Effect of Planting Date and Plant Density on Yield and Quality of Soybean Forage in Jeju

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ABSTRACT : Soybean [*Glycine max* (L.) Merr.) is known to produce the highest total digestible mutrients (TDN) yield among summer grain legumes in Jeju area but little is known about the effects of cultural practices on forage yield and quality. A determinate soybean cv. Baegunkong was planted on 5 June, 20 June, and 3 July and grown at four plant densities (30, 50, 70 and 90 plants m^{-2}) in 1998 in Jeju to evaluate the effects of planting date and plant density on the yield and quality of soybean forage. Days to flowering decreased from 47 to 38 days, average plant height from 61 to 51 cm and main stem diameter from 6.31 to 5.00 mm as planting was delayed from 5 June to 3 July. Average plant height quadratically increased from 45 to 62 cm as plant density increased from 30 to 90 plants m^{-2}. Planting date did not affect the average dry matter, crude protein, and TDN yields. The average dry matter and TDN yields displayed a quadratic response to plant density and the optimum plant density for both dry matter and TDN yields was estimated about 60 plants m^{-2}. Plant density had no effect on crude protein yield. Planting date did not significantly influence forage quality. The crude protein content was not significantly influenced by plant density. Increasing plant density slightly increased acid detergent fiber content but slightly decreased TDN content.

Keywords : soybean, planting date, plant density, forage yield, forage quality.

Although presently grown almost entirely as a grain legume, soybean was a popular main summer annual green manure and forage legume in Jeju Island until N fertilizers were readily available and cheap. Sorghum [*Sorghum bicolar* (L.) Monench] has been recommended for a summer forage crop in the island because of their high productivity. Comparing with sorghum, soybean produces much higher quality forage although forage yield of soybean is much less. Kang *et al.* (1998a) reported that crude protein (CP), crude fiber and total digestible nutrients (TDN) content of soybean forage harvested at stage R6 was about 20, 65, and 25%, respectively while those of sorghum forage harvested at 30% heading about 8, 52, and 38%, respectively. Because of increasing proportion of seed with high protein and digestibility, soybean forage quality does not decrease with aging (Munoz *et al.*, 1983). Kang *et al.* (1998a) also reported that among grain legumes [soybean, mungbean, cowpea (*Vigna sinsensis* L.), and adzuki bean], the dry matter (DM), CP, and TDN yields of soybean forage averaged across two planting dates and three cultivars were greatest with about 5,650, 1,060, and 3,640 kg ha^{-1}, respectively, in Jeju. They concluded that soybean could be the best forage legume for grass-legume forage rotation in this region and good CP supplementary forage to sorghum with low CP content because of higher CP content of soybean forage. Lee (1989) has shown that corn-soybean intercropping can increase CP yield without a decrease in DM yield in comparison with corn monocropping for silage. However, Redfearn *et al.* (1999) found that intercropping tall-statured forage-type soybean with another tall-growing forage does not appear to be practical because of the decrease in dry matter accumulation of soybean.

Compared with sorghum for which the recommended N rate is 250 kg ha^{-1}, soybean requires only about 16% of N fertilizer required for sorghum. Soybean fixes N in the atmosphere and some of fixed N by soybean become available for the next crop. Cropping soybean usually increase the yield of the next crop (Bagayoko *et al.*, 1992).

In the USA, soybean was primarily a forage crop and grown for hay and silage with cowpea, millet (*Panicum* spp.) or sorghum (Smith & Huyser, 1987). Soybean was frequently grown with corn (*Zea mays* L.) to increase soil N and to improve the quality of silage. Perennial legumes have now largely replaced soybean for forage production but soybean is still considered a viable alternative forage during periods of decreased productivity of perennial forage species (Hintz *et al.*, 1992; Munoz *et al.*, 1983). Hintz *et al.* (1992) evaluated management practices for soybean forage such as plant density, row spacing, cultivar, and harvest maturity and found that harvest maturity had the greatest effect on forage yield and quality. The study indicated that soybean could produce forage similar in quality to alfalfa and that management practices typically used for grain production are suitable for forage production. In Korea, cultivar and harvest maturity effects also has been reported (Lee *et al.*, 1995; Shin, 1987) but there is little information on forage yield and

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Table 1. The initial chemical properties of surface soil (0~10 cm) at the experimental site.

pH (1:5)	O.M.	Av. P_2O_5	Ex. cations				EC
			Ca	Mg	K	Na	
	g kg^{-1}	mg kg^{-1}		cmol$^+$ kg^{-1}			dS m^{-1}
4.38	58.1	188	1.97	0.78	0.61	0.16	0.84

quality of soybean grown at different planting date and plant densities. The objective of this study was to evaluate forage yield and quality of soybean in order to determine the optimum plant density at various planting dates in Jeju area.

