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Varietal Differences in Palatability of Orchardgrass (*Dactylis glomerata* L.) and Breeding for Palatability and Quality

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Abstract

Palatability of 14 varieties of orchardgrass (*Dactylis glomerata* L.) was evaluated with Holstein heifers by using a trough cafeteria method for 4 years. Highly significant differences in the palatability of varieties were recognized throughout the growing seasons in each year. Multiple regression analysis was carried out in 15 cafeteria trials to identify the variables which could predict the palatability of varieties. Among 41 available variables, the best combinations of 2 variables were identified in each growing season. For all the seasons, the concentration of Ca, the concentration of P, and flexibility of leaf and stem were considered to be the best positive predictors for the palatability. In contrast, ADF and 3 kinds of diseases (Rhynchosporium scald, rust and total leaf diseases) were considered to be the best negative predictors for the palatability. Lude, a French variety, exhibited superior characteristics in quality compared with other varieties, namely, high palatability, resistance to rust and total leaf diseases, high flexibility of leaf and stem and the highest concentration of Ca among the tested varieties. Intake of fresh materials in 2 varieties, Lude and Akimidori was compared by using Holstein heifers, It was observed that the estimated increase of dry matter intake (DMI, $g/kgBW^{0.75}$) of Lude over Akimidori was 3.49 g at the same DMD level, High palatability in Lude might have a positive effect on the DMI level and could increase it more than expected from the DMD level. A model for the improvement of both palatability and quality which includes digestibility and mineral-balances was proposed as a part of the forage breeding program in Japan.

Discipline: Grassland / Plant breeding
Additional key words: cafeteria trial, calcium disease, flexibility, Holstein heifer, intake

Introduction

Orchardgrass (*Dactylis glomerata* L.) is one of the most important pasture grasses with high adaptability in a wide range of environments. It is grown in Japan very widely from cool regions (Hokkaido and Tohoku areas) to warm regions (Kanto to Kyushu areas). Several varieties with high yield and resistance to main diseases have been bred in Japan. However, compared with other temperate grasses, some reports indicated that the quality, palatability[2,7,16,17], and animal productivity[1,3,4,6] in the case of orchardgrass were not appreciably high. Research and programs for the improvement of quality in orchardgrass should be urgently promoted in Japan. This study was conducted to analyze the variations among varieties of orchardgrass in palatability and quality traits with a view to developing a breeding program for both high palatability and high quality in Japan.

Varietal differences in palatability

1) Analysis of relative palatability values

Palatability of varieties of orchardgrass was evaluated with Holstein heifers by using a trough cafeteria method during a period of 4 years[9] (Table 1). The 14 varieties used in this study were Akimidori, Makibamidori, Kitamidori, Lude, Lully, Lutetia, Lucifer, Prairial, Potomac, Cambria, Sylvan, Jesper, Juno and Frode (Table 2). Among these varieties, Akimidori was used as

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Table 1. Animals used in the cafeteria trial

Year	Cutting	Breed	Number of animals	Average liveweight (kg)
1991	1st – 6th	Holstein (heifer)	4 (2 pairs)	315 (Apr.) – 429 (Nov.)
1992	1st – 5th	Holstein (heifer)	4 (2 pairs)	271 (Apr.) – 361 (Nov.)
1993	3rd – 5th	Holstein (heifer)	4 (2 pairs)	269 (Jun.) – 303 (Oct.)
1994	3rd	Holstein (heifer)	4 (2 pairs)	347 (Jun.)

Table 2. Orchardgrass varieties used in the study

Variety	Symbol	Breeding country
Akimidori	A	Japan
Makibamidori	M	Japan
Kitamidori	K	Japan
Lude	L	France
Lully	Y	France
Lutetia	T	France
Lucifer	U	France
Prairial	R	France
Sylvan	S	UK
Cambria	C	UK
Jesper	J	Denmark
Potomac	P	USA
Juno	N	Canada
Frode	F	Sweden

the standard variety for all the cafeteria trials. Table 3 shows the results of 45 trials. Relative palatability value of each variety was expressed in percentage of intake per diet of the variety within the same variety group. The analysis of variance was based on this value. F values of sources for the variety indicated that the differences in the relative palatability values among varieties were highly significant ($P<0.001$ or $P<0.01$) for 42 out of 45 trials.

