Effect of Seeding Rate on Growth, Yield and Chemical Composition of Forage Rape Cultivars

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ABSTRACT

Four introduced forage rape cultivars 'Akela', 'Ramon', 'Sparta', and 'Velox' and a leading rapeseed cultivar Hallayuchae were seeded on 1 October 1994 on 20-cm rows at seeding rates of 3, 5, 7, 10, 13, and 15 kg/ha to select the best adapted forage rape cultivars and to determine the optimum seeding rate in the Cheju area. Days to flowering of each cultivar was not significantly affected by seeding rate. Average plant height increased from 151 to 164 cm as seeding rate increased from 3 to 10 kg/ha and then decreased to 156 cm at 15 kg/ha. Stem diameter linearly decreased with increasing seeding rate. The optimum seeding rate for the greatest dry matter and protein yields of five cultivars ranged from 10.7 to 11.8 and 10.8 to 14.4 kg/ha, respectively. Dry matter yields of five cultivars ranged from 7.72 and 22.01 Mg/ha. Sparta produced the greatest dry matter yield, followed by Akela, Ramon, Hallayuchae, and Velox. Crude protein yields of five cultivars ranged from 0.29 to 1. 08 Mg/ha. Sparta produced the greatest crude protein yield, followed by Akela, Ramon, Velox, and Hallayuchae. As seeding rate increased, crude protein content linearly increased but crude fiber content linearly decreased. The forage cultivars had higher crude protein and lower crude fiber than the oilseed cultivar Hallayuchae. Our results demonstrate that Sparta was the best adapted cultivar to Cheju area and the optimum seeding rate for Sparta was about 10 kg/ha.

Key words : forage rape, seeding rate, dry matter yield.

Brassica species such as turnip, rape, kale and swede are used as a primary source of herbage for dairy and livestock production in environments such as that of northern Europe, where it is too cold to grow corn. Brassicas have increased popularity as supplemental forage crops in North America (Guillard et. al., 1995). Studies in Korea demonstrated that forage rape had the greater yield potential and higher quality in both northern and southern parts of South Korea (Kim et al., 1986; Kim et al., 1990). Kim et al. (1990) reported that there were cultivar differences for dry matter yield of forage rape. They also reported that dry matter yield of forage rape was higher than that of oats, turnips, rye and ryegrass in Suwon (northwestern part of South Korea) when crops were seeded in late summer and early fall, and harvested in late fall. Cultivars of forage rape have not yet been developed and released in Korea. Therefore, seeds of forage rape cultivars have being imported from Europe. Kim & Kim (1987) reported that forage rape cultivars outyielded a leading Korean rapeseed cultivar in the Taekwanryong (Northeastern part of South Korea) area. According to Ahn et al. (1989), dry matter and digestible dry matter yields at flowering (in mid- and late April) of 17 forage rape cultivars introduced from Europe ranged from 4.19 to 10.65 Mg/ha and from 2.40 to 8.35 Mg/ha, respectively, in Mooahn (southwestern part of South Korea).

The forage yield of rape is highly dependent upon seeding rate. Cho & Song (1995) reported that the highest forage yield of a local rapeseed cultivar in Cheju was obtained with a seeding rate of 9 kg/ha. The performance of introduced forage rape cultivars has not been evaluated intensively in Cheju area. The optimum seeding rate for introduced forage rape cultivars has not investigated in South Korea. The objectives of this study were to select the best cultivars adapted to Cheju area and to determine the optimum seeding rate for the best cultivars.

MATERIALS AND METHODS

A 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. Mean soil test values were: pH = 5.7, organic matter = 6%, and available P_2O_5 = 51.1 ppm. Exchangeable K and Ca were 1.2 and 1.0 me/100g, respectively. Four forage rape cultivars (Akela, Ramon, Sparta and Velox) and a rapeseed cultivar (Hallayuchae) were seeded on 1 October 1994 on 20-cm rows at seeding rates of 3, 5, 7, 10, 13 and 15 kg/ha. Fertilizer was applied at a rate of 75-250-150 kg/ha (N-P_2O_5-K_2O) at planting. At 70 days after seeding, 75 kg N per ha was topdressed. Experimental units contained twelve rows with 3 m long. The experimental design was a split-plot arrangement in a randomized complete block with three replications. The main-plots consisted of six seeding rates and the subplots five cultivars.

