Effect of Planting Date and Planting Density on Growth and Yield of Soybean in Cheju Island

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ABSTRACT

Two determinate soybean cultivars, 'Baegunkong' and 'Namhaekong', were planted on 8 June, 23 June, and 8 July 1996 at Cheju at planting densities of 33, 43, 53, 63 plants per m² to determine the optimum planting density of double crop soybean for recently recommended cultivars in Cheju area at various planting dates. The plant height, and the diameter and node number of main stems decreased as planting was delayed. The plant height increased but the stem diameter and node number decreased with increasing planting density. Pod number per plant was greater for Namhaekong than for Baegunkong and was not affected by planting date. Pod number per plant decreased but pod numbers per m² increased with increasing planting density. The number of seeds per pod was greater at the two later plantings and fewer at the highest planting density. 100-seed weight decreased with delaying planting. The seed weight was lighter at the highest planting density for Baegunkong but there was no difference for Namhaekong among the planting densities. The seed yield of Baegunkong was greater for 23 June and 8 July plantings (2,280 and 2,420 kg/ha) than for 8 June planting (1,450 kg/ha) while that of Namhaekong was greatest at 23 June planting (2,690 kg/ha) compared with 8 June and 8 July plantings (1,890 and 2,080 kg/ha). Across the planting dates and cultivars, seed yield increased from 1,860 to 2,290 kg/ha as the planting density increased from 33 to 53 plants/m² and then leveled off with a further increase in planting density.

Key words : soybean, planting date, planting density.

Soybean is usually grown as a double crop in Cheju island and the optimum planting date is mid-June. Soybean cultivars differ in response to planting date (Boquet et al., 1982; Ju et al., 1996; Parker et al., 1981). Soybean is often planted after mid-June in Cheju area because of double cropping and adverse weather. Late plantings of determinate soybean are lower in yield because of reductions in branch number, pod number, and seed number (Board, 1995; Boquet, 1990; Boquet et al., 1982). Higher planting density would compensate for lower individual plant yield. Boquet (1990) reported that an increase in planting density above that needed at optimal date was necessary to obtain the highest yields at post-optimal planting dates.

Thirty-three plants per m² are recommended for soybean in Cheju regardless of planting date. There is little information on the effects of planting density on the growth and yield of recently recommended soybean cultivars at different planting dates in Cheju area. The objective of this study was to examine the effects of planting date and planting density on the growth and yield of two leading determinate soybean cultivars in order to determine the optimum planting density for recently recommended cultivars in Cheju area at various planting dates.

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MATERIALS AND METHODS

A field study was conducted at the Research Farm of the College of Agriculture, Cheju National University (33°27′ 20′ N latitude, 277 m altitude) on volcanic ash soil. Mean soil test values for surface soil (0 to 10 cm) were: pH = 5.6, organic matter = 49.6 g/kg, and available P_2O_5 = 142.1 mg/kg. Exchangeable Ca, Mg, K, and Na were 2.15, 0.78, 0.91, and 0.12 cmol/kg, respectively.

Two soybean cultivars, 'Baegunkong' and 'Namhaekong', were hand planted on 8 June, 23 June, and 8 July on 60-cm rows with plant spaces of 10.0, 7.8, 6.2 and 5.2 cm within a row. Three seeds were planted per hill and later thinned to 2 plants per hill to obtain planting densities of 33, 43, 53, 63 plants per m². Fertilizer was applied prior to planting at a rate of 40-60-50 kg/ha (N-$P_2O_5K_2O$). Recommended pesticides were used to control weeds, diseases, and insects.

Experimental units contained five rows with 3 m long (9 m²). The experimental design was a split-split-plot arrangement in a randomized complete block with four blocks. The main-plots consisted of three planting dates, the subplots two cultivars and sub-subplots four planting densities.

Flowering date (R2 stage) was recorded. At maturity, ten representative plants in the center rows of each plot were sampled to determine agronomic traits such as plant height, stem diameter, branch number per plant, and yield components. Seed yield was determined by hand harvest of three interior rows 2 m long (3.6 m²) and corrected to 13% moisture. Analysis of variance was performed with SAS General Linear Models procedure with mean separation according to least significant difference (LSD).

Air temperature and precipitation were obtained from the Cheju Agricultural Experiment Station (4.1 km from the experimental site) and shown in Table 1.

RESULTS AND DISCUSSION

Days to flowering and lodging

Because the number of days from planting to flo-

Table 1. Normal mean air temperature and precipitation, and departures from normal for a soybean growing season in 1996 at Cheju.