According to the relative palatability value, Table 3 shows that a French variety Lude (L) exhibited a high palatability in most seasons of the years in the current study. Compared with the standard variety Akimidori (A), significant differences ($P<0.05$) in the value of Lude (L) were recognized throughout the seasons of the years, except for the reproductive stage in the 2nd cutting, the 4th cutting in 1993 and 3rd cutting in 1994.

2) Palatability of the variety Lude

In order to compare the relative palatability values of the varieties obtained from 3 different variety groups in the same cutting period, as shown in Table 3, the value of palatability (%) of each variety was defined as the difference between the relative palatability value of the variety and the value of the standard variety Akimidori. The values of palatability in Akimidori were always expressed as 0% in this definition. The values of palatability of Lude and Akimidori are shown in Fig. 1 with the maximum and minimum values of palatability obtained from all the variety groups in the same cutting period. As pointed out in Table 3, it was also confirmed in Fig. 1 that Lude showed a high palatability among all the tested varieties for most of the seasons of the years.

Predictors for palatability

Multiple regression analysis was carried out to identify variables which could predict the values of palatability of varieties in 15 cafeteria trials in spring, summer and autumn seasons[13]. Characters used in this analysis are listed in Table 4. Agronomic characters[10], fiber and degradability characters[11], mineral elements[12], free sugars[12], leaf morphological[10] and physical characters[11] were measured or analyzed to predict the values of palatability. Among 41 available variables, which represent these characters, best combinations of 2 variables were detected in each growing season (Table 5). Contribution ratios due to regression (R^2) of the palatability on 2 best variables ranged approximately from 0.6 to 0.95 in all the 15 trials. For all the seasons, the concentration of Ca, the concentration of P and flexibility of leaf and stem measured by the hand-touching method were considered to be the best positive predictors for the palatability of varieties. In contrast, ADF and 3 kinds of diseases (Rhynchosporium scald, rust and total leaf diseases) were considered to be the best negative predictors for the palatability of varieties[13].

Characters of the palatable variety Lude and positive effect of palatability on intake

1) Characters of the variety Lude

Lude, a French variety, exhibited superior characteristics in quality compared with other varieties in our study, namely, high palatability, resistance to rust and total leaf diseases[10], high flexibility of leaf and stem[10], the highest concentration of Ca and ratio of Ca/P, and the lowest ratio of K/(Ca+Mg) among all the tested varieties (Fig. 1). Although Lude is susceptible to summer blight and its value of DM degradability by cellulase solution is average among the varieties, it could become a promising breeding material for the improvement of both palatability and quality in orchardgrass, especially for the warm

Table 3. Results of 45 trials during 4 years: F values in the analysis of variance and Tukey's studentized range tests for the relative palatability values of varieties in each cafeteria trial