Flowering date was recorded to determine days from seeding to flowering. Plant height and stem diameter were measured at full flowering on ten representative plants. Forage was hand harvested from eight center rows 2 m long (3.2 m^2) at a 3-cm cutting height at full flowering. Harvested material was weighed fresh. Subsample was collected for each plot and separated into leaves and stems + inflorescences, dried at 80℃ for 5 days in a forced oven, and weighed to determine dry matter yield. Dry samples were ground through 1 mm-sieve for the analysis of chemical compositions. Total nitrogen (N) was

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measured by the Kjeldhal procedure and reported as crude protein (N × 6.25). Crude fat, crude ash, crude fiber and nitrogen free extract were determined by AOAC methods.

Analysis of variance (ANOVA) was used to test significant main effects and interactions. Single degree of freedom contrasts were tested for seeding rate effects and regression equations were developed on the basis of highest-order significant orthogonal contrast. The summary of ANOVA was not shown in this report to save space. Cultivar means and seeding rate means when there was no functional relationship between seeding rates and the traits were compared using Duncan's Multiple Range test. The optimum seeding rate at which maximum dry matter and protein yields occurred was determined by differentiating the resulting quadratic equations with respect to seeding rate.

RESULTS AND DISCUSSION

Only main effects of seeding rate and cultivar on days to flowering, stem diameter, leaf weight ratio, and crude fiber and stem N free extract (NFE) contents were shown in Table 1 because seeding rate × cultivar interaction was not significant at 0.05 probability level (ANOVA not shown). The effects of seeding rate × cultivar interaction on the other traits are shown in Tables 2 to 6.

Days to flowering, plant height, stem diameter and leaf weight ratio

Days from seeding to flowering was not significantly affected by seeding rate. Days to flowering for Hallayuchae, a leading oilseed cultivar, was 181 days and those for four forage cultivars ranged from 188 to 200 days (Table 1).

Average plant height across the cultivars increased from 151 to 164 cm as seeding rate increased from 3 to 10 kg/ha and then decreased to 156 cm at 15 kg/ha (Table 2). Ramon was tallest at a seeding rate of 7 kg/ha but the other cultivars at 10 kg/ha. Ramon, Sparta and Velox were taller than Akela and Hallayuchae. Stem diameter was significantly influenced by seeding rate and cultivar. Stem diameter decreased from 2.1 to 1.8 cm as seeding rate increased from 3 to 15 kg/ha (Table 1). Sparta (1.8 cm) had thinner stem than the other cultivars (1.9 to 2.1 cm) did. Leaf weight ratio decreased from 31.2 to 22.9% as seeding rate increased from 3 to 15 kg/ha. Velox (35.0%) had the highest leaf weight ratio, followed by Hallayuchae (33.7%), Ramon (26.3%), Akela (23.0%) and Sparta (20.1%).

Dry matter and crude protein yields

Dry matter and crude protein yields were significantly

Table 1. Main effects of seeding rate and cultivar on days to flowering, stem diameter, leaf weight ratio, and crude fiber and N free extract (NFE) content of forage rape.

