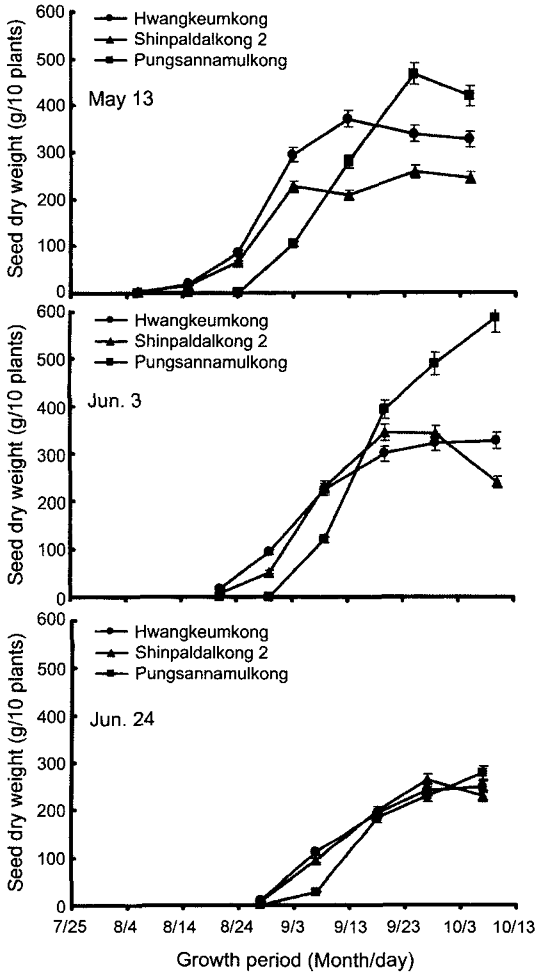

Fig. 5. Seed dry weight from R5 to R8 growth stages of three soybean cultivars according to three planting dates.

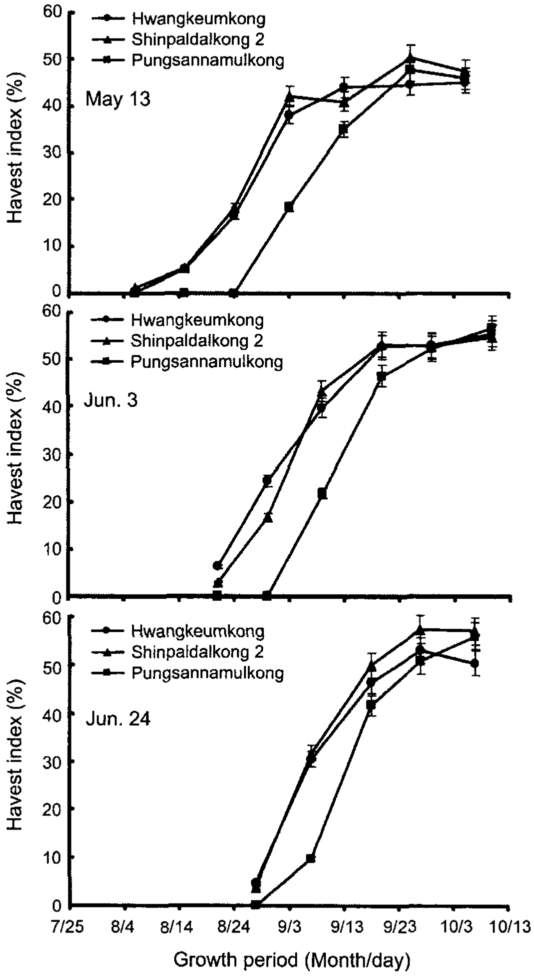

Fig. 6. Harvest index from R5 to R8 growth stages of three soybean cultivars according to three planting dates.

shown). This result was probably due to the metabolic limitations for assimilate transport from leaves to the growing pods in soybean plants at May 13 planting.

Seed dry weights of soybean plants during seed filling periods showed the similar trends with pod dry weights (Fig. 5). At earlier seed growth, large seeded cultivar showed higher seed dry weight, but higher seed dry weight was appeared with small seeded cultivar at later seed growth due to more numbers in a plant. Beginning seed of two cultivars was started at early, mid, and late August following three planting dates, respectively, and that of cultivar 'Pungsannamulkong' was late August at May 13 and June 3 plantings and early September at June 24 planting (Table 1).

Based on stem, pod, and seed dry weights, apparent harvest index was measured to three soybean cultivars at three planting dates (Fig. 6). Harvest index at May 13 planting was significantly decreased as compared to both June 3 and 24 plantings. And linear increases in harvest indices were occurred from late August at all three planting dates. Three soybean cultivars showed the similar trends in the increment of harvest indices. Rao *et al.* (2002) reported that biomass and harvest index were important determinants of seed yield (Frederick *et al.*, 1991; Shiraiwa & Hashikawa, 1995; Morrison *et al.*, 1999). This late August is the periods of temperature decrement and day length decline rapidly (data not shown).