Month	Mean air temperature (℃)		Precipitation (mm)	
	Normal†	Departure‡	Normal*	Departure**
June	20.8	+1.1	174.5	+ 23.3
July	25.4	−1.2	263.5	−209.3
Aug.	27.9	−2.3	267.2	−189.5
Sept.	21.7	−0.5	152.9	−138.3
Oct.	17.5	−1.6	56.1	+ 47.2
Nov.	12.4	−1.3	67.0	+ 37.4

† 10-year (1987-1996) mean.
‡ Departure from the normal.

Table 2. Days to flowering for two soybean cultivars at three planting dates.

Planting date		Baegunkong	Namhaekong
8	June	47	46
23	June	40	40
8	July	37	38

wering was not affected by planting density, planting date × cultivar effect for this trait is shown in Table 2. Days to flowering for the two cultivars was similar and decreased from about 47 to 37 days probably due to higher temperatures as planting was delayed from 8 June to 8 July.

Rain and wind on 26 August resulted in the lodging of Baegunkong in the 8 June planting and Namhaekong in the three plantings (Table 3). Lodging was greater at higher planting densities for 8 June planting but was not affected by planting density for 23 June and 8 July plantings. It appeared that the lodging did not significantly influence yields of this study because of no significant correlation between the lodging scores and seed yields.

Stem traits

Summary of analysis of variance for the stem traits, yield and yield components are shown in Table 4. Planting date, cultivar, and planting density had a significant effect on most of the variables. However, two- or three factor interactions were significant at 5% level only for plant height, seed number per pod, 100-seed weight, and seed yield and the averages of planting date × cultivar × planting density treatments for these traits are presented in Table 5. For other traits, only the main effects of the treatments are shown in Tables 6 and 7.

Plant height was significantly affected by planting date, planting density, planting date × cultivar, planting date × planting density and planting date × cultivar × planting density (Table 4). As planting was delayed from 8 June to 8 July, the plant height of Baegunkong decreased from 73 to 55 cm while that of Namhaekong from 68 to 58 cm (Table 4). Compared with Namhaekong, plant height of Baegunkong increased greatly at 8 June planting than at the later plantings with an increase in planting density. Parker et al. (1981) reported that plant height increased with succeeding planting until early June and then decreased with a further delayed planting.

The main stem diameter was significantly affected by the planting date and the planting density (Table 4). It was greater for 8 June and 23 June plantings than for 8 July planting and greater for Namhaekong than for Baegunkong (Table 6). The main stem node number was significantly affected by the planting date, cultivar, and planting density (Table 4). As the planting was delayed from 8 June to 8 July, the stem node number decreased from 13.1 to 11.8 (Table 6). Baegunkong had 0.7 more nodes than Namhaekong. The main stem node number decreased with increasing planting density. The branch number per plant or m^2 was not significantly affected by the planting date. Namhaekong had 0.7 more branches per plant than Baegunkong. The branch number per plant decreased from 2.8 to 1.6 as planting density increased from 33 to 63 plants per m^2. This result agrees with previous reports (Ju et al., 1996; Lee, 1974). However, the branch number per m^2 was similar among the plant densities ranging from 91 to 99 (Table 7). Kim et al. (1993) reported that branch number per m^2 increased as planting density increased from 16 to 32 plants per m^2. The difference in this trait between the two studies might be due to differences in the planting densities tested.

Table 3. Lodging scores of Baegunkong (Baegun) and Namhaekong (Namhae) as affected by planting date and planting density.

Planting density (Plants /m^2)	Planting date					
	8 June		23 June		8 July	
	Baegun	Namhae	Baegun	Namhae	Baegun	Namhae
33	1.0†	0.3	0	2.5	0	0.8
43	0.8	1.5	0	2.5	0	0.8
53	2.0	3.8	0	2.5	0	0.8
63	2.3	3.3	0	2.5	0	1.3

† Scores were given from 0 to 9 with 0 meaning no lodging and 9 meaning all plants lodged.

Table 4. Analysis of variance for the agronomic characteristics of two soybean cultivars grown at three planting dates and four planting densities.

Source of variation	df	Plant height	Stem diameter	No. of main stem nodes	No. of branches per plant	No. of branches per m²	No. of seeds per pod
Planting date (P)	2	*	**	**	NS	NS	**
Cultivar (C)	1	NS	NS	**	**	**	**
P×C	2	*	NS	NS	NS	NS	NS
Planting density (D)	3	**	**	**	**	NS	*
P×D	6	**	NS	NS	NS	NS	*
C×D	3	NS	NS	NS	NS	NS	NS
P×C×D	6	**	NS	NS	NS	NS	*

Source of variation	df	No. of pods per plant	No. of pods per m²	No. of seeds per plant	No. of seeds per m²	100-seed weight	Seed yield
Planting date (P)	2	NS	NS	*	*	**	*
Cultivar (C)	1	**	**	*	*	**	NS
P×C	2	NS	NS	NS	NS	NS	*
Planting density (D)	3	**	**	**	**	**	*
P×D	6	NS	NS	NS	NS	**	NS
C×D	3	NS	NS	NS	NS	*	NS
P×C×D	6	NS	NS	NS	NS	NS	NS

*, ** Significant at 5 and 1% probability levels, respectively; NS Not significant.