Treatment	Days to flowering	Stem diameter (cm)	Leaf weight ratio (%)	Crude fiber content (%)		Stem NFE (%)
				Leaf	Stem	
Seeding rate (kg/ha)						
3	191	2.1	31.2	17.0	45.3	35.5
5	191	2.0	29.4	16.7	44.5	35.1
7	191	2.0	28.6	16.4	43.5	34.5
10	191	2.0	27.8	15.8	42.5	34.3
13	191	1.8	26.2	14.9	41.7	35.5
15	191	1.8	22.9	14.4	40.9	37.3
	Coefficients of regression equations relating seeding rate					
Intercept	NS	2.16	37.53	17.81	45.24	37.96
Linear	NS	−0.025	−2.999	−0.220	−0:359	−0.919
Quadratic	NS	NS	0.341	NS	NS	0.057
Cubic	NS	NS	−0.014	NS	NS	NS
R^2	0.01	0.96	0.99	0.98	0.99	0.95
Cultivar						
Akela†	195b‡	1.9^{ab}	23.0^{c}	14.7^{b}	40.1^{d}	35.1^{c}
Ramon	191^{c}	2.0^{ab}	26.3^{b}	16.4^{a}	44.7b	35.7^{bc}
Sparta	200^{a}	1.8^{b}	20.1^{d}	16.5^{a}	41.5^{c}	39.2^{a}
Velox	188^{d}	2.1^{a}	35.0^{a}	14.7^{b}	40.6^{cd}	36.3^{b}
Hallayuchae	181^{e}	2.1^{a}	33.7^{a}	17.0^{a}	48.5^{a}	30.4^{d}

† Akela, Ramon, Sparta, and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar

‡ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

Table 2. Plant height (cm) of five rape cultivars as affected by seeding rate.

Seeding rate (kg/ha)	Akela†	Ramon	Sparta	Velox	Hallayuchae	Mean
3	132.7	164.3	161.4	156.9	142.4	151.5
5	142.9	165.5	167.1	160.9	150.4	157.4
7	144.6	168.2	167.5	162.0	158.2	160.1
10	157.0	166.7	169.7	165.9	159.9	163.9
13	154.2	158.6	158.1	165.1	160.2	159.2
15	151.4	156.1	157.5	160.8	153.7	155.9
Mean	147.1^{c}‡	163.2^{a}	163.6^{a}	161.9^{a}	154.1^{b}	158.0
	Coefficients of regression equations relating seeding rate					
Intercept	114.21	157.44	151.57	147.84	123.86	138.95
Linear	6.962	2.799	4.241	3.393	7.146	4.920
Quadratic	−0.297	−0.197	−0.262	−0.165	−0.342	−0.254
R^2	0.94	0.94	0.86	0.91	0.98	0.97

† Akela, Ramon, Sparta and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar

‡ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

affected by seeding rate, cultivar and seeding rate × cultivar interaction. The optimum seeding rates for the greatest dry matter yields of five cultivars ranged from 10.7 to 11.8 kg/ha (Table 3). These results are similar to those of Cho & Song (1995) who obtained the highest fresh forage yield at a seeding rate of 9 kg/ha for a local rapeseed cultivar. Averaged across seeding rate, Sparta (22.01 Mg/ha) produced the greatest dry matter yield, followed by Akela (15.24 Mg/ha), Ramon (11.28 Mg/ha), Hallayuchae (8.51 Mg/ha) and Velox (7.21 Mg/ha). Dry matter yield was significantly correlated with days to flowering ($r=0.75$, $p<0.001$, $n=90$) (data not shown), corroborating results of Kim & Han (1984).

The optimum seeding rates for the greatest crude protein yield of five cultivars ranged from 10.8 to 14.4 kg/ha (Table 3). Averaged across the seeding rates, Sparta (1075 kg/ha) produced the greatest crude protein yield, followed by Akela (871 kg/ha), Ramon (479 kg/ha), Velox (435 kg/ha) and Hallayuchae (290 kg/ha). Crude protein yield depended more on dry matter yield ($r=0.93$, $p<0.001$, $n=90$) than crude protein content in leaves ($r=0.59$, $p<0.001$, $n=90$) and stems ($r=0.68$, $p<0.001$, $n=90$) (data not shown).