Cumulative total dry matters of stem, leaf, pod, and seed of three soybean cultivars at three planting dates are shown in Fig. 7. Total dry weight was highest at May 13 planting and increased to a maximum around R5/R6 growth stages at all three plantings (Kumudini *et al.*, 2001). The vegetative dry weight including leaf and stem increased to a maximum around R4/R5 growth stage and then declined. However, May 13 planting showed the lag phase in total dry weight increment on the middle of August impling the overgrowth of vegetative organs such as leaves and stems and/or the competition between soybean plants as shown in crop growth rate (Fig. 2). This lag phase at May 13 planting

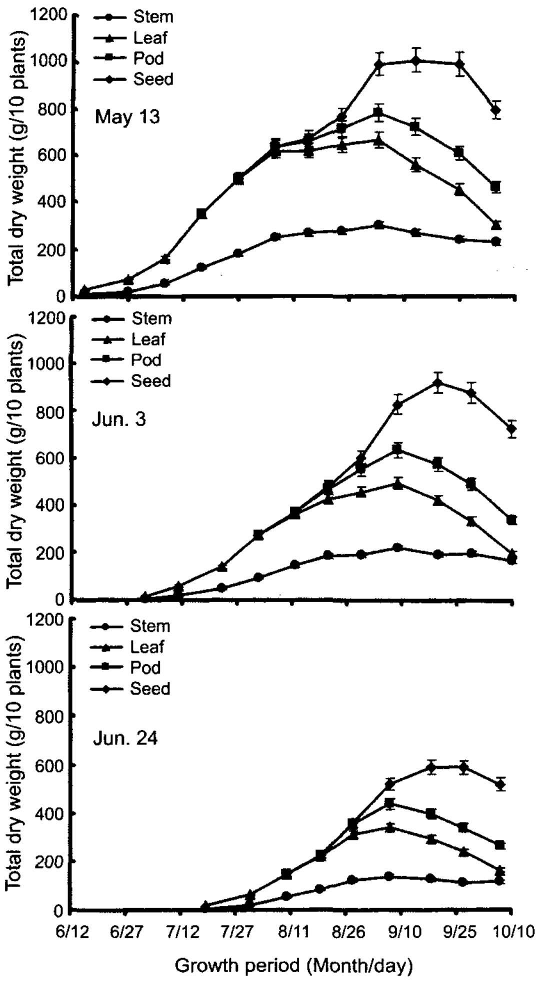

Fig. 7. Total dry weight of stem, leaf, pod, and seed from V5 to R8 growth stages of three soybean cultivars according to three planting dates.

would be probably severe in the case of heavy rains during August which occurred normally in normal years.

Soybean yield and yield components of three cultivars at three planting dates are obtained as shown in Table 2. Harvesting rate as the ratio of harvested density to planted density was significantly increased with planting date delayed showing negative correlation (-0.7835*) and was found differences among cultivars. Plant height, branch number, node number, and pod number were lowered at June 24 planting compared to both May 13 and June 3 plantings. One hundred seed dry weight was higher at May 13 planting than other two plantings. Cultivar differences were found from those characteristics as reported by Carter & Boerma (1979), and Weaver *et al.* (1991).

Harvest index of three soybean cultivars was significantly lowered 8-9 percent at May 13 planting as compared with June 3 and 24 plantings. Harvest index was also negatively correlated with planting date (-0.7404*). Seed yield was highest at June 3 planting as average of 4.01 t/ha, and no difference was found between May 3 and June 24 plantings. Cultivar 'Hwangkeumkong' showed lower yield than other two cultivars. Popp et al. (2002) reported that cultivar yields from early soybean plantings were generally higher than those from later plantings on dryland soybean production. However, seed yield of three soybean cultivars was not increased at May 13 planting in the weather conditions which had rainy season during July. Therefore, mid June would be counted a favorable planting time for stable production strategy in those soybean cultivars. The results of this experiment could be concluded that soybean yield in relation to planting dates examined was mainly associated with harvest index and harvesting rate, and planting date of cultivars depending on maturity group would be considered

Table 2. Yield and yield components of three soybean cultivars according to three planting dates.

Planting date	Cultivar	Harvesting rate† (%)	Plant height (cm/plant)	Branch (no./plant)	Node (no./plant)	Pod (no./plant)	Seed dry weight (g/100)	Harvest index (%)	Seed yield (t/ha)
May 13	Hwangkeumkong	61	84	4.7	16	43	27	45	2.37
	Shinpaldalkong 2	82	78	2.5	17	44	22	48	4.03
	Pungsannamulkong	63	83	7.2	19	123	11	46	4.61
	Mean	69c	82a	4.8b	17a	70a	20a	46b	3.67ab
June 3	Hwangkeumkong	72	81	4.9	16	47	23	54	3.81
	Shinpaldalkong 2	84	76	2.9	15	39	22	55	3.75
	Pungsannamulkong	76	82	9.6	19	103	10	57	4.46
	Mean	77b	80a	5.8a	17ab	63a	18b	55a	4.01a
June 24	Hwangkeumkong	83	78	3.8	16	31	23	50	2.62
	Shinpaldalkong 2	95	60	2.9	15	37	21	57	3.82
	Pungsannamulkong	92	77	6.3	18	62	10	56	3.32
	Mean	90a‡	72b	4.3b	16b	43b	18b	54a	3.25b

Table 2. Continued.

Planting date	Cultivar	Harvesting rate† (%)	Plant height (cm/plant)	Branch (no./plant)	Node (no./plant)	Pod (no./plant)	Seed dry weight (g/100)	Harvest index (%)	Seed yield (t/ha)
Mean	Hwangkeumkong	72b	81a	4.5b	16b	41b	24a	50b	2.93b
	Shinpaldalkong 2	87a	71b	2.8c	16b	40b	22b	53a	3.87a
	Pungsannamulkong	77b	81a	7.7a	19a	96a	10c	53a	4.13a

†Harvesting rate = Harvested density/Planted density * 100
‡Numbers within columns by the same letter do not differ at the 5% level Duncan's multiple range test.

soybean plants to reach the growth stage of R4/R5 after mid August for adequate seed yield.

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