Agronomic Characteristics of Introduced Triticales

Chang Hwan Cho*, Seung Gil Yun**, Kazuo Ataku***, and Taiki Yoshihira***

ABSTRACT

This study was conducted to obtain basic information on the development of new triticale cultivars with good quality and high productivity for soiling feed. Twelve cultivars introduced from Poland, Canada and two cultivars developed in Korea were planted in the experimental field at Ansong National University in 1995. Major growth traits and nutrient components for feed were measured and analyzed using principal component analysis and average linkage cluster analysis. 'Prego', 'Prag 46/3', and 'Clercal' were relatively high in forage yield. Most of forage nutrient contents except cellulose were higher in Prego, Clercal, and 'Cumulus' than other cultivars. Results of principal component analysis on 11 traits including forage yield and nutrient contents showed that 72.59% of total variation were explained by the first and second principal components. The Z_1 had high correlation with the contents of forage nutrient components and Z_2 with plant height, fresh, and dry weight. Fourteen cultivars were classified into 7 groups by multivariate analysis. Clercal and Prego in Group I could be useful source for the improvement of triticale as an important forage crop because they exhibited high productivity as well as high contents of nutrient components for feed.

Key words : triticale, forage yield, nutrient contents, multivariate analysis.

Corn, Italian ryegrass, wheat, and barley have been commonly cultivated for soiling animal feeds in Korea. Rye has been widely cultivated as a forage crop with good adaptability to environments and fast regrowth after overwintering. Thus, rye could be grown in environments where other forage crops are not available (Park et al., 1990). But it has been reported that rye has short harvesting period as a soiling feed since it tends to be lignified soon after emergence of ear and to decrease palatability (Kim et al., 1988abc).

Triticale has been known as a valuable forage crop. Although it has weak cold tolerance and slow early growth, it produces soiling feed equal to rye and even more than other species such as oat, wheat and barley (Brown & Almondares, 1976). In addition, triticale could be better than rye for soiling feed quality, because it has low cellulose accumulation after heading (Hwang et al., 1985), high percentage of leaf blade in top dry matter, and slow aging (Lee et al., 1985; Park et al., 1990). Therefore, selection of triticale cultivars with high productivity and quality could be valuable.

The objectives of this study were to analyze forage nutrient composition and growth characteristics of the newly introduced 12 triticale cultivars and to classify superior cultivars with high quality and productivity using multivariate statistical analysis. Furthermore, the results from our studies are important for the optimum use of breeding materials.

MATERIALS AND METHODS

A field study was conducted at the experimental plots of Ansong National University. Fourteen cultivars with high forage productivity were tested in this study. Six triticale cultivars including 'Mardar', 'Presto', 'Moniko', 'Lasko', 'Pablo', and Prego were from Poland. Six cultivars such as Cumulus, 'Prag 46/1', 'Prag 46/3', 'PW-101', 'Pika', and Clercal were from Canada. 'Paldanghomil' and 'Sinkihomil' developed in Korea were also included as check cultivars. The cultivars tested in this study had been grown for 2 years to acclimate in the experimental site prior to conducting this study. The cultivars were planted on March 15, 1995 by hill seeding with two lines per row, and thinned to one plant per hill after emergence. The interrow space, ridge width and row spacing were 60, 20, and 10cm, respectively. The plots were arranged in a randomized complete block design (RCB). The plots were fertilized at the rate of 120kg N, 90kg P_2O_5, 70kg K_2O, and 10M/T compost per ha. Half of the nitrogen was applied by split application as basal dressing before planting, and the rest as top dressing at the middle and end of March, respectively. The other fertilizers were applied as basal dressing. Plant growth was measured using the standard method designed by Rural Development Administration. Plants were sampled at milk-ripe stage (June 15), dried at 70℃ in the oven and ground through a 40-mesh screen. The nutrient components such as crude protein, crude fat, crude ash, cellulose, phosphorus, potassium, calcium, magnesium contents were determined for each sample by the AOAC methods (AOAC, 1984).

Statistical analysis was performed by using PC Statistical Analysis System (SAS) (Kim & Jhun, 1989). Differences among mean values were tested by Duncan's multiple range test. Triticale cultivars were classified by community analysis using the average linkage method (Kang & Lee, 1996) and principal component analysis (Kim & Jhun, 1989). Eleven traits measured for the forage productivity and nutrient component contents were used in

* College of Agriculture, Dankook University, Chonan 330-714, Korea.
** Dept. of Agronomy, Ansong National Univ., Ansong 456-800, Korea.
*** Dept. of Dairy Science, Rakuno Gakuen Univ., Hokkaido, Japan.
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the multivariate analysis.