Chemical composition

Chemical composition in leaf and stem except stem NFE was significantly affected by seeding rate, cultivar and seeding rate × cultivar interaction. Stem NFE was affected by seeding rate and cultivar. Crude protein con-

Table 3. Dry matter and crude protein yields of five rape cultivars as affected by seeding rate

Seeding rate	Dry matter yield (Mg/ha)						Crude protein yield (kg/ha)					
(kg/ha)	Akela†	Ramon	Sparta	Velox	Halla	Mean	Akela	Ramon	Sparta	Velox	Halla	Mean
3	9.71	7.47	15.76	4.04	3.90	8.18	458	263	658	226	116	344
5	13.71	9.74	18.55	5.84	6.72	10.91	663	374	796	344	211	477
7	16.19	11.96	23.88	8.67	9.65	14.07	854	480	1144	525	311	663
10	16.92	13.32	25.85	8.78	10.22	15.02	1006	589	1304	533	345	755
13	17.71	12.86	24.40	8.23	10.92	14.82	1132	587	1263	511	407	780
15	17.22	12.33	23.65	7.72	9.65	14.11	1115	584	1285	472	351	762
Mean	15.24^{b}‡	11.28^{c}	22.01^{a}	7.21^{e}	8.51^{d}	12.84	871^{b}	479^{c}	1075^{a}	435^{b}	290^{d}	630
	Coefficients of regression equations relatingseeding rate											
Intercept	3.94	2.35	6.22	−0.69	−1.98	1.97	59.90	11.18	107.88	−79.16	−88.39	2.36
Linear	2.37	1.95	3.50	1.83	2.28	2.38	147.45	92.99	195.36	117.49	76.92	125.91
Quadratic	−0.100	−0.086	−0.158	−0.086	−0.100	−0.106	−5.106	−3.672	−7.888	−5.443	−3.129	−5.037
R^2	0.97	0.99	0.96	0.94	0.98	0.98	1.00	0.99	0.96	0.95	0.97	0.99
Opti. rate§	11.8	11.3	11.1	10.7	11.4	11.3	14.4	12.7	12.4	10.8	12.3	12.5

† Akela, Ramon, Sparta and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar.

‡ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

§ The optimum seeding rate for the greatest dry matter yield or crude protein yield was calculated by differentiating the quadratic equation.

tent in leaf and stem linearly increased with increasing seeding rate but there were differences in the slopes of linear equations among the cultivar, resulting in seeding rate × cultivar interaction (Table 4). Crude protein contents ranged from 3.7 to 10.8% for leaf and from 2.5 to 5.3% for stem. Crude protein content in leaf and stem was negatively correlated with crude fiber content in leaf ($r=-0.67$, $p<0.001$, $n=90$) and stem ($r=-0.84$, $p<0.001$, $n=90$) which linearly decreased with increasing seeding rate. These results agree with those of Wiedenhoeft & Barton (1994) who reported that fiber content was negatively correlated with protein content of brassica herbage.

The forage cultivars had higher crude protein in leaf (6.4 to 9.3%) and stem (3.4 to 4.5%) than the oilseed cultivar Hallayuchae (4.4 and 2.8%). Among the forage cultivars, Akela and Velox had the highest crude protein content in leaf and stem, followed by Sparta and Ramon. Ahn et al. (1989) also found that Akela and Velox had the highest protein content of the 17 forage rape cultivars tested.

Crude fat content in leaf and stem tended to be higher at higher seeding rates (Table 5). The crude fat content of leaves for forage cultivar (4.1 to 9.5%) was higher than that for the oilseed cultivar Hallayuchae (3.7%) while that of stems for forage cultivars (3.3 to 7.2%) was lower

Table 4. Crude protein content (%) in the leaf and stem of five rape cultivars as affected by seeding rate.

