(Korean J. Crop Sci.) 43(4) : 245~249(1998)

Forage Yield and Quality of Summer Grain Legumes and Forage Grasses in Cheju Island

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ABSTRACT

Soybean [*Glycine max* (L.) Merr.), mungbean [*Vigna radiata* (L.) Wilcz.], cowpea [*V. unguiculata* (L.) Walp.], adzuki bean [*V. angularis* (Willd.) Ohwi & Ohashi], maize [*Zea mays* L.], sorghum [*Sorghum bicolor* (L.) Moench], sorghum × sudangrass [*S. bicolor* intraspecific hybrid], and Japanese millet [*Echinochloa crusgalli* var. *frumentacea* (Link) W.F. Wight] were grown at two planting dates (18 June and 15 July) at Cheju in 1997 to select the best forage legumes adapted to Cheju Island for grass-legume forage rotation. Averaged across planting dates and cultivars, dry matter (DM), crude protein (CP), and total digestible nutrient (TDN) yields were 5,646, 1,056, and 3,637 kg/ha for soybean, 4,458, 676, and 2,661 kg/ha for mungbean, 3,289, 553, and 2,055 kg/ha for cowpea, 3,931, 674, and 2,489 kg/ha for adzuki bean, 12,695, 969, and 7,642 kg/ha for maize, 17,071, 1,260, and 8,857 kg/ha for sorghum, 16,355, 1,163, and 8,543 kg/ha for sorghum x sudangrass hybrid, and 8,288, 929, and 4,091 kg/ha for Japanese millet. Soybean was higher in CP, ether extract (EE), and TDN content but was lower in nitrogen free extract content compared with the three other legumes. The legumes had much higher CP (13.7 to 21.9%), EE (2.42 to 6.23%), and TDN (58.7 to 69.9%) content but lower in crude fiber (CF) content (17.3 to 25.3%) than did the grasses tested except maize which had relatively lower CF content but higher TDN content. These results suggest that soybean could be the best forage legume for grass-legume forage rotation in the Cheju region.

Key words : soybean, mungbean, adzuki bean, cowpea, sorghum, sorghum × sudangrass, dry matter, crude protein, total digestible nutrient.

Sorghums, including sorghum × sudangrass and Italian ryegrass are recommended for summer and winter forage crops, respectively, in Cheju Island because of their high productivity. The recommended N rates for sorghums and Italian ryegrass are 250 and 200 kg/ha, respectively. Growing these grasses every year will increase NO_3-N contamination of ground waters and lead to a decrease in soil pH with an accompanying decrease in forage yields unless lime sufficient to neutralize the acidity formed is applied to the soil (Tisdale & Nelson, 1975).

It is very important to reduce the NO_3-N contamination of ground waters in this region because ground water is the main sources of drinking water. Of 163 drinking-water wells in the island, 18 wells exceeded the Korean drinking-water standard (10 mg N/L) in 1993 and fertilizer N was considered to be an important contamination source of NO_3-N to ground water. Present water pollution concerns make grass-legume rotation an attractive means to reduce use of N fertilizers. In addition to a decreased need for N fertilizer for subsequent crops, growing legumes in rotation increases yields and helped to control pests (Bagayoko et al., 1992; Porter et al., 1997). However, there is no popular summer annual forage legume on this island because high yielding summer annual forage legumes have not developed in Korea. Until N fertilizers were readily available and cheap, soybean was a popular main summer annual green manure and forage legume in Cheju province. Soybean appeared to be a good forage legume for grass-legume rotation in Korea where cultural practices for perennial legumes had not been well established (Lee et al., 1995; Shin, 1987). In the USA, perennial legumes have now largely replaced soybean for forage production but soybean is still considered as a viable alternative forage during periods of decreased productivity of perennial forage species (Hintz et al., 1992; Munoz et al., 1983). There is little information on forage yield and quality of summer annual grain legumes in this region. The objective of this study was to determine forage yield and quality of summer annual grain legumes in order to select the best forage legumes adapted to this region for grass-legume forage rotation.

