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Biomass Partitioning during Early Growth Stage of Soybean in Response to Planting Time

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ABSTRACT : Seedling establishment of soybean [*Glycine max* (L.) Merr.] is a critical factor in production system and cultural practices. The objective of this study was to identify the components of soybean seedling developments encompassing planting dates and cultivars that respond to emergence, early growth stage and dry matter accumulation. Three soybean cultivars, Hwangkeumkong, Shinpaldalkong 2, and Pungsannamulkong, were planted at Baegsan silty loam soil. Planting date was May 13, June 3, and June 24 in 2001. Sprinkler irrigation was accompanied with 30 mm after seeding for three planting dates. Soybean seedlings were sampled at the growth stages from VE to V5. Days to emergence of soybean seedlings were taken 8 at May 13 and 5 at June 24 plantings. Emergence percentage was over 90 at three planting dates. May 13 planting took 33 days and June 24 planting was 25 days for reaching V5 growth stage. Cotyledon number was decreased after V2. Significant cultivar difference was found in cotyledon dry weight until V2 which differed in seed dry weights at the planting times. Leaf and total dry weights of soybean seedlings were not differed from V1 to V3 among planting dates and cultivars. Leaf water contents were generally ranged 78 to 85%. Branch was appeared from V4. Leaf/stem ratio among cultivars was similar at five growth stages and gradually increased from 2.1 at V1 to 2.8 at V5. The results based on this experiment indicated that seedling establishment of soybean was continued from VE to V3 growth stages affecting mainly by planting date and soil moisture.

Keywords **:** soybean, cotyledon, days to emergence, emergence percentage, leaf dry weight, stem dry weight.

Seedling establishment is an important factor in soybean production and cultural practices. Rapid and uniform emergence and early growth of seedlings from the soil is a critical period in the life cycle of soybean plants. Germination and seedling growth of soybeans are affected by soil temperatures in the seed zone. Inouye (1953) reported the optimum temperature for germination to be 24 to 36°C, the minimum to be 2 to 4°C, and the maximum to be 42 to 44°C. Higher temperature at planting season in the field generally accelerated germination and seedling growth of soybean seeds (Seong *et al.*, 1986). Field emergence of soybean seeds generally takes 5 to 7 days, but under unfavorable conditions, emergence may take 12 days (Pendleton & Hartwig, 1973). Planting dates of soybeans can be varied from mid-April to mid-July in the cultural practices which are exposed the wide range of temperatures (Popp *et al.*, 2002). However, recommended planting dates are encouraged from early-May to late-June according to crop sequences on conventional soybean production system.

Hunter & Erickson (1952) concluded that the minimum seed moisture content required for germination of soybeans was about 50 percent. However, Waldren & Flowerday (1982) reported that water requirement to begin germination of soybeans is about 60 percent of its dry weight. When soybean seeds absorb the required water from soil moisture in planted seed zone, proper emergence percentage and days to emergence can be expected in the field conditions. Soil moisture at the planting time is a limited factor with the differences of soil structure, drought and cultural conditions. Consequently, the success or failure of soybean seedling establishment is mainly dependent on adequate soil moisture during germination and emergence of soybean seeds. Effects of soil moisture on germination and seedling growth of soybean cultivars were found in the research reports (Lee *et al.*, 1992; Seong *et al.*, 1986).

Depending on time and location of planting, soil conditions can vary from cold and wet to hot and dry. Various germination and seedling growths of soybean seeds were appeared in the references (Lee *et al.*, 1992; Seong *et al.*, 1997). However, detailed seedling growth in each growth stage of soybean plants at the field was not detected under adequate soil moisture conditions by sprinkler irrigation during soybean planting season. The objective of this study was to identify the components of soybean seedling developments encompassing planting dates and cultivars that respond to emergence, early growth stage and dry matter accumulation in the field conditions.