Year, Cutting	Group[1)]	Date of cutting and feeding	F values of sources: Variety(VA)	Heifer pair(HA)	VA×HA	Abbreviation of variety name[2)] (relative palatability value %, letter[3)])			
1991 1st	1	Apr.23	12.90***	1.51	0.06	P (63.4 ^{a}),	N (81.2 ^{a}),	Y (60.7 ^{a}),	A (19.6 ^{b})
1991 1st	2	Apr.24	36.61***	0.00	1.75	T (38.2 ^{b}),	S (78.9 ^{a}),	K (88.3 ^{a}),	A (30.7 ^{b})
1991 1st	3	Apr.26	51.49***	0.03	3.00*	J (89.2 ^{a}),	**L (57.6 ^{b})**,	C (30.1 ^{c}),	A (30.7 ^{c})
1991 2nd	1	May 21	31.14***	5.33*	0.21	P (40.0 ^{b}),	N (21.5 ^{c}),	Y (79.9 ^{a}),	A (63.2 ^{a})
1991 2nd	2	May 22	56.91***	0.01	1.58	T (82.0 ^{a}),	S (73.2 ^{a}),	K (17.7 ^{c}),	A (51.3 ^{b})
1991 2nd	3	May 23	5.60**	0.64	2.30	J (44.5 ^{b}),	**L (75.8 ^{a})**,	C (70.5 ^{a}),	A (62.7 ^{ab})
1991 3rd	1	Jun.18	15.37***	0.09	0.94	P (81.4 ^{a}),	N (70.4 ^{a}),	Y (75.6 ^{a}),	A (44.1 ^{b})
1991 3rd	2	Jun.19	8.26***	2.06	0.11	T (57.3 ^{b}),	S (78.5 ^{a}),	K (74.6 ^{a}),	A (52.1 ^{b})
1991 3rd	3	Jun.21	13.80***	0.52	1.40	J (79.5 ^{a}),	**L (79.2 ^{a})**,	C (52.5 ^{b}),	A (44.5 ^{b})
1991 4th	1	Jul.17	12.08***	6.60*	1.11	P (81.1 ^{a}),	N (68.5 ^{a}),	Y (69.6 ^{a}),	A (50.0 ^{b})
1991 4th	2	Jul.18	1.31	0.19	2.14	T (62.4),	S (67.9),	K (65.0),	A (57.7)
1991 4th	3	Jul.19	18.31***	2.63	1.60	J (65.7 ^{b}),	**L (83.9 ^{a})**,	C (40.3 ^{c}),	A (51.2 ^{bc})
1991 5th	1	Sep.11	17.74***	1.04	0.45	P (43.5 ^{bc}),	N (55.8 ^{b}),	U (79.3 ^{a}),	A (33.2 ^{c})
1991 5th	2	Sep.12	28.80***	4.25*	1.14	T (87.6 ^{a}),	M (52.4 ^{c}),	K (69.2 ^{b}),	A (34.3 ^{d})
1991 5th	3	Sep.13	8.02***	0.85	0.71	J (64.7 ^{a}),	**L (62.3 ^{a})**,	F (37.8 ^{b}),	A (43.4 ^{b})
1991 6th	1	Nov.12	13.65***	3.04	1.14	**L (85.6 ^{a})**,	R (70.9 ^{a}),	C (75.8 ^{a}),	A (41.1 ^{b})
1991 6th	2	Nov.13	6.74***	0.03	6.44***	T (83.9 ^{a}),	S (66.1 ^{ab}),	M (69.5 ^{ab}),	A (51.0 ^{b})
1991 6th	3	Nov.14	1.40	1.96	1.62	P (61.5),	U (74.1),	Y (69.9),	A (57.0)
1992 1st	1	Apr.28	22.65***	0.07	0.26	J (67.7 ^{a}),	Y (36.9 ^{b}),	M (77.0 ^{a}),	A (37.7 ^{b})
1992 1st	2	Apr.30	25.37***	0.71	0.23	**L (76.9 ^{a})**,	R (49.1 ^{b}),	S (69.1 ^{a}),	A (29.2 ^{c})
1992 1st	3	May 1	26.31***	0.21	0.48	P (86.4 ^{a}),	T (44.1 ^{b}),	C (35.8 ^{b}),	A (32.9 ^{b})
1992 2nd	1	Jun.2	32.41***	1.89	0.66	J (49.3 ^{b}),	Y (38.8 ^{b}),	M (46.8 ^{b}),	A (84.3 ^{a})