MATERIALS AND METHODS

This field study was conducted at the Research Farm of the College of Agriculture, Cheju National University (33°N latitude, 277 m altitude) on volcanic ash soil at Cheju in 1997. The initial chemical properties of surface soil (0~10 cm) are shown in Table 1. Three soybean cultivars (Baegunkong, Namhaekong, and Sobaeknamulkong), two mungbean cultivars (Keumsungnogdu and Nampyungnogdu), one Cheju native cowpea, 'Chungjupat' adzuki bean, 'Pioneer 3525' maize, 'Pioneer 931' sorghum, 'Pioneer 988' sorghum × sudangrass hybrid,

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Received 31 Aug. 1998.

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

Planting date	pH (1:5)	O.M. (g /kg)	Av. P_2O_5 (mg /kg)	Ex. cations($cmol^+$ /kg)				CEC ($cmol^+$ /kg)	EC (dS /m)
				Ca	Mg	K	Na		
18 June	5.5	53.9	149	3.10	1.34	1.32	0.27	10.3	0.14
15 July	5.3	47.4	219	2.16	1.07	1.34	0.22	8.5	0.13

and one Cheju native Japanese millet were planted on 50-cm row spacing on 18 June and 15 July.

At planting, legumes were fertilized with 40 kg N/ha, 70 kg P_2O_5/ha, and 60 kg K_2O/ha. Maize, sorghum, sorghum × sudangrass hybrid, and Japanese millet were fertilized with 100 kg N/ha, 150 kg P_2O_5/ha, and 100 kg K_2O/ha except Japanese millet which received 60 kg N/ha. At 46 days after planting (7 to 8 leaf stages), 100 kg N/ha was applied to maize planted on 18 June but not on 15 July because of dark green leaves of plants seeded on 15 July. Japanese millet planted on 18 June was fertilized with 45 kg N/ha after the first harvest. Nitrogen, P_2O_5 and K_2O were applied as urea, fused phosphate, and muriate of potash. Plant populations for soybean and mungbean were 400,000 plants/ha and those for adzuki bean and maize were 533,000 and 100,000 plants/ha, respectively. Seeding rate for sorghum, sorghum × sudangrass hybrid and Japanese millet was 30 kg/ha. The herbicide alachlor (2-chloro-2', 6'-diethyl-N-[methoxymethyl] acetanilide) granules at 2.0 kg a.i./ha were broadcast applied as pre-emergence for legumes and maize. No herbicide was applied for sorghum, sorghum × sudangrass hybrid, and Japanese millet, and all plots for these crops were hand-weeded.

Individual plots had five rows, 4 m long. The experimental design was a randomized complete block with four replications. Early season injury by bean stem miner (*Melanagromyza sojae* Zehntner) resulted in poor stand establishment of cowpea and adzuki bean planted on 18 June and thus data for the two crops planted on 18 June were not collected.

Temperature and rainfall data (Table 2) were obtained from the Cheju Agricultural Experiment Station located about 4.1 km from the experimental site. The mean air temperatures for June and July were above normal and those for August through October were below normal. Rainfall for these six months was below normal. Rain and wind on 5 and 6 August caused severe lodging of the grasses. Several days after lodging, 93% of maize, sorghum and sorghum × sudangrass hybrid plants and 79% of Japanese millet plants recovered from the lodging. The lodging might somewhat have decreased the DM yield of the grasses.

Table 2. Normal mean air temperature and precipitation, and departures from normal from 1996 growing season at Cheju.

Month	Mean air temperature (℃)		Precipitation (mm)	
	Normal†	Departure‡	Normal	Departure
June	20.8	+1.5	174.5	−77
July	25.4	+0.9	263.5	−159
Aug.	27.9	−0.3	267.2	−71
Sept.	21.7	−4.1	152.9	−102
Oct.	17.5	−1.3	56.1	−50

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

The initial flowering (heading dates for the grasses) and harvest dates are shown in Table 3. Legumes, maize, sorghum and sorghum × sudangrass hybrid, and Japanese millet were harvested at R6 (Fehr & Carviness, 1977), 36 to 40 days after silking, 30% heading, and mid-heading stages, respectively. Plant height was measured at harvest on ten representative plants. Canopy height was measured for cowpea because the plants were viny. Forage was hand harvested from three center rows 2 m long (3 m^2) at about 7-cm cutting height. Harvested material was weighed fresh. Subsample was collected from each plot and dried at 80℃ in a forced oven to a constant weight, and then weighed to determine dry matter yield. Dried samples were ground through 1 mm-sieve for the analysis of chemical compositions. Total nitrogen was determined by the Kjeldhal method and reported as CP (N × 6.25). Ether extract, nitrogen free extract (NFE), CF, and crude ash (CA) were determined by AOAC methods. Percentage total digestible nutrient was calculated according to the equation given by Wardeh (1981).