MATERIALS AND METHODS

Field experiment was conducted at the research farm of

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College of Life and Environmental Sciences, Korea University, Namyangju city, Gyeonggi province in 2001. Three recommended cultivars of soybean [*Glycine max* (L.) Merr.] were obtained from the National Crop Experiment Station, RDA. The cultivars, Hwangkeumkong (large seed), Shinpaldalkong 2 (medium seed), and Pungsannamulkong (small seed) were planted at Baegsan silty loam soil. Planting density was 60×15 cm with 2 seeds in depth of 3 cm. Planting dates were May 13, June 3, and June 24. 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. 30 mm irrigation was accompanied by sprinkler after seeding for three planting dates.

Eight soybean seedlings were sampled at the growth stages from VE to V5 by cutting the cotyledonary nodes. The growth stage was identified by Fehr & Caviness (1977). Days to emergence and emergence percentage of soybean seedlings were measured at each planting plots. Soybean seedling samples from the treatment combination plots were separated to cotyledon, leaf, and stem from V1 to V5 growth stages. Cotyledon number, fresh weight and dry weight of the samples were measured. Fresh weight, dry weight, water content, plant height, branch number, leaf number and leaf/stem ratio of soybean seedlings were obtained at each samples. Dry weights of the samples were taken at 80°C for 48 hours. The collected data were analyzed using SAS package for mean analyses.

RESULTS ANDDISCUSSION

Emergence of soybean seedling was significantly different at three planting dates. Days to emergence of soybean seedlings were taken 8 days at May 13 and 5 days at June 24 planting (Table 1). The average of 5 years of mid-May and late-June plantings in previous observations showed 9 and 4 days, respectively. This result was due to temperature fluctuation in experimental year which was higher in mid-May and lower in late- June compared to the normal year (data not shown). Holshouser & Whittaker (2002) reported that days to emergence of soybean seedlings were ranged from 7 to 13 with the plantings of mid-April to late-April. Emergence percentage of soybean seedlings was over 90 at three planting dates with sprinkler irrigation after seeding and no differences were found among planting dates and cultivars. This high emergence percentage of soybean seedlings at the field condition was primary due to irrigation after seeding and was not easily achieved in the conventional plantings. Soil temperature and moisture for seed germination of soybean were critical factors in the references (Lee *et al.*, 1992; Seong *et al.*, 1986) and seedling emergence percentage was affected more by soil moisture conditions.

Development of growth stage of three soybean cultivars was differed at three planting dates as shown in Fig. 1. May 13 planting took 33 days and June 24 planting was 25 days for reaching V5 growth stage of soybean seedlings. This 8 days decrement of seedling growth period in June 24 planting was the result of temperature increment with late planting which has the advantage of soybean growth. No larger differences in growth period of soybean seedlings were

Table 1. Seed dry weight, days to emergence, and emergence percentage of three soybean cultivars according to three planting dates.

Planting date	Cultivar	Seed dry weight	Days to emergence	Emergence percentage
		(g/100 seeds)	(days)	(%)
May 13	Hwangkeumkong	25.3	8	87.3
	Shinpaldalkong 2	20.0	8	96.0
	Pungsannamulkong	13.3	8	94.3
	Mean	19.5	8(9)	92.5
June 3	Hwangkeumkong	25.1	6	90.3
	Shinpaldalkong 2	20.0	6	97.5
	Pungsannamulkong	13.0	6	97.8
	Mean	19.4	6	95.2
June 24	Hwangkeumkong	25.0	5	97.3
	Shinpaldalkong 2	19.8	5	98.3
	Pungsannamulkong	13.0	5	98.0
	Mean	19.3	5(4)	97.9
	F-test	NS		NS