Seeding rate	Leaf						Stem					
(kg/ha)	Akela†	Ramon	Sparta	Velox	Halla	Mean	Akela	Ramon	Sparta	Velox	Halla	Mean
3	7.3	5.5	6.0	8.1	3.7	6.1	3.9	2.7	3.6	4.0	2.5	3.3
5	8.0	5.8	6.0	8.5	3.7	6.4	3.9	3.1	3.9	4.3	2.8	3.6
7	9.3	6.5	7.3	8.8	3.9	7.1	4.0	3.1	4.1	4.5	2.9	3.7
10	9.9	6.8	8.1	8.9	4.3	7.6	4.8	3.5	4.3	4.6	2.9	4.0
13	10.4	6.8	8.3	9.4	5.2	8.0	5.2	3.9	4.5	4.7	3.0	4.3
15	10.8	6.9	8.9	9.5	5.6	8.4	5.3	4.2	4.7	4.7	3.0	4.4
Mean	9.3^{a}‡	6.4^{c}	7.4^{b}	8.9^{a}	4.4^{d}	7.3	4.5^{a}	3.4^{c}	4.2^{b}	4.4^{ab}	2.8^{d}	3.9
Coefficients of regression equations relating seeding rate												
Intercept	6.75	5.36	5.20	7.88	2.91	5.61	3.30	2.37	3.43	4.0	2.55	3.08
Linear	0.287	0.117	0.253	0.112	0.168	0.186	0.136	0.119	0.085	0.054	0.034	0.091
R^2	0.94	0.86	0.93	0.96	0.93	0.98	0.94	0.98	0.98	0.85	0.74	0.99

† Akela, Ramon, Sparta and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar.

‡ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

Table 5. Crude fat and ash contents in the leaf and stem of five rape cultivars as affected by seeding rate.

Seeding rate	Leaf						Stem					
(kg/ha)	Akela†	Ramon	Sparta	Velox	Halla	Mean	Akela	Ramon	Sparta	Velox	Halla	Mean
Crude fat content (%)												
3	3.0^{d}‡	8.1^{d}	3.1^{d}	2.9^{d}	2.7^{e}	4.0^{d}	6.2^{f}	6.2^{d}	3.0^{e}	4.6^{d}	6.9^{f}	5.4^{d}
5	3.3^{d}	9.8^{b}	4.9^{c}	3.5^{c}	3.1^{d}	4.9^{c}	6.5^{d}	6.7^{c}	3.1^{d}	5.1^{c}	7.4^{e}	5.8^{c}
7	3.6^{c}	9.9^{b}	5.7^{b}	4.2^{b}	3.8^{c}	5.4^{b}	6.7^{c}	6.7^{c}	3.2^{c}	5.7^{d}	9.9^{a}	6.4^{b}
10	5.3^{a}	10.3^{a}	5.7^{b}	4.2^{b}	4.0^{bc}	5.9^{a}	8.1^{a}	6.8^{b}	4.4^{a}	5.9^{a}	9.5^{b}	6.9^{a}
13	5.5^{a}	10.4^{a}	5.6^{b}	4.2^{b}	4.3^{a}	6.0^{a}	8.1^{a}	7.5^{a}	3.5^{b}	5.9^{a}	9.3^{c}	6.9^{a}
15	4.2^{b}	8.9^{c}	6.9^{a}	5.4^{a}	4.2^{ab}	5.9^{a}	7.6^{b}	6.1^{e}	2.7^{f}	5.9^{a}	9.1^{d}	6.3^{b}
Mean	4.2^{c3}	9.5^{a}	5.3^{b}	4.1^{d}	3.7^{e}	5.4	7.2^{b}	6.6^{c}	3.3^{e}	5.5^{d}	8.7^{a}	6.3
Crude ash content (%)												
3	18.4^{b}	13.8^{c}	13.3^{e}	16.0^{d}	12.6^{d}	14.8^{f}	12.1^{d}	9.4^{a}	10.7^{e}	12.1^{d}	8.3^{c}	10.5^{e}
5	18.5^{b}	14.2^{b}	13.4^{e}	16.2^{d}	13.3^{c}	15.1^{d}	12.2^{d}	9.6^{a}	11.3^{d}	12.5^{cd}	9.8^{ab}	11.1^{d}
7	19.0^{a}	14.3^{b}	14.6^{c}	16.2^{d}	13.9^{b}	15.6^{c}	14.6^{a}	9.8^{a}	11.6^{cd}	13.2^{b}	9.9^{ab}	11.8^{b}
10	17.5^{c}	14.8^{a}	15.5^{a}	20.5^{a}	14.3^{a}	16.5^{a}	14.0^{b}	9.8^{a}	13.3^{a}	14.4^{a}	10.2^{a}	12.3^{a}
13	16.4^{d}	15.1^{a}	15.1^{b}	19.4^{b}	14.6^{a}	16.1^{a}	13.1^{c}	9.6^{a}	12.1^{b}	14.0^{a}	9.8^{ab}	11.7^{b}
15	14.8^{e}	15.0^{a}	14.2^{d}	17.4^{c}	13.7^{b}	15.0^{e}	12.7^{c}	9.4^{a}	12.0^{bc}	12.7^{c}	9.5^{b}	11.3^{c}
Mean	17.4^{b}§	14.5^{c}	14.3^{d}	17.6^{a}	13.7^{e}	15.5	13.1^{a}	9.6^{c}	11.8^{b}	13.2^{a}	9.6^{c}	11.5