Seed yield components

The number of pods per plant or per m² was significantly affected by cultivar and planting density (Table 4). Namhaekong had 5 more pods per plant than Baegunkong (Table 6). There was no significant difference in main stem pod number per plant between two cultivars but Namhaekong had 3.5 more branch pods per plant than Baegunkong which had 5.3 branch pods (data not shown). As planting density increased from 33 to 63 plants per m², the pod number per plant decreased from 28.9 to 18.8, corroborating the result of Carpenter & Board (1997), but the pod number per m² increased from 952 to 1,187 (Table 7). These results agree with the results of Lee (1974) that pod number per m² increased with increasing planting density. However, Carpenter and Board (1997) obtained similar pod number per m² among the plant populations from 7 to 23 plants per m² when most pods (75~87%) came from branch pods. In this study branch pods accounted for 25 to 37% of total pods (data not shown).

The number of seeds per pod was significantly affected by the planting date, cultivar, planting density, planting date × planting density, and plant date × cultivar × planting density (Table 4). The number of seeds per pod increased as the planting was delayed (Table 5), corroborating results of Elmore (1990). Namhaekong had 0.2 more seeds per pod than Baegunkong. Seed number per pod was fewer at the highest planting density than at the lower planting densities. Although planting date × planting density and planting date × cultivar × planting density interactions were significant for seed number per pod, there was no clear trend.

The number of seeds per plant or per m² was significantly influenced by the planting date, cultivar, and planting density (Table 4). Seed number increased from 32.4 to 44.8 seeds per plant as planting was delayed from 8 June to 8 July (Table 6). Namhaekong had 13.9 more seeds per plant than Baegunkong. As planting density increased from 33 to 63 plants per m², seed number declined from 50.5 to 31.2 seeds per plant (Table 6) but increased from 1,666 to 1,966 seeds per m² (Table 7). These results agree with Park et al. (1990) but not with Carpenter & Board (1997). The different responses between the Carpenter & Board study and this study may have resulted from the lower branch pod contribution in this study as mentioned above.

Averaged over cultivars and planting densities, 100-seed weight declined from 17.1 to 14.5 g as planting was delayed from 8 June to 8 July (Table 5). These results are in agreement with some investigators (Beatty et al., 1982; Elmore, 1990). Seed weight was lighter for Namhaekong which had more seeds per pod than Baegunkong. Although significant planting date × planting density interaction was observed for the seed weight, there was no consistent trend. The seed weight was lighter at the highest planting density for Baegunkong while there was no difference in seed weight for Namhaekong among the planting densities, resulting in a significant cultivar × planting density interaction. However, other researchers (Lee, 1974; Park et al., 1990) reported that seed weight

Table 5. Plant height, seed number per pod, 100-seed weight, and seed yield of Baegunkong (Baegun) and Namhaekong (Namhae) as affected by the planting date and planting density.

Planting density (Plants /m²)	Planting date								
	8 June			23 June			8 July		
	Baegun	Namhae	Mean	Baegun	Namhae	Mean	Baegun	Namhae	Mean
				Plant height (cm)					
33	63.1	63.9	63.5	61.6	58.8	60.2	51.2	55.7	53.5
43	69.5	65.1	67.3	62.1	62.4	62.3	53.2	57.7	55.5
53	78.8	68.4	73.6	64.4	67.0	65.7	56.8	59.2	58.0
63	79.7	72.5	76.1	65.2	68.9	67.1	57.2	59.6	58.4
Mean	72.8	67.5	68.1	63.3	64.3	63.3	54.6	58.1	56.4
LSD1*=8.9, LSD2=1.6, LSD3=4.3, LSD4=2.7, LSD6=3.9, LSD7=10.3, LSD9=4.6, LSD10=6.8, LSD11=9.3									
				No. of seeds per pod					
33	1.27	1.77	1.52	1.68	1.89	1.78	1.78	1.93	1.85
43	1.36	1.54	1.45	1.59	1.94	1.76	1.78	1.98	1.87
53	1.40	1.68	1.54	1.61	1.78	1.69	1.73	2.06	1.89
63	1.23	1.49	1.35	1.58	1.76	1.67	1.76	2.01	1.88
Mean	1.31	1.62	1.46	1.61	1.84	1.72	1.76	1.99	1.87
LSD1=0.14, LSD2=0.06, LSD4=0.97, LSD6=0.16, LSD9=0.19, LSD10=1.66, LSD11=0.20									
				100-seed weight (g)					
33	19.7	15.3	17.5	18.8	15.1	17.0	16.1	12.6	14.4
43	19.9	16.0	18.0	18.2	14.1	16.2	16.4	13.1	14.8
53	18.5	14.5	16.5	19.2	15.0	17.1	16.1	13.1	14.6
63	17.7	15.2	16.5	17.4	14.8	16.1	15.8	12.6	14.2
Mean	19.0	15.3	17.1	18.4	14.8	16.6	16.1	12.9	14.5
LSD1=1.02, LSD2=0.45, LSD4=0.8, LSD5=0.6, LSD8=0.7, LSD10=1.2									
				Seed yield (kg /ha)					
33	1,170	1,730	1,450	1,870	2,340	2,110	2,190	1,850	2,020
43	1,480	1,940	1,710	2,290	2,680	2,485	2,270	2,070	2,170
53	1,660	1,950	1,810	2,520	2,830	2,680	2,570	2,240	2,410
63	1,500	1,940	1,720	2,450	2,910	2,680	2,640	2,170	2,410
Mean	1,450	1,890	1,670	2,280	2,690	2,490	2,420	2,080	2,250
LSD1=46, LSD2=13, LSD3=36, LSD7=65									