( ) : Average of 5 years

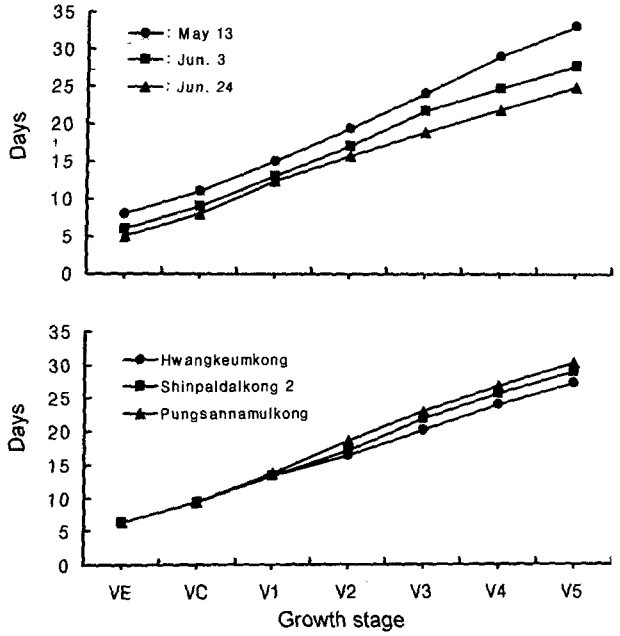

Fig. 1. Required days for the development of growth stages of three soybean cultivars according to three planting dates.

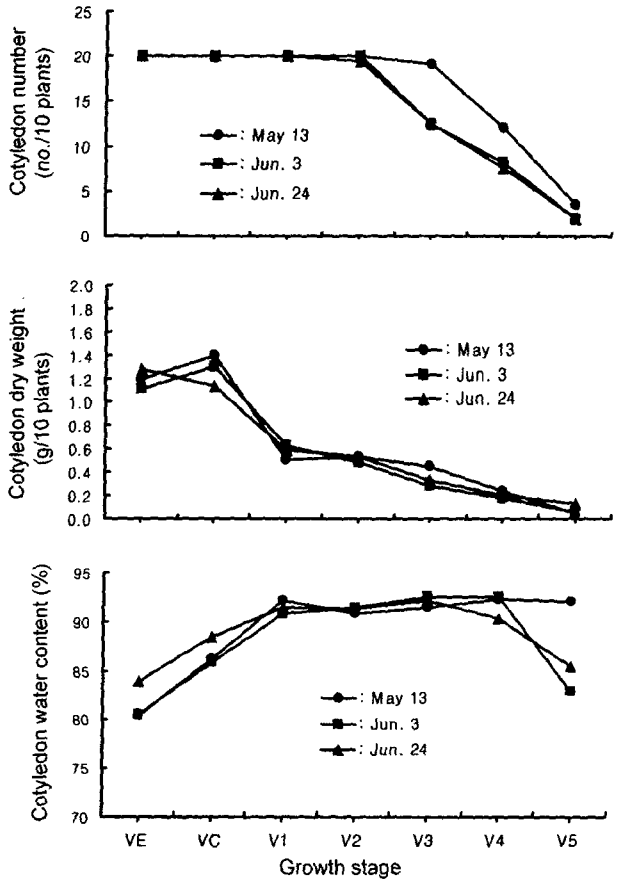

Fig. 2. Cotyledon number, dry weight, and water content from VE to V5 growth stages of soybean seedlings according to three planting dates.