RESULTS AND DISCUSSION

Growth characteristics

Growth characteristics of 14 triticale cultivars are listed in Table 1. Significant differences were observed among cultivars for heading date. It ranged from May 14 to 30. Mardar and Presto were earlier than Sinkihomil for heading date, but the other cultivars except Cumulus were later than the checks. Presto showed the earliest heading date in this study and produced ears about one week earlier than Sinkihomil.

Introduced cultivars except PW101 and Pika were significantly shorter than the checks for plant height. However, they had larger flag leaf area as compared to the check cultivars. Especially, Monika, Clercal, and Prag 46/1 had significantly larger flag leaf area. Most of triticale cultivars except Cumulus and Pablo exhibited fewer number of leaves as compared to the checks. Fresh and dry weight of all introduced cultivars were significantly lower than Sinkihomil but greater than Paldanghomil. Prego, Prag 46/3, Presto, and, Clercal had relatively higher fresh and dry weight.

Park et al. (1990) reported that triticale was favorable as a feed because it had high leaf area index with good maintenance after heading. This study also showed that introduced cultivars had greater flag leaf area than Sinkihomil and Paldanghomil.

Contents of the forage nutrient components

Nutrient components of triticale cultivars are presented in Table 2. There were significant differences among cultivars in each of nutrient contents. Crude protein content ranged from 6.55% to 11.80%. Prego showed the highest crude protein content, and was followed by Clercal, Prag 46/3, and Cumulus. These cultivars had higher crude protein content than Sinkihomil. Crude fat content ranged from 1.35% to 2.50%. Prego, Clercal, Cumulus, and Mardar exhibited higher crude fat content than Sinkihomil but no significant difference was found among them. Cellulose content was the highest in Pika (32.37%), and was followed by Mardar and Clercal. Presto had the lowest cellulose content (4.37%).

Prego exhibited the highest in crude ash (12.93%) and P_2O_5 (0.76%) content, while Pika showed the lowest in crude ash (5.77%) and P_2O_5 (0.71%) content. K_2O content ranged from 1.13% to 2.04% with significant differences among cultivars. Prego had the highest in K_2O content, and was followed by Clercal, Cumulus and Mardar. This result was similar to the results for P_2O_5 content. CaO content was the highest in Prego (0.13%) and was the lowest in Pika (0.05%). Triticale cultivars had very low MgO content ranging from 0.05% to 0.07%.

In summary, the examined forage nutrient components varied among triticale cultivars. For the most of nutrient components, Prego, Clercal, Cumulus, and Mardar were higher than Sinkihomil but had no significant differences among themselves. Cellulose content, which has been reported to have negative correlation with digestibility of livestock (Lee et al., 1985), was low in Prego, Clercal, and Cumulus. These three cultivars, therefore, were considered as high-grade forage crops. On the other hand, Paldanghomil was remarkably lower than others in the content of forage nutrient components.

Table 1. Agronomic traits of 14 triticale cultivars.

Cultivars	Heading date	Plant height (cm)	Area of flag leaf (cm^2)	No. of leaves	Fresh weight per plant (g)	Dry weight per plant (g)
Mardar	May 14^{g}	149.9^{c}	47.1^{c}	37.9^{cd}	128.3^{e}	48.1^{ef}
Presto	May 18^{f}	114.3^{gh}	15.4^{i}	21.4^{f}	139.7^{d}	53.1^{de}
Cumulus	May 20^{e}	121.1^{ef}	43.7^{cd}	46.3^{a}	132.7^{de}	52.0^{de}
Lasko	May 22^{d}	114.5^{gh}	27.9^{h}	17.1^{g}	120.0^{f}	48.5^{ef}
Moniko	May 22^{d}	109.2^{i}	55.8^{a}	21.2^{f}	115.7^{f}	49.1^{e}
Clercal	May 22^{d}	118.0^{fg}	51.6^{b}	27.3^{e}	157.0^{c}	56.5^{cd}
Prag 46/1	May 23^{d}	114.2^{gh}	55.5^{b}	22.5^{f}	106.3^{g}	42.5^{g}
Prag 46/3	May 23^{d}	124.1^{e}	34.8^{g}	26.5^{e}	182.3^{b}	58.8^{c}
Pablo	May 25^{c}	112.9^{hi}	39.5^{ef}	45.7^{a}	136.7^{d}	49.7^{e}
PW101	May 25^{c}	141.2^{d}	42.5^{de}	23.1^{f}	132.7^{de}	49.1^{e}
Prego	May 27^{b}	110.4^{hi}	27.0^{h}	41.7^{b}	181.3^{b}	63.2^{b}
Pika	May 30^{a}	153.9^{b}	38.5^{f}	35.0^{d}	132.3^{de}	49.7^{e}
Paldanghomi+	May 3^{h}	168.2^{a}	12.3^{i}	42.9^{ab}	96.0^{h}	44.2^{fg}
Sinkihomil*	May 20^{e}	151.0^{bc}	38.7^{f}	40.0^{bc}	228.0^{a}	86.4^{a}