† Akela, Ramon, Sparta and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar.

‡ Within column, means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

§ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

Table 6. Leaf N free extract content (%) of five rape cultivars as affected by seeding rate.

Seeding rate (kg/ha)	Akela†	Ramon	Sparta	Velox	Hallayuchae	Mean
3	55.8	54.5	60.0	57.0	63.3	58.1
5	54.8	52.7	58.3	56.6	62.2	56.9
7	53.2	52.1	55.2	56.0	60.8	55.5
10	52.3	51.9	54.6	51.7	60.2	54.1
13	53.7	53.0	55.1	53.0	60.1	55.0
15	56.9	54.6	55.3	54.0	60.8	56.3
Mean	54.5^{c}‡	53.1^{d}	56.4^{b}	54.7^{c}	61.2^{a}	56.0
	Coefficients of regression equation relating seeding rate					
Intercept	61.12	57.80	65.03	61.44	66.27	62.29
Linear	−1.930	−1.362	−1.885	−1.383	−1.103	−1.523
Quadratic	0.1079	0.0766	0.0836	0.0571	0.0489	0.0743
R^2	0.91	0.99	0.95	0.74	0.99	0.96

† Akela, Ramon, Sparta and Velox are forage cultivars ; Hallayuchae is an oilseed cultivar.
‡ Cultivar means followed by the same letter are not significantly different at 5% probability level according to Duncan's Multiple Range Test.

than that for the oilseed cultivar (8.7%).

The highest crude ash content in leaf and stem was obtained at the seeding rate of 7 to 13 and 7 to 10 kg/ha, respectively, depending on cultivars, resulting in significant seeding rate × cultivar interaction (Table 5). The forage cultivars had higher crude ash content in leaf (14.3 to 17.6%) and stem (9.6 to 13.2%) compared with the oilseed cultivar (13.7 and 9.6%).

Averaged across five cultivars, crude fiber content in leaf decreased from 17.0 to 14.4% and in stem from 44.1 to 39.3% as seeding rate increased from 3 to 15 kg/ha (Table 1). Akela and Velox had lower crude fiber content in leaf (14.7 and 14.7%) and stem (40.1 and 40.6%) while the other cultivars had about 17% in leaf and 41.5 to 48.5% in stem.

Nitrogen free extract (NFE) content in leaf and stem decreased as seeding rate increased up to 10 kg/ha and then decreased with a further increase in seeding rate (Table 6). However, there were significant differences in the slopes of quadratic equations for leaf NFE among cultivars, resulting in significant seeding rate × cultivar interaction. Across the seeding rates, Hallayuchae (62.2%) had the highest leaf NFE content, followed by Sparta (56.4%), Velox (54.7%), Akela (56.9) and Ramon (56.9%). Sparta (39.2%) had the highest stem NFE content, followed by Velox (36.3), Ramon (35.7%), Akela (35.1%) and Hallayuchae (30.4).

Our study showed that in terms of dry matter and crude protein yields, Sparta was the best adapted cultivar to Cheju area and the optimum seeding rate for Sparta was 11 kg/ha when seeded in late September to early October. The optimum seeding rate for forage rape might depend on seeding date. Therefore, the effects of seeding date × seeding rate interaction on forage yield and quality need to be evaluated further in Cheju area.

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