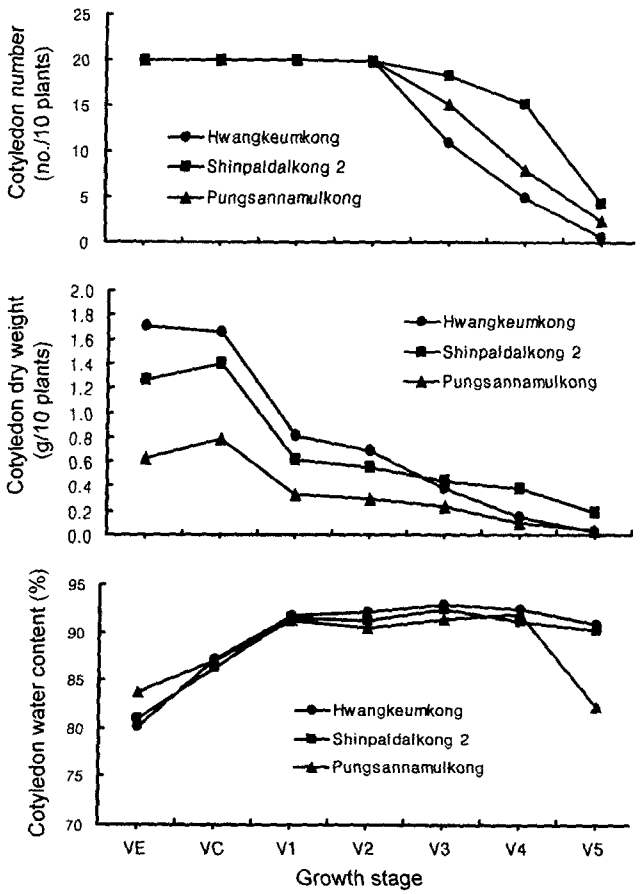

Fig. 3. Cotyledon number, dry weight, and water content from VE to V5 growth stages of three soybean cultivars.

found until V5 growth stage among three cultivars. Cotyledon number, dry weight, and water content of soybean seedlings were similar among three planting dates (Fig. 2). Number of cotyledons was decreased after V2 growth stage except May 13 planting and cotyledon dry weight was also decreased with growth stage development. The cotyledons of soybean seedlings are naturally dropped after the role of cotyledons as nutrient supplier was finished to transport the metabolic components for the emerging new plant parts (Seong *et al.*, 1997). Cotyledon water content was increased from 80 at VE to 90% at V1 and paralleled until V3 growth stage. Soybean cultivar effects on cotyledon characteristics were similar with planting dates except cotyledon dry weight until V2 growth stage which differed in seed dry weights according to planting times (Fig. 3).

Leaf dry weight and water content of three soybean cultivars according to three planting dates were shown in Table 2. Leaf dry weight of soybean seedlings among three planting dates was not differed from V1 to V3 growth stages. However, significant different leaf dry weights were found

Table 2. Leaf dry weight, and leaf water content from V1 to V5 growth stages of three soybean cultivars according to three planting dates.

Planting date	Cultivar	Leaf dry weight (g/10 plants)					Leaf water content (%)				
		Growth stage					Growth stage				
		V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
May 13	Hwangkeumkong	1.21	2.40	5.20	12.28	18.01	78.1	80.7	79.9	82.9	84.0
	Shinpaldalkong 2	0.90	2.76	5.11	16.08	21.38	80.5	78.5	81.6	79.1	80.7
	Pungsannamulkong	0.99	2.49	5.94	11.51	19.08	77.6	75.6	79.1	83.9	82.8
	Mean	1.04	2.55	5.41	13.29	19.49	78.7	78.3	80.2	82.0	82.5
June 3	Hwangkeumkong	1.03	3.01	6.25	8.63	10.29	80.7	80.3	83.8	82.0	85.6
	Shinpaldalkong 2	1.05	2.88	5.15	7.98	11.18	80.0	78.9	83.1	84.2	84.7
	Pungsannamulkong	0.76	1.91	3.56	5.81	8.53	81.1	79.5	82.8	85.2	84.6
	Mean	0.95	2.60	4.99	7.48	10.00	80.6	79.6	83.2	83.8	85.0
June 24	Hwangkeumkong	0.88	2.40	4.25	9.48	14.70	84.5	81.9	85.7	84.9	82.0
	Shinpaldalkong 2	0.81	2.63	3.68	8.66	13.63	83.4	77.9	84.8	82.0	80.5
	Pungsannamulkong	0.88	2.16	4.04	8.34	11.63	79.3	81.2	83.5	81.5	80.8
	Mean	0.85	2.40	3.99	8.83	13.31	82.4	80.3	84.7	82.8	81.1
	F-test	NS	NS	NS	*	**	NS	NS	*	NS	*
	Hwangkeumkong	1.04	2.60	5.24	10.13	14.34	81.1	81.0	83.1	83.3	83.9
	Shinpaldalkong 2	0.93	2.75	4.65	10.90	15.39	81.3	78.4	83.2	81.8	82.0
	Pungsannamulkong	0.88	2.19	4.51	8.55	13.08	79.3	78.8	81.8	83.5	82.7
	F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	*

Table 3. Stem dry weight, and stem water content from V1 to V5 growth stages of three soybean cultivars according to three planting dates.