Note : Common letters following mean values in each column indicate no significant difference at the 5% level by Duncan's multiple range test.
+ Check cultivars.

Table 2. Difference of forage nutrient components of 14 triticale cultivars.

Cultivars	Crude protein	Crude fat	Cellulose	Crude ash	P_2O_5	K_2O	CaO	MgO
	(%)							
Mardar	9.24^{bc}	2.42^{ab}	31.5^{a}	8.23^{d}	0.713^{ab}	1.86^{ab}	0.104^{bc}	0.066^{a-c}
Presto	7.89^{de}	1.96^{d-f}	24.4^{d}	7.03^{d-f}	0.586^{d-f}	1.48^{d}	0.069^{e}	0.055^{b-d}
Cumulus	9.98^{b}	2.43^{ab}	26.4^{cd}	9.43^{c}	0.730^{ab}	1.89^{ab}	0.121^{ab}	0.055^{b-d}
Lasko	8.11^{de}	1.50^{g}	26.6^{cd}	6.60^{ef}	0.623^{c-e}	1.50^{d}	0.085^{de}	0.068^{ab}
Moniko	8.18^{de}	2.11^{c-e}	28.0^{bc}	6.70^{ef}	0.710^{a-c}	1.60^{cd}	0.093^{cd}	0.061^{a-d}
Clercal	10.09^{b}	2.45^{ab}	30.0^{ab}	11.63^{b}	0.760^{a}	1.99^{a}	0.117^{ab}	0.070^{ab}
Prag 46 /1	9.65^{b}	1.76^{f}	26.3^{cd}	6.63^{ef}	0.596^{d-f}	1.50^{d}	0.070^{e}	0.063^{a-d}
Prag 46 /3	6.65^{f}	1.85^{ef}	27.7^{bc}	6.20^{ef}	0.595^{d-f}	1.52^{d}	0.025^{g}	0.055^{b-d}
Pablo	8.13^{de}	1.79^{f}	27.8^{bc}	7.17^{de}	0.550^{ef}	1.48^{d}	0.105^{bc}	0.064^{a-d}
PW101	8.22^{de}	2.20^{b-d}	27.4^{bc}	5.97^{ef}	0.653^{b-d}	1.78^{bc}	0.097^{cd}	0.065^{a-d}
Prego	11.80^{a}	2.50^{a}	26.0^{cd}	12.93^{a}	0.760^{a}	2.04^{a}	0.132^{a}	0.075^{a}
Pika	6.55^{f}	1.82^{f}	32.4^{a}	5.77^{f}	0.520^{f}	1.13^{e}	0.039^{gf}	0.045^{d}
Paldanghomil	7.61^{e}	1.35^{h}	26.3^{cd}	6.13^{ef}	0.563^{d-f}	1.28^{e}	0.049^{f}	0.047^{cd}
Sinkihomil	8.70^{cd}	2.29^{a-c}	28.1^{bc}	7.13^{d-f}	0.653^{b-d}	1.72^{bc}	0.093^{cd}	0.065^{a-d}

Varietal classification by multivariate analysis

1. Varietal classification by the principal component analysis

Fourteen cultivars were evaluated on forage production-related traits, such as plant height, fresh and dry weight, and on feed nutrient component-related traits such as crude protein, crude fat, cellulose, crude ash, P_2O_5, K_2O, CaO, and MgO contents. The results of principal component analysis on those traits are listed in Table 3.