MATERIALS AND METHODS

A field study was conducted in 1998 at the Research Farm of College of Agriculture, Cheju National University (33° 27' 20" N latitude, 277 m altitude) on a volcanic soil with low nutrient status. Mean soil test values for surface soil (0 to 10 cm) were shown in Table 1.

A soybean cultivar, Baegunkong was planted on 5 June, 20 June and 3 July on 50-cm rows with plant spaces of 13.3, 8.0, 5.7 and 4.4 cm within a row. Three seeds were planted per hill and later thinned to 2 plants per hill to obtain plant densities of 30, 50, 70, and 90 plants m^{-2}. Fertilizer was applied prior to planting at a rate of 40, 60, and 50 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. Recommended pesticides were used to control weeds, diseases and insects.

Each experimental plots contained four rows with 4 m long (8 m^2 per plot). The experimental design was a split-plot arrangement in a randomized complete block with four blocks. The main-plots consisted of three planting dates, and subplots four plant densities.

Flowering date (R2 stage) was recorded. Lodging was not recorded because considerable lodging was not observed until harvest. At stage R6 (Fehr *et al.*, 1971), plant height and stem diameter of ten representative plants in the center two rows of each plot were measured and forage was hand harvested from 2 m of two center rows (2 m^2) at about 2-cm cutting height. A subsample was collected for each plot and dried at 80°C in a forced oven to a constant weight, and then weighed to determine dry matter yield. Dried samples were ground through 1 mm-sieve and were analyzed for NDF and ADF (Goering & Van Soest, 1970) and total N (Leco dry combustion method, Reco Corp., 1998), which was reported as CP (N × 6.25). Total digestible nutrient content was calculated according to the equation given by Lee *et al.* (1997). Analysis of variance was performed with SAS General Linear Models procedure and planting date means were separated according to least significant difference (LSD) and trend comparisons were used for plant density.

Air temperature and precipitation were obtained from the Jeju Agricultural Experiment Station (4.1 km from the experimental site) and shown in Table 2. Comparing the 11 year mean (1987-1997), mean air temperatures of 1998 growing season were slightly cooler in early June and late August, and warmer in early July and early to mid-August. Plants somewhat were exposed to drought from August to September.

Table 2. Ten day average of normal mean air temperature and precipitation, and departures from normal from 1998 growing season at Jeju.

Month	Ten days	Mean air temperature		Precipitation	
		Normal†	Departure‡	Normal	Departure
		---------- °C ----------		---------- mm ----------	
June	Early	19.6	-1.7	28.6	+6.7
	Middle	20.9	-0.7	77.0	-8.8
	Late	22.1	+0.7	87.1	+23.2
July	Early	23.7	+3.3	76.0	-65.8
	Middle	26.0	+0.2	36.0	-18.2
	Late	26.3	-4.0	62.4	+54.3
Aug.	Early	26.7	+1.4	60.3	-8.8
	Middle	25.7	+1.7	98.1	-96.4
	Late	24.8	-3.5	82.8	-15.6
Sept.	Early	24.0	-1.3	56.0	-56.0
	Middle	21.9	+0.5	27.1	+69.5
	Late	20.2	+0.6	65.8	+193.6

† 11-year (1987-1997) mean.
‡ Departure from normal.

RESULTS AND DISCUSSION

Days to flowering, plant height, and stem diameter

Because the number of days from planting to flowering was not affected by plant density, only planting date effect

Table 3. Effect of planting date on flowering (50% of plants) and harvest dates of soybean grown as forage in 1998.

Planting date	Flowering date	Harvest date
5 June	22 July (47)	2 Sept. (89)
20 June	30 July (40)	9 Sept. (81)
3 July	10 Aug. (38)	23 Sept. (82)

†Numbers in parenthesis are days after planting.