Planting date	Cultivar	Stem dry weight (g/10 plants)					Stem water content (%)				
		Growth stage					Growth stage				
		V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
May 13	Hwangkeumkong	0.58	1.04	1.85	4.39	7.34	84.2	85.8	84.3	86.2	86.0
	Shinpaldalkong 2	0.45	0.94	1.83	4.84	7.54	81.5	85.3	85.1	83.5	84.3
	Pungsannamulkong	0.34	1.08	2.94	3.94	6.90	83.4	82.0	84.4	87.2	85.6
	Mean	0.45	1.01	2.20	4.39	7.26	83.0	84.4	84.6	85.6	85.3
June 3	Hwangkeumkong	0.58	1.34	2.29	3.06	3.54	84.2	85.2	87.6	87.1	88.2
	Shinpaldalkong 2	0.46	0.86	1.88	2.44	3.89	84.5	85.0	87.1	87.4	87.1
	Pungsannamulkong	0.31	0.69	1.39	2.28	3.14	84.3	86.2	87.1	88.3	87.3
	Mean	0.45	0.96	1.85	2.59	3.53	84.3	85.5	87.3	87.6	87.5
June 24	Hwangkeumkong	0.53	1.11	1.71	5.86	5.18	87.1	85.9	87.1	81.6	84.4
	Shinpaldalkong 2	0.43	0.80	1.30	3.33	4.75	85.6	84.9	86.5	83.2	83.6
	Pungsannamulkong	0.48	0.89	1.50	3.00	3.86	85.0	85.8	86.5	84.1	84.7
	Mean	0.48	0.94	1.50	4.06	4.60	85.9	85.5	86.7	83.0	84.2
	F-test	NS	NS	NS	NS	**	NS	NS	**	*	**
	Hwangkeumkong	0.56	1.16	1.95	4.44	5.35	85.2	85.6	86.3	85.0	86.2
	Shinpaldalkong 2	0.45	0.86	1.66	3.54	5.39	83.9	85.1	86.2	84.7	85.0
	Pungsannamulkong	0.38	0.89	1.94	3.08	4.64	84.2	84.7	86.0	86.5	85.9
	F-test	NS	NS	NS	NS	*	NS	NS	NS	NS	*

from V4 to V5 growth stages among three planting dates showing higher in May 13 planting which delayed development of growth stage due to lower temperatures. No cultivar differences of leaf dry weights were found from V1 to V5 growth stages. Leaf water content was not consistent among three planting dates and three cultivars probably

Table 4. Plant height, branch number, leaf number, total dry weight, and leaf/stem ratio from V1 to V5 growth stages of soybean plants according to three planting dates.

Division	Planting date	Growth stage				
		V1	V2	V3	V4	V5
Plant height (cm)	May 13	3.53a	4.83a	6.70a	11.20a	15.10a
	Jun. 3	3.57a	5.50a	10.33b	12.60a	16.77a
	Jun. 24	6.27b	7.70b	9.80b	12.00a	14.50a
	Mean	4.46	6.01	8.94	11.93	15.46
Branch number (no./plant)	May 13	-	-	-	0.27a	0.87a
	Jun. 3	-	-	-	0.13a	0.17b
	Jun. 24	-	-	-	0.50a	1.00a
	Mean	-	-	-	0.30	0.68
Leaf number (no./plant)	May 13	2.0a	3.0a	4.3a	7.5b	9.2b
	Jun. 3	2.0a	3.3b	4.7a	5.6a	6.4a
	Jun. 24	2.0a	3.2ab	4.1a	5.5a	7.2a
	Mean	2.0	3.2	4.4	6.2	7.6
Total dry weight (g/10 plants)	May 13	1.49a	3.56a	7.63a	17.68b	26.75c
	Jun. 3	1.40a	3.56a	6.84a	10.06a	13.51a
	Jun. 24	1.33a	3.33a	5.49a	12.89a	17.91b
	Mean	1.41	3.48	6.65	13.54	19.39
Leaf/Stem ratio	May 13	2.35a	2.52a	2.54a	3.01a	2.68a
	Jun. 3	2.16a	2.79a	2.68a	2.88a	2.83a
	Jun. 24	1.81a	2.63a	2.67a	2.34a	2.91a
	Mean	2.11	2.65	2.63	2.74	2.81