Among 11 principal components analyzed in this study, eigen values were 5.99 in Z_1, 1.98 in Z_2, 1.27 in Z_3, 0.60 in Z_4, and 0.39 in Z_5. Up to 54.49% of total variance could be explained by the first principal component (Z_1) only. Most (93.08%) of total variance was explained by the first five principal components (Z_1-Z_5). This result indicates that the classification of 14 cultivars by 11 traits can be accomplished by the upper 5 principal components.

Correlation coefficients between principal components and feed-related traits are presented in Table 4. The first principal component showed positive correlations with all of the forage nutrient components except cellulose. The second principal component was positively correlated with plant height, fresh and dry weight, but negatively correlated with forage nutrient components. Therefore, cultivars with high values in the first principal component are likely to have high forage nutrient contents. Cultivars with high values in the second principal component are considered to be high in the forage yield with low nutrient contents.

Fig. 1 shows the scattered diagram of the cultivars based on Z_1 and Z_2 score, and the mean values of each classified group are listed in Table 5.

The cultivars were classified into 7 groups based on the results of the principal component analysis. Group Ⅰ included Clercal and Prego. These two cultivars showed high nutrient contents and high fresh weight for feed, even though they had shorter plant height than average value. In Group Ⅱ, Mardar and Cumulus were included. They exhibited lower fresh/dry weight and shorter plant height than the check cultivar, Sinkihomil, but their values were close to the mean of all cultivars. Sinkihomil was included in Group Ⅲ. It showed long plant height and high fresh and dry weight. But its forage nutrient contents were close to the mean of other cultivars. Group IV included Presto, Lasko, Pablo, Prag 46/1, Moniko, and PW101. They were below average in the plant height, fresh weight, dry weight, and forage nutrient contents. Prag 46/3, which showed high dry weight but low forage

Table 3. Eigen values and contribution rates to total variance of each principal component obtained from principal component analysis of 11 feed quality-related traits.

Items	Principal components				
	Z_1	Z_2	Z_3	Z_4	Z_5
Eigen value	5.99	1.98	1.27	0.60	0.39
Contribution (%)	54.49	18.03	11.61	5.44	3.51
Cumulative contribution (%)	54.49	72.52	84.13	89.57	93.08

Table 4. Correlation coefficients between feed-related traits and principal components and the cumulative contribution of three principal components.

Traits	Principal components			Cumulative
	Z_1	Z_2	Z_3	contribution
Plant height	−0.433	0.539*	0.466	0.695
Fresh weight	0.440	0.809**	−0.340	0.963
Dry weight	0.404	0.801**	−0.400	0.965
Crude protein	0.895**	−0.232	0.031	0.849
Crude fat	0.850**	0.282	0.235	0.857
Cellulose	−0.072	0.436	0.777**	0.799
Crude ash	0.881**	−0.055	0.063	0.783
P_2O_5	0.906**	−0.040	0.204	0.864
K_2O	0.961**	0.023	0.081	0.930
CaO	0.881**	−0.198	0.124	0.831
MgO	0.793**	−0.253	−0.076	0.699

*, ** : Significant at 5% and 1% level, respectively.

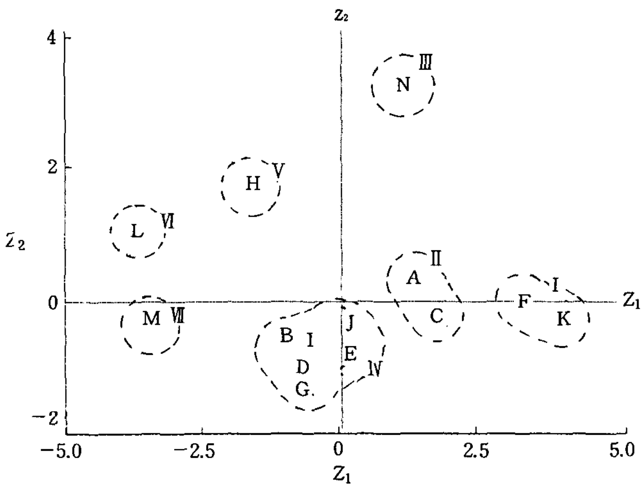

Fig. 1. Scattered diagram of 14 triticale cultivars based on Z_1 and Z_2 principal components.