Table 4. Mean square values and significance of analysis of variance for agronomic characteristics of soybean forage as affected by planting date and plant density in 1998.

Source of variation	df	Plant height	Stem diameter	DM† yield	CP yield	TDN yield	CP content	NDF content	ADF content	TDN content
						× 1000‡				
Block	3	50.97^{NS}	1.31^{NS}	9193$^{(*)}$	473.1$^{(*)}$	3607^{NS}	8.07^{NS}	0.91^{NS}	1.80^{NS}	1.12^{NS}
Planting date (P)	2	436.31*	7.10**	2937^{NS}	487.0$^{(*)}$	1331^{NS}	63.04$^{(*)}$	1.96^{NS}	4.01^{NS}	2.51^{NS}
Error a	6	43.32	0.53	2543	125.6	1153	14.10	2.61	4.91	3.07
Plant density (D)	3	670.40***	6.32***	1338^{NS}	4.5^{NS}	445^{NS}	6.53^{NS}	4.26*	7.63**	4.76**
Linear	1	1886.46***	17.97***	224^{NS}	8.4^{NS}	8^{NS}	7.83^{NS}	2.28^{NS}	19.34***	12.07***
Quadratic	1	118.44*	0.85*	3261*	5.1^{NS}	1126$^{(*)}$	8.38^{NS}	0.00^{NS}	3.53$^{(*)}$	2.21$^{(*)}$
Cubic	1	5.83^{NS}	0.18^{NS}	528^{NS}	0.1^{NS}	202^{NS}	3.38^{NS}	10.50**	0.00^{NS}	0.00^{NS}
P × D	6	4.75^{NS}	0.30*	109^{NS}	2.2^{NS}	37^{NS}	1.23^{NS}	1.41^{NS}	0.21^{NS}	0.13^{NS}
Error b	27	16.24	0.09	777	35.0	290	3.00	1.18	1.16	0.72

(*), *, **, ***Significant at the 10, 5, 1 and 0.1% probability levels, respectively; NS, not significant.
†DM, dry matter; CP, crude protein; TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber.
‡To obtain the actual mean squares, the reported values must be multiplied by the factor.

on this trait was shown in Table 3. Days to flowering decreased from about 47 to 38 days as planting was delayed from 5 June to 3 July probably due to higher temperatures for the latter plantings.

Mean square values and significance of analysis of variance for the traits measured as affected by planting date and plant density are shown in Table 4. Planting date × plant density interaction was not significant even at 10% level except for main stem diameter. Therefore, only the main effects of the treatments on the traits are shown in Table 5 and 6. Regression equations relating plant density to various traits that showed significant trend were presented in Table 7.

Planting date significantly affected plant height and main stem diameter at the 5% probability level and CP yield and CP content at the 10% probability level. Plant density significantly affected plant height, main stem diameter, and forage quality except CP content. There were significant quadratic trends between plant density and DM ($p<0.05$) and TDN ($p<0.10$) yields.

As planting was delayed from 5 June to 3 July, mean plant height decreased from 61 to 51 cm and main stem diameter from 6.31 to 5.00 cm when averaged across four plant densities. As plant density was increased from 30 to 90 plants m^{-2}, mean plant height across three planting dates quadratically increased from 45 to 62 cm, and the stem diameter linearly

Table 5. Plant height, stem diameter, and yield of dry matter (DM), crude protein (CP), and total digestible nutrients (TDN) of soybean forage as affected by planting date and plant density in 1998.

Treatment	Plant height	Stem diameter	DM† yield	CP yield	TDN yield
	cm	mm	kg ha^{-1}		
Planting date					
5 June	61.3	6.31	6008	848	3740
20 June	53.3	5.60	6857	1153	4315
3 July	51.5	5.00	6332	1146	3991
LSD (5%)	5.7	0.63	NS	NS	NS
Plant density, plants m^{-2}					
30	45.2	6.61	6093	1057	3879
50	54.6	5.69	6488	1063	4058
70	59.3	5.30	6831	1056	4261
90	62.4	4.91	6183	1020	3850
Response†	Q	Q	Q	NS	Q

†Q, quadratic; NS, not significant at the 10% probablity level; Regression equations relating plant density are presented in Table 7.

Table 6. Forage quality of soybean forage as affected by planting date and plant density in 1998.