Table 5. Plant height, branch number, leaf number, total dry weight, and leaf/stem ratio from V1 to V5 growth stages of three soybean cultivars.

Division	Cultivar	Growth stage				
		V1	V2	V3	V4	V5
Plant height (cm)	Hwangkeumkong	5.30c	6.87a	9.67a	12.80a	16.07a
	Shinpaldalkong 2	4.53b	5.93a	8.67a	11.07a	15.17a
	Pungsannamulkong	3.53a	5.23a	8.50a	11.93a	15.13a
	Mean	4.45	6.01	8.95	11.93	15.46
Branch number (no./plant)	Hwangkeumkong	-	-	-	0.13a	0.60a
	Shinpaldalkong 2	-	-	-	0.13a	0.63a
	Pungsannamulkong	-	-	-	0.63a	0.80a
	Mean	-	-	-	0.30	0.68
Leaf number (no./plant)	Hwangkeumkong	2.0a	3.2a	4.4a	5.9a	7.3a
	Shinpaldalkong 2	2.0a	3.2a	4.2a	6.4a	7.4a
	Pungsannamulkong	2.0a	3.1a	4.4a	6.3a	8.1a
	Mean	2.0	3.2	4.3	6.2	7.6
Total dry weight (g/10 plants)	Hwangkeumkong	1.60a	3.76a	7.19a	14.56a	19.69a
	Shinpaldalkong 2	1.36a	3.63a	6.31a	14.44a	20.79a
	Pungsannamulkong	1.25a	3.08a	6.45a	11.63a	17.71a
	Mean	1.40	3.49	6.65	13.54	19.40
Leaf / Stem ratio	Hwangkeumkong	1.85a	2.24a	2.67a	2.41a	2.73a
	Shinpaldalkong 2	2.06a	3.19a	2.79a	3.07a	2.86a
	Pungsannamulkong	2.40a	2.51a	2.43a	2.75a	2.83a
	Mean	2.10	2.65	2.63	2.74	2.81

rainfall differences during sampling periods, and ranged 78 to 85% in mean values. Stem dry weight of three soybean cultivars according to three planting dates was showed similar results with leaf dry weight and appeared difference at V5 growth stage (Table 3). Differences in stem water content among three planting dates were found from V3 to V5 growth stages and ranged 83 to 87%. Stem water content of three soybean cultivars was differed at growth stage of V5.

Plant height, branch number, leaf number, total dry weight, and leaf/stem ratio of soybean seedlings were summarized in Table 4. Among three planting dates, differences in plant height of soybean seedlings were found from V1 to V3 growth stages showing higher in June 24 planting which was higher temperatures. Number of branches was appeared from V4 growth stage according to three planting dates. Total dry weight was increased rapidly during progress of growth stage and differed among three planting dates from V4 to V5 growth stages. Leaf/stem ratio was not differed at all growth stages among three planting dates and increased gradually with development of growth stage.

Plant height of soybean seedlings among three cultivars was differed only in V1 growth stage which showed larger seeded cultivar having higher plant height (Table 5). Total dry weight was not differed at all growth stages measured among three cultivars. Leaf /stem ratio among three cultivars was similar at five growth stages and gradually increased from 2.1 at V1 to 2.8 at V5 growth stages. The results from this experiment indicated that seedling establishment of soybeans was continued from VE to V3 growth stages affecting mainly by planting dates which exposed range of temperatures and by soil moisture conditions which fluctuated with rainfall in the planted field. And, the young vegetative plants of soybean will be started from V4 growth stage which showing the differences of various growth characteristics.

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