1992 2nd	2	Jun.3	192.95***	7.89**	2.98*	**L (33.7 ^{b})**,	R (19.8 ^{c}),	S (40.8 ^{b}),	A (91.0 ^{a})
1992 2nd	3	Jun.4	94.26***	0.00	1.87	P (34.9 ^{b}),	T (75.7 ^{a}),	C (31.6 ^{b}),	A (80.7 ^{a})
1992 3rd	1	Jul.7	17.58***	0.03	1.73	J (55.2 ^{b}),	Y (56.3 ^{b}),	M (86.3 ^{a}),	A (58.3 ^{b})
1992 3rd	2	Jul.8	10.81***	0.15	1.53	**L (70.4 ^{a})**,	R (62.9 ^{a}),	S (76.8 ^{a}),	A (46.4 ^{b})
1992 3rd	3	Jul.9	34.95***	3.11	0.99	P (76.5 ^{a}),	T (39.7 ^{b}),	C (78.7 ^{a}),	A (33.5 ^{b})
1992 4th	1	Sep.16	42.04***	0.14	5.35**	J (33.3 ^{c}),	Y (71.8 ^{a}),	M (55.9 ^{b}),	A (34.4 ^{c})
1992 4th	2	Sep.17	22.07***	0.14	0.19	**L (57.4 ^{a})**,	R (33.9 ^{b}),	S (48.0 ^{a}),	A (31.5 ^{b})
1992 4th	3	Sep.18	16.68***	2.29	3.71*	P (41.3 ^{b}),	T (51.0 ^{ab}),	C (58.1 ^{a}),	A (25.0 ^{c})
1992 5th	1	Nov.17	18.76***	2.51	2.79*	J (37.4 ^{b}),	Y (74.5 ^{a}),	M (52.6 ^{b}),	A (74.9 ^{a})
1992 5th	2	Nov.18	11.92***	1.05	1.19	**L (80.1 ^{a})**,	R (45.4 ^{c}),	S (74.7 ^{ab}),	A (58.8 ^{bc})
1992 5th	3	Nov.19	16.55***	0.07	3.21*	P (57.9 ^{bc}),	T (41.7 ^{c}),	C (85.5 ^{a}),	A (64.1 ^{b})
1993 3rd	1	Jun.29	7.20***	-	-	J (40.1 ^{b}),	Y (52.0 ^{ab}),	M (71.7 ^{a}),	A (33.7 ^{b})
1993 3rd	2	Jun.30	8.68***	-	-	**L (76.6 ^{a})**,	R (76.0 ^{a}),	S (52.3 ^{b}),	A (55.8 ^{b})
1993 3rd	3	Jul.1	14.15***	-	-	P (67.0 ^{ab}),	T (56.5 ^{b}),	C (35.4 ^{c}),	A (81.1 ^{a})
1993 4th	1	Aug.24	11.60***	11.15**	6.34***	J (48.3 ^{ab}),	Y (60.2 ^{a}),	M (31.8 ^{c}),	A (46.4 ^{b})
1993 4th	2	Aug.25	21.82***	0.55	6.09**	**L (40.5 ^{b})**,	R (33.5 ^{bc}),	S (24.4 ^{c}),	A (59.1 ^{a})
1993 4th	3	Aug.26	21.95***	0.80	0.33	P (50.8 ^{a}),	T (13.3 ^{b}),	C (46.2 ^{a}),	A (57.5 ^{a})
1993 5th	1	Oct.26	4.37**	0.50	0.38	J (38.5 ^{b}),	U (59.8 ^{a}),	Y (41.1 ^{ab}),	A (33.4 ^{b})
1993 5th	2	Oct.27	7.65***	0.30	0.84	**L (78.6 ^{a})**,	S (52.5 ^{b}),	M (52.2 ^{b}),	A (44.6 ^{b})
1993 5th	3	Oct.28	14.79***	0.03	3.46*	P (73.8 ^{a}),	T (29.1 ^{b}),	C (73.3 ^{a}),	A (48.0 ^{b})
1994 3rd	1	Jun.27	1.82	0.23	2.11	J (65.0),	Y (71.1),	M (63.5),	A (56.8)
1994 3rd	2	Jun.28	5.61**	0.54	1.71	**L (77.1 ^{a})**,	R (48.5 ^{b}),	S (60.5 ^{ab}),	A (63.6 ^{ab})
1994 3rd	3	Jun.29	10.27***	0.87	2.67	P (77.2 ^{a}),	T (52.5 ^{b}),	C (57.8 ^{b}),	A (46.1 ^{b})