* LSD (0.05) for meaningful comparison of treatment means are shown; LSD1-planting date means, LSD2-plant density means, LSD3-cultivar means for the same or different planting date, LSD4-plant density means for the same planting date, LSD5-plant density means for the same cultivar, LSD6-plant density means for the same planting date and cultivar, LSD7-planting date means for the same or different cultivar, LSD8-cultivar means for the same or different plant density, LSD9-cultivar means for the same planting date and plant density, LSD10-planting date means for the same or different plant density, LSD11-planting date means for the same cultivar and plant density.

was not significantly influenced by the planting density.

Seed yield

Seed yield was significantly affected by the planting date, planting density, and planting date x cultivar (Table 4). Mean seed yield for 8 June, 23 June, and 8 July plantings were 1,670, 2,490, and 2,250 kg/ha, respectively (Table 5). Kang (1971) reported that the seed yield of Hill and a Korean local cultivar was greater at Cheju for 10 and 25 June plantings than for 10 and 25 May, and 10 July plantings. He also found that the highest seed yields were obtained at 17 plants per m² for 10 May to 10 June plantings and at 33 plants for 25 June and 10 July plantings. Across the planting dates and cultivars, seed yield increased from 1,860 to 2,290 kg/ha as planting density increased from 33 to 53 plant per m² and then leveled off with a further increased planting density, in-

Table 6. The main effects of the planting date, cultivar and planting density on stem traits and yield components of soybean.

Treatment	Stem diameter (cm)	No. of main stem nodes	No. of branches per plant	No. of pods per plant	No. of seeds per plant
Planting date					
8 June	0.39	13.1	2.2	21.6	32.4
23 June	0.36	12.6	2.4	23.8	41.7
8 July	0.31	11.8	1.7	23.9	44.8
LSD (0.05)	0.04	0.4	NS	NS	8.4
Cultivar					
Baegunkong	0.35	12.8	1.7	20.6	32.7
Namhaekong	0.34	12.1	2.4	25.6	46.6
LSD (0.05)	NS	0.4	0.2	2.7	5.0
Planting density (plants /m^2)					
33	0.39	12.9	2.8	28.9	50.5
43	0.36	12.6	2.3	24.2	41.4
53	0.34	12.4	1.8	20.5	35.5
63	0.32	12.1	1.6	18.8	31.2
LSD (0.05)	0.02	0.2	0.2	1.8	3.6

Table 7. Effects of planting density on the number of branches, pods, and seeds per m^2.

Planting density (plants /m^2)	No. of branches	No. of pods	No. of seeds
33	91.0	952	1,666
43	97.1	1,040	1,781
53	94.4	1,088	1,881
63	98.6	1,187	1,966
LSD (0.05)	NS	75	145

dicating that the recently released soybean cultivars are adapted to higher planting densities than the old cultivars. Seed yield for Baegunkong was greater for 23 June and 8 July plantings while the highest seed yield for Namhaekong was obtained for 23 June planting, resulting in a significant planting date x cultivar interaction. The lower seed yield of two cultivars for the 8 June planting resulted from the lower seed number per pod compared with the later plantings. The cause of the fewer seeds per pod at the earliest planting is not clear. The lighter seed weight accounted for the lower seed yield of Namhaekong at 8 July planting because the other yield components were similar or greater at the latest planting in comparison with the earlier plantings. Our data indicate that yield of recently recommended soybean cultivars grown as a double crop in Cheju area is likely to be more stable at about 50 plants per m^2 regardless of planting date.

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