A=Mardar, B=Presto, C=Cumulus, D=Lasko, E=Moniko, F=Clercal, G=Prag 46/1, H=Prag 46/3, I=Pablo, J=PW101, K=Prego, L=Pika, M=Paldanghomil, N=Sinkihomil.

nutrient contents, belonged to the Group Ⅴ. Pika in Group Ⅵ had a little low forage nutrient contents except cellulose content. Paldanghomil in Group Ⅶ was inferior to other cultivars for the feed-related traits.

2. Classification of cultivars by cluster analysis

Cluster analysis using average distance ($\sqrt{D^2}$ value) as an index of similarity was performed on 11 traits of triticale cultivars and the results are presented in Fig. 2.

When classification was performed at $\sqrt{D^2}$=0.7, 14 cultivars were clustered into 7 groups; Group Ⅰ (Mardar and Cumulus), Group Ⅱ (Clercal and Prego), Group Ⅲ (Sinkihomil), Group Ⅳ (Presto, Lasko, Pablo, Prag 46/1, Moniko, and PW101), Group Ⅴ (Prag 46/3), Group Ⅵ (Pika), and Group Ⅶ (Paldanghomil). This result was

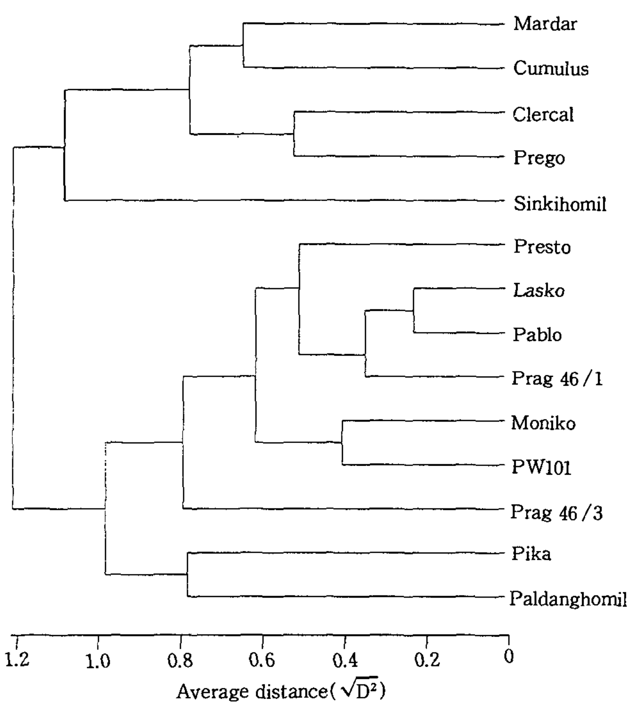

Fig. 2. Dendrogram of 14 triticale cultivars resulted from average linkage cluster analysis of 11 traits.

Table 5. Mean values of feed quality-related traits in 7 groups classified by principal component analysis.

Groups	No. of cultivars	Plant height	Fresh weight	Dry weight	Crude protein	Crude fat	Cellulose	Crude ash	P_2O_5	K_2O	CaO	MgO
		(cm)	……(g)	……	……	……	……	……(%)	……	……	……	……
Ⅰ	2	114.2	169.2	59.9	10.945	2.247	28.000	12.283	0.760	2.015	0.125	0.073
Ⅱ	2	135.5	130.5	50.1	9.612	2.427	28.909	8.833	0.722	1.875	0.113	0.061
Ⅲ	1	151.0	228.0	86.4	8.700	1.850	28.100	7.133	0.653	1.723	0.093	0.065
Ⅳ	6	117.7	125.2	48.7	8.362	1.887	26.739	5.729	0.617	1.556	0.087	0.063
Ⅴ	1	124.1	182.3	58.8	6.647	1.850	27.667	6.200	0.595	1.516	0.025	0.055
Ⅵ	1	153.9	132.3	49.7	6.550	1.820	32.367	5.767	0.520	1.133	0.039	0.045
Ⅶ	1	168.2	96.0	44.2	7.605	1.350	26.333	6.133	0.563	1.283	0.049	0.047
Means		137.8	151.9	66.3	8.846	1.919	28.302	7.440	0.624	1.586	0.076	0.058

very similar to that from principal component analysis. Each group except Group Ⅳ had only one or two cultivars. This classification did not show clear similarities among cultivars.

Clercal and Preg in Group Ⅰ might be useful cultivars for forage production and also for breeding sources of triticale cultivars with good quality and high yield. These two cultivars exhibited greater forage productivity, higher forage nutrient contents, and lower cellulose content than other cultivars.

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