Relative palatability value was expressed in percentage of intake per diet of the variety within the same variety group.
*,**,***: Significant at 5%, 1% and 0.1% levels, respectively. The values of variety Lude are indicated in bold characters.
1): Different varieties were evaluated in each group. 2): See Table 2.
3): Different letters within the same variety group are significantly different at 5% level.

region of Japan because of its high adaptability to the climatic conditions.

2) Positive effect of palatability on intake

Intake of fresh materials in 2 varieties, Lude and Akimidori was compared by using Holstein heifers[14]. Each measurement of the intake was carried out during a period of 3 days together with palatability tests. Mean value of dry matter intake (DMI, g/kgBW$^{0.75}$) of Lude was 0.8 g, 2.3 g and 2.5 g higher than that of Akimidori in the first trial in July 1993, second trial in November 1993, and third trial in June 1994, respectively. Dry mat-

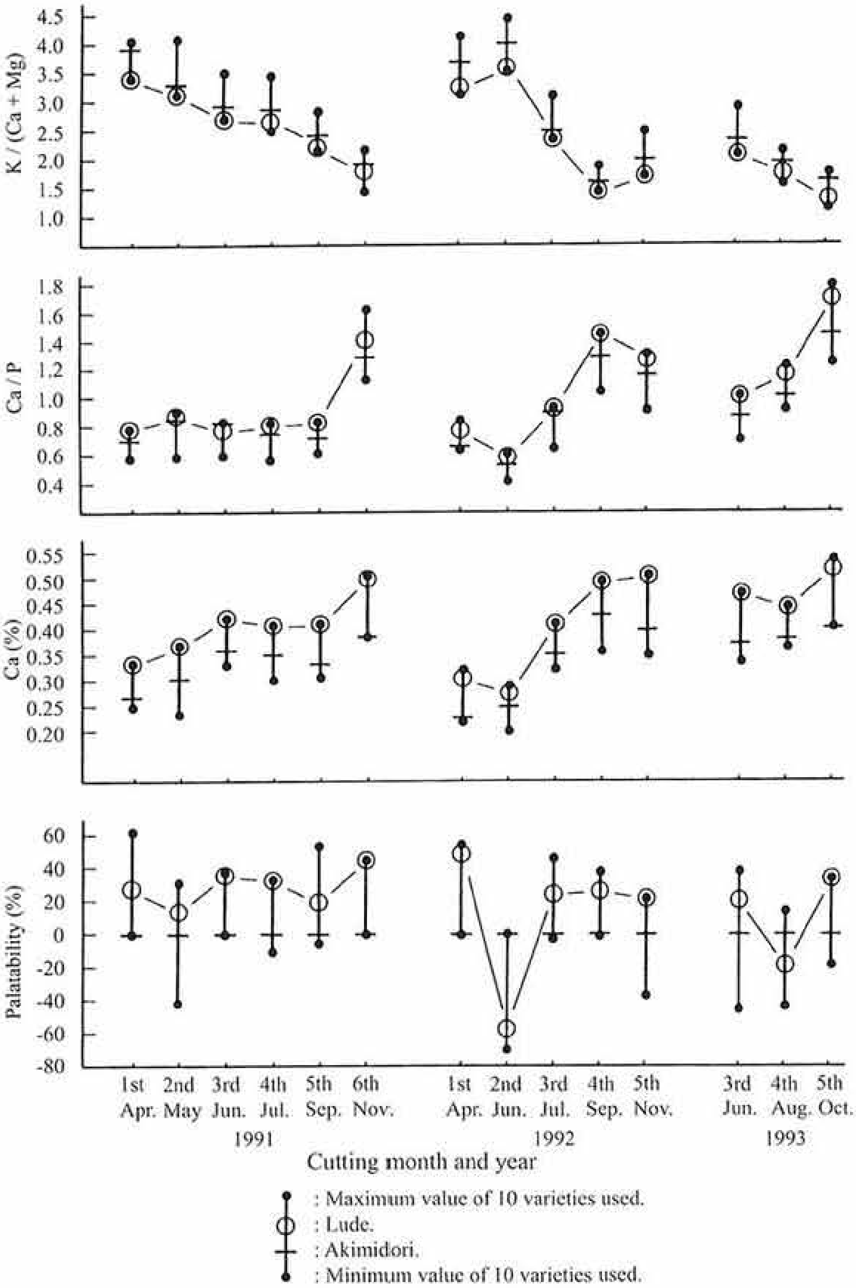


Fig. 1. Palatability (%), concentration of Ca (% DM), Ca/P ratio and K/(Ca+Mg) ratio (equivalent basis) of varieties at cutting times in 1991, 1992 and 1993