Treatment	CP†	NDF	ADF	TDN
	%			
Planting date				
5 June	14.2	59.8	33.7	62.3
20 June	16.7	60.2	32.8	63.0
3 July	18.1	60.5	32.8	63.0
LSD (5%)	NS	NS	NS	NS
Plant density, plants m^{-2}				
30	17.2	60.1	32.0	63.6
50	16.4	59.4	33.1	62.5
70	16.3	60.9	33.7	62.3
90	15.4	60.3	33.7	62.3
Response‡	NS	C	Q	Q

†CP, crude protein; TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber.
‡Q, quadratic; C, cubic; NS, not significant at the 10% probablity level; Regression equations relating plant density are presented in Table 7.

Table 7. Regression equations with coefficients of determination relating plant density and various traits and the calculated optimum plant density (plants m^{-2}) for DM and TDN yields.

Variable	Regression equation	r^2 or R^2	Opti. plant density
Plant hight	$Y = 26.37 + 0.751X - 0.0039X^2$	0.997	
Stem diameter			
5 June planting	$Y = 8.15 - 0.0305X$	1.000	
20 June planting	$Y = 9.56 - 0.111X + 0.00066X^2$	0.954	
3 July planting	$Y = 7.56 - 0.074X + 0.00045X^2$	0.999	
DM yield	$Y = 4195.2 + 81.25X - 0.6516X^2$	0.868	62
TDN† yield	$Y = 2794.0 + 46.52X - 0.3829X^2$	0.849	61
NDF content	$Y = 74.1 - 0.861X + 0.016X^2 - 0.0000871X^3$	1.000	
ADF content	$Y = 29.29 + 0.11X - 0.00068X^2$	1.000	
TDN content	$Y = 65.75 - 0.087X + 0.00054X^2$	1.000	

†DM, dry matter; TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber.

decreased for 5 June planting but quadratically for 20 June and 7 July plantings, causing the significant planting date × plant density interaction for the stem diameter. Kang *et al.* (1998b) also reported that both the plant height and stem diameter of two soybean cultivars tended to decrease as planting was delayed from 8 June to 8 July, in 1996 at Jeju. According to Johnson (1987), soybean plants are generally taller when planted between mid-May and early June and decrease with either very early or late plantings. Parker *et al.* (1981) also reported that plant height increased with succeeding planting until early June and then decreased with a further delayed planting. Plant height of soybean usually increases but the stem diameter decreases with increasing plant density (Kang *et al.*, 1998a; Kim *et al.*, 1993).

DM, CP, and TDN yields

Although 20 June and 3 July plantings produced 849 and 324 kg ha^{-1} more DM than 5 June planting when averaged across four plant densities, the DM yield differences between plant dates were not statistically significant at the 10% probability level because of the larger error mean square value (Tables 4 and 5). The DM yield exhibited a significant quadratic response to plant density, with maximum DM yield (6,728 kg ha^{-1}) at 62 plants m^{-2} (Table 7). Crude protein yield for 20 June and 3 July plantings tended to be greater (significant at the 10% probability level) comparing with 5 June planting because of greater DM yield and higher CP content for the later plantings but was not influenced by plant density. Total digestible nutrients yield was not affected by planting date but quadratically increased with increasing planting density, with maximum TDN yield (4,207 kg ha^{-1}) at 61 plants m^{-2} (Table 7). Kang *et al.* (1998b) observed greater soybean seed yield for 23 June planting than for 8 June and 8 July plantings in Jeju. They also reported that soybean seed yield increased up to 53 plants m^{-2}. Kang (1971) reported that the soybean seed yield of 'Hill' and a Korean local cultivar was greater for 10 and 25 June plantings than for 10 and 25 May, and 10 July plantings. Hintz *et al.* (1992) reported that the higher planting rate (740,000 plants ha^{-1}) produced 0.1 Mg ha^{-1} more soybean forage than lower planting rate (247,000 plants ha^{-1}) averaged over all main effects (two row spacings, three cultivars, and four harvest stages).

Forage quality

Planting date did not significantly influence CP, NDF, ADF, and TDN contents. However, mean CP content across four plant densities tended to increase with delayed plantings (significant at the 10% probability level, Tables 4 and 6). The CP content was not significantly influenced by plant density. The relationship between plant density and NDF content was cubic, but the magnitude of the difference is small and of little practical importance. Increasing plant density slightly increased ADF content but slightly decreased TDN content. Hintz *et al.* (1992) also found that the soybean forage produced under the higher planting rate was slightly lower in CP and higher in NDF and ADF concentrations than that produced under the lower planting rate.

In conclusion, the optimum planting date seems to be mid-June for both soybean seed and forage productions in Jeju area. Our data also indicates forage yield of grain-type soybean grown as double crop on the volcanic soils with low nutrient status is like to be more stable at about 60 plants m^{-2} regardless of planting date.

REFERENCES

Bagayoko, M., S. C. Mason, and R. J. Sabata. 1992. Effects of previous cropping systems on soil nitrogen and grain sorghum yield. *Agron. J.* 84 : 862-868.

Fehr, W. R., C. E. Caviness, D. T. Burmood, and J. S. Pennington. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. *Crop Sci.* 11 : 929-931.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses. Agric. Handb. 379, U. S. Gov. Print. Office, Washington DC.

Hintz, R. W., K. A. Albrecht, and E. S. Oplinger. 1992. Yield and quality of soybean forage as affected by cultivar and management practices. *Agron. J.* 84 : 795-798.

Johnson, R. R. 1987. Crop management. p. 355-390. In J. R. Wilcox (ed.) Soybeans: Improvement, production and uses. 2nd ed. Agron. Monogr. 16. ASA, CSSA, and SSSA, Madison, WI.

Kang, C. S. 1971. Experiment on planting date and plant density for recommending soybean cultivars. Jeju Provincial Rural Development Administration Annual Research Report for 1970. p. 59-62.

Kang, Y. K., N. K. Cho, W. B. Yook, and M. S. Kang. 1998a. Forage yield and quality of summer grain legumes and forage grasses in Cheju Island. *Korean J. Crop Sci.* 43(4) : 245-249.

Kang, Y. K., M. R. Ko, N. K. Cho, and Y. M. Park. 1998b. Effect of planting date and planting density on growth and yield of soybean in Cheju Island. *Korean J. Crop Sci.* 43(1) : 44-48.

Kim, H. S., E. H. Hong, S. I. Park, and Y. K. Park. 1993. Responses of growth and yield characters on planting density in determinate and indeterminate soybeans. *Korean J. Crop Sci.* 38(2) : 189-195.

Lee, J. S., I. H. Jo, and J. H. Ahn. 1997. Harvest management and nitrogen fertilization level to maximize nutrient yield of reed canarygrass (*Phalaris arundinacea* L.) in uncultivated rice paddy. *J. Kor. Grassl. Sci.* 17(2) : 123-134.

Lee, S. K. 1989. Studies on corn-legume intercropping system. Effects of corn-soybean intercropping on chemical composition and TDN yield. *J. Kor. Grassl. Sci.* 9(2) : 113-118.

Lee, S. M., J. Y. Koo, and B. T. Jeon. 1995. The effect of cultivation period on growth characteristics, palatability and forage yield of soybean cultivars. *J. Kor. Grassl. Sci.* 15(2) : 132-139.

Munoz, A. E., E. C. Holt, and R. W. Weaver. 1983. Yield and quality of soybean hay as influenced by stage of growth and plant density. *Agron. J.* 75 : 147-149.

Parker, M. B., W. H. Marchant, and B. J. Mullinix Jr. 1981. Date of planting and row spacing effects on four soybean cultivars. *Agron. J.* 73 : 759-762.

Reco Corp. 1998. FP-528 protein/nitrogen analyzer instruction manual. Reco Corp., St. Joseph, MI.

Redfearn, D. D., D. R. Buxton, and T. E. Devine. 1999. Sorghum intercropping effects on yield, morphology, and quality of forage soybean. *Crop Sci.* 39 : 1380-1384.

Shin, C. N. 1987. Effect of various growth stages on the dry matter yield and nutritive value of soybean. *Korean J. Anim. Sci.* 29(5) : 235-239.

Smith, K. J. and W. Huyser. 1987. World distribution and significance of soybean. p. 1-22. In J. R. Wilcox (ed.) Soybeans: Improvement, production and uses. 2nd ed. Agron. Monogr. 16. ASA, CSSA, and SSSA, Madison, WI.