$$TDN (\%) = -17.265 + 1.212CP (\%) + 2.464\ EE (\%) + 0.835NFE (\%) + (\%)\ 0.448\ CF (\%)$$

RESULTS AND DISCUSSION

Plant height and DM, CP, and TDN yields

Plant height (canopy height for cowpea) and DM, CP, and TDN yields are shown in Table 3. Because sorghum and sorghum × sudangrass hybrid tested in this study were very similar in traits measured, these two grasses are referred to as sorghums in this section. As expected, the evaluated legumes were much shorter than the grasses. Plant heights of the legumes ranged from 42.2 to 66.9 cm and varied with species and cultivars. Plant height of the grasses ranged from 159.4 to 330.9 cm and sorghums were tallest followed by maize and Japanese millet.

Averaged across cultivars, soybean produced 5,761 kg/ha of DM which was 20% greater than that of the 18 June planting of mungbean. However, the average DM

Table 3. Initial flowering and harvest dates, plant height, and dry matter (DM), crude protein (CP) and total digestible nutrient (TDN) yields of some summer annual legumes and grasses planted on two dates.

Crop[†]	Cultivar	Initial flowering date[‡]	Harvest date	Plant height (cm)	DM yield	CP yield (kg/ha)	TDN yield
				18 June planting			
Soybean	Baegunkong	3 Aug.	7 Sept. (81)[§]	66.9	6,012	1,027	3,736
	Namhaekong	4 Aug.	7 Sept. (81)	62.6	5,824	1,091	3,742
	Sobaeknamulkong	1 Aug.	7 Sept. (81)	53.9	5,446	1,026	3,434
Mungbean	Keumsungnogdu	3 Aug.	1 Sept. (75)	53.9	4,739	663	2,787
	Nampyungnogdu	3 Aug.	1 Sept. (75)	51.1	4,948	679	2,921
Maize	Pioneer 3525	22 Aug.	1 Oct. (105)	176.8	11,169	881	6,825
Sorghum (S)	Pioneer 931	24 Sept.	18 Sept. (92)	317.0	18,778	1,260	9,867
			(16 Oct.)[¶] (120)	(32.0)	(289)	(65)	
S×sudangrass	Pioneer 988	24 Sept.	18 Sept. (92)	330.9	17,896	1,166	9,570
			(16 Oct.) (120)	(31.8)	(311)	(68)	
Japanese millet	Cheju native	1 Sept.	1 Sept. (75)	173.6	10,246	984	5,243
			(16 Oct.) (120)	(37.3)	(561)	(100)	
LSD (0.05)				15.8	1,729	243	940
				(3.6)	(135)	(22)	
				15 July planting			
Soybean	Baegunkong	20 Aug.	26 Sept. (73)	60.0	5,812	1,012	3,712
	Namhaekong	18 Aug.	26 Sept. (73)	61.8	5,758	1,081	3,683
	Sobaeknamulkong	11 Aug.	26 Sept. (73)	42.2	5,022	1,096	3,512
Mungbean	Keumsungnogdu	22 Aug.	18 Sept. (65)	61.9	4,245	687	2,554
	Nampyungnogdu	20 Aug.	18 Sept. (65)	55.7	3,898	675	2,382
Cowpea	Cheju native	23 Aug.	18 Sept. (65)	61.3[#]	3,289	552	2,055
Adzuki bean	Chungjupat	21 Aug.	26 Sept. (73)	45.0	3,931	674	2,489
Maize	Pioneer 3525	11 Sept.	17 Oct. (94)	209.8	14,220	1,057	8,459
Sorghum (S)	Pioneer 931	16 Oct.	13 Oct. (90)	321.3	15,074	1,196	7,847
S×sudangrass	Pioneer 988	16 Oct.	13 Oct. (90)	321.5	14,502	1,091	7,515
Japanese millet	Cheju native	7 Sept.	9 Sept. (54)	159.4	5,768	774	2,938
LSD (0.05)				9.3	1,391	139	792

[†] Data for cowpea and adzuki bean planted on 18 June were not obtained because of poor stand establishment.
[‡] Silking date for maize and heading date for sorghum, sorghum × sudangrass and Japanese millet.
[§] Numbers in parentheses are days after planting.
[¶] Data in parentheses in the second rows are for the second harvest.
[#] Canopy height.

yield of soybeans was 30 to 53% of the grasses tested which produced 10,807 to 19,067 kg/ha depending on species.

For 15 July plantings, among the legumes evaluated, soybean (5,531 kg/ha) averaged across cultivars yielded the greatest DM followed by mungbean (4,072 kg/ha), adzuki bean (3,931 kg/ha) and cowpea (3,289 kg/ha). The average DM yield of soybeans was 37 to 98% of the grasses tested which produced 5,768 to 15,074 kg/ha of DM. Among the grasses, sorghums had the greatest DM yield while Japanese millet had the least. There was no significant cultivar difference in DM yield for soybean and mungbean regardless of planting dates. Lee et al. (1995), however, reported that DM yields of ten Korea recommended soybean cultivars ranged from 6,020 to 10,603 kg/ha at 90 days after planting at Chungju. Shin (1987) reported that a soybean genotype planted in mid-May produced 12,440 kg/ha of DM in South Korea. The DM yields of soybeans were lower in this study than in other studies, indicating growing conditions for soybean in this study were not so favorable. Dry matter yields of soybeans in the USA were reported to be 6.8 to 15 Mg/ha at R7 stage (Hintz et al., 1992; Munoz et al., 1983).

At 18 June planting, soybeans (1,048 kg/ha) averaged across cultivars had 56 and 19% greater CP yields than mungbean and maize, and had similar CP yield to Japanese millet but had 18% less than sorghums. At 15

July planting, soybean (1,063 kg/ha) across cultivars produced 56, 93, 58, and 37% greater CP than did mungbean, cowpea, adzuki bean, and Japanese millet but was similar to maize and sorghums for CP yield.

At 18 June planting, soybeans (3,637 kg/ha) averaged across cultivars had 27% greater TDN yields than did mungbean and but had 31, 47, and 63% less than did Japanese millet, maize, and sorghums. At 15 July planting, TDN yield was 47, 77, 46, and 24% higher in soybean than in mungbean, cowpea, adzuki bean and Japanese millet, respectively. The TDN yield of soybean was 47 and 43% of sorghums and maize. There was no significant difference in TDN yield between cultivars for soybean, mungbean and sorghums regardless of planting dates.

Forage quality

Soybean was significantly higher in CP, EE, and TDN content but was lower in NFE content compared with the other legumes (Table 4). The legumes had much higher CP, EE, and TDN content but lower CF content than did the grasses except maize which had a relatively lower CF content but higher TDN content. Crude protein content of legumes ranged from 13.7 to 21.9% while those of the grasses from 6.48 to 13.5%. Among the grasses, Japanese millet had the highest CP content regardless of planting date while sorghums had the least.

Ether extract content of the legumes ranged from 2.42 to 6.23% while those of grasses from 1.64 to 2.83%. The soybean cultivar, Sobaeknamulkong planted on 15 July had much higher EE content than the two other cultivars probably because of early maturity of Sobaeknamulkong at 15 July planting in comparison with the two other cultivars (Table 4).

Among the legumes, adzuki bean (53.7%) had relatively higher NFE content compared with cowpea (48.7%), mungbean (48.5 to 53.2%), and soybeans (44.0 to 47.8%). The higher NFE content in adzuki bean resulted from relatively lower CF content. Among the grasses, maize had the highest NFE content (61.5%), sorghums had an intermediate (46.3%), and Japanese millet had the

Table 4. Forage quality of some summer annual legumes and grasses planted on two dates.

Crop†	Cultivar	CP‡	EE	NFE	CF	CA	TDN
		(%)					
				18 June planting			
Soybean	Baegunkong	17.07	3.13	47.8	24.6	7.39	62.1
	Namhaekong	18.91	4.20	44.9	24.3	7.69	64.4
	Sobaeknamulkong	19.26	3.41	45.7	23.3	8.28	63.1
Mungbean	Keumsungnogdu	13.93	2.42	52.0	21.7	9.94	58.7
	Nampyungnogdu	13.73	2.42	53.2	20.9	9.79	59.1
Maize	Pioneer 3525	7.93	2.45	63.2	22.3	4.12	61.2
Sorghum (S)§	Pioneer 931	6.75	2.59	45.0	39.6	6.08	52.6
S×sudangrass§	Pioneer 988	6.48	2.71	47.8	36.6	6.48	53.5
Japanese millet§	Cheju native	9.65	2.83	42.7	31.5	13.26	51.2
LSD (0.05)		1.85	0.80	1.8	2.4	0.90	2.2
				15 July planting			
Soybean	Baegunkong	17.41	4.29	45.6	25.3	7.38	63.8
	Namhaekon	18.79	3.92	46.0	23.2	8.11	63.9
	Sobaeknamulkong	21.79	6.23	44.0	19.3	8.66	69.9
Mungbean	Keumsungnogdu	16.42	2.63	49.2	22.2	9.54	60.2
	Nampyungnogdu	17.29	3.03	48.5	21.1	10.13	61.1
Cowpea	Cheju native	16.74	3.53	48.7	22.6	8.45	62.5
Adzuki bean	Chungjupat	17.21	2.90	53.7	17.3	8.91	63.3
Maize	Pioneer 3525	7.49	2.72	59.7	24.9	5.19	59.5
Sorghum (S)	Pioneer 931	7.94	1.94	46.0	36.8	7.27	52.1
S×sudangrass	Pioneer 988	7.56	1.64	46.6	37.9	6.28	51.8
Japanese millet	Cheju native	13.47	2.56	37.2	32.4	14.37	50.9
LSD (0.05)		1.57	0.75	2.6	1.7	0.97	1.6

† Data for cowpea and adzuki bean planted on 18 June were not obtained because of poor stand establishment.

‡ CP:crude protein, EE:ether extract, NFE:nitrogen free extract, CF:crude fiber, CA:crude ash, TDN:total digestible nutrient.

§ CP content at the second harvest for sorghum, sorghum×sudangrass and Japanese millet planted on 18 June was 22.5, 22.1 and 17.7%, respectively.

lowest (40.0%) averaged across planting dates.

The CF content of the legumes ranged from 17.3 to 25.3% while those of the grasses from 22.3 to 39.6%. Soybean tended to have higher CF content compared with the other legumes. The growth stage at harvest may influence CF content of soybean forage because fiber increase from R1 to R5 and then decrease from R5 to R7 (Hintz et al., 1992). Among the grasses, maize averaged across planting dates had the lowest CF content (23.6%), Japanese millet had intermediate (32.0%) and sorghums had the highest (37.6%).

The CA content of the legumes ranged from 7.4 to 10.1% while those of the grasses from 4.1 to 14.4%. Among the legumes, mungbean had the greatest CA content (9.5 to 10.1%) and the three other legumes had the similar CA content (7.4 to 8.9%). Two mungbean cultivars were similar in CA content, while among soybean cultivars Sobaeknamulkong had higher CA content (8.5%) than did the two cultivars (7.6%). Averaged across planting dates, maize had the lowest CA content (4.7%), sorghums had intermediate (6.5%), and Japanese millet had the greatest (13.8%). The higher CA content in Japanese millet might be result from high Si content. Averaged across planting dates and cultivars, soybean (64.5%) had slightly higher TDN content than the other legumes (58.7 to 63.3%). Among the grasses, maize (60.3%) had higher TDN than did the three grasses (50.9 to 53.5%).

Our data indicate that sorghums are the best adapted forage grasses in this region on the basis of TDN yield and among the popular summer grain legumes, soybean, in terms of CP and TDN yields, can be the best forage legume for grass-legume forage rotation in this region and good CP supplementary forage to sorghums with low CP content. Soybean requires only a quarter of N fertilizer compared with sorghums because of N_2 fixation and thus soybean cropping will reduce the NO_3-N contamination of ground waters. Some of fixed N by soybean becomes available for the next crop. Cropping soybean usually increases the yield of the next crop (Bagayoko et al., 1992).

ACKNOWLEDGEMENTS

This study is supported by Korea Ministry of Education through Research Fund.

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