ter digestibility (DMD) of each variety was predicted from the degradability by 1% cellulase solution. Regression equation of DMI on DMD was calculated in each variety. According to the t-distribution statistics, the regression coefficient of original equations in each variety could be pooled statistically. The pooled equations were as follows: DMI of Akimidori = –44.72 + 1.79 DMD; DMI of Lude = –41.23 + 1.79 DMD (Fig. 2). The intercept of regression line on these equations was, however, significantly different. Based on the difference in the values of intercept, the estimated increase of DMI value in Lude over Akimidori was 3.49 g at the same DMD level. Palatability of Lude measured by using the same heifers was also significantly higher than that of Akimidori in each trial[14]. High palatability in Lude might have a positive effect on the DMI level and could increase it more than expected from the DMD level.

Proposed model for developing new varieties with high palatability in Japan

1) Methods for selection of palatability and digestibility

Table 4. Characters used for single and/or multiple regressions with palatability

Number	Character	Scoring method or measuring unit	Abbreviation in Table 5
1.	Degree of heading	(1 to 9 = full)	HED
2.	Degree of booting	(1 = vegetative growth to 5 = first heading)	BOT
3.	Flexibility of leaf and stem	(1 to 9 = flexible)	FLX
4.	Green leaf / whole plant	(% DM)	
5.	Stem / whole prant	(% DM)	
6.	Dead leaf / whole leaf	(% DM)	RDL
7.	Leaf character; width	(mm)	
8.	Leaf character; serration	(1 to 9 = most)	
9.	Leaf character; trichome	(1 to 9 = most)	
10.	Disease; Rhynchosporium scald	(1 to 9 = severe occurrence)	DRS
11.	Disease; rust	(1 to 9 = severe occurrence)	DRT
12.	Disease; summer blight	(1 to 9 = severe occurrence)	
13.	Disease; mosaic	(1 to 9 = severe occurrence)	
14.	Disease; total leaf diseases	(1 to 9 = severe occurrence)	DTL
15.	Fiber character; neutral detergent fiber	(% DM)	NDF
16.	Fiber character; acid detergent fiber	(% DM)	ADF
17.	Fiber character; hemicellulose (NDF−ADF)	(% DM)	HEM
18.	DM Degradability = $a + b(1-e^{-ct})$; a: instantly soluble fraction by buffer solution.	(% DM)	
19.	b: insoluble but potentially degradable fraction by 1% cellulase solution.	(% DM)	
20.	c: rate constant of the degradation of fraction b.	(h^{-1})	
21.	a + b: potential degradability.	(% DM)	Dab
22.	Leaf tension; maximum load	(gf)	TLD
23.	Leaf tension; maximum stretch	(mm)	TST
24.	Leaf compression load	(kgf)	CLD
25.	Electric power consumption by grinding mill for leaf samples	(10^{-3}Wh)	GLF
26.	Dynamic viscoelastic measurement; dynamic modulus	(10^{9}dyn/cm^{2})	VDM
27.	Dynamic viscoelastic measurement; loss tangent	(10^{-2})	
28.	Mineral element; N	(% DM)	
29.	Mineral element; P	(% DM)	P
30.	Mineral element; K	(% DM)	K
31.	Mineral element; Mg	(% DM)	Mg
32.	Mineral element; Ca	(% DM)	Ca
33.	Mineral element; Zn	(ppm DM)	
34.	Mineral element; Mn	(ppm DM)	Mn
35.	Mineral element; Cu	(ppm DM)	
36.	Mineral element; Co	(ppm DM)	Co
37.	Free sugar; sucrose	(% DM)	SUC
38.	Free sugar; glucose	(% DM)	GLU
39.	Free sugar; fructose	(% DM)	FRU
40.	Free sugar; total	(% DM)	
41.	Specific volatile compound[a)]		

a): Reported by Dohi et al[5].

(1) Palatability

In order to develop useful selection criteria for palatability, the flexibility of leaf and stem and the concentration of Ca were considered[15]. As for the flexibility, 6 persons gave independently similar scores for the flexibility of tested strains by using a simple method of hand-touching and it was considered that the method for measuring the flexibility might be easy and reliable. Therefore, it could be one of the most useful criteria for estimating the palatability of breeding materials in orchardgrass. As for the Ca concentration, the increase of the Ca concentration in orchardgrass was considered to be effective for the improvement of both palatability and mineral-balances with Mg, K and P.

Table 5. Characters and their contribution ratios due to regression (R^2 or r^2) most closely correlated with palatability of 10 varieties used

Season	Year, Cutting	Character [a]		R^2 or r^2
Spring	1991 1st	−BOT	+FRU	0.712*
		+P	−Mn	0.710*
	1992 1st	−K	+TST	0.749**
Heading in spring	1991 2nd	+Ca		0.933***
		−ADF		0.911***
		+K		0.832***
		+FLX		0.817***
	1992 2nd	−HED		0.821***
		−ADF		0.786***
		+P	−ADF	0.893***
		−HED	−ADF	0.880***
Early summer	1991 3rd	+P	−Mn	0.580*
	1991 4th	+FLX		0.805***
		+FLX	−DRS	0.892***
	1992 3rd	−DRS		0.612**
		−DRS	−VDM	0.843**
		−DRS	+P	0.781**
	1993 3rd	−CLD		0.637**
		−CLD	−HED	0.821**
		+P	−Mn	0.756**
	1994 3rd	−GLU	+RDL	0.740**
		−FRU	+CLD	0.637*
Late summer	1991 5th	+N	+SUC	0.843**
		−ADF	−Mg	0.829**
	1992 4th	+Ca		0.700**
		+Ca	−GLF	0.965***
		+Ca	−TST	0.868***
	1993 4th	−NDF		0.731**
		+K		0.616**
		+K	−SUC	0.913***
		+K	+Co	0.877***
Autumn	1991 6th	+GLF		0.642**
		−DTL		0.610**
		+FLX	+TLD	0.849**
		−DTL	+P	0.774**
	1992 5th	+P	−RDL	0.683*
		+P	−DRT	0.647*
	1993 5th	+Dab	+HEM	0.730*

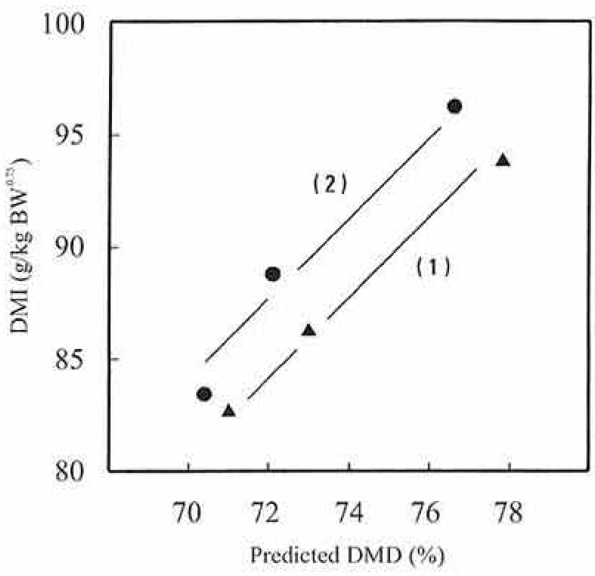
*, **, ***: Significant at 5%, 1% and 0.1% levels, respectively.
+: Positive coefficient of correlation.
−: Negative coefficient of correlation.
a): Abbreviations are the same as in Table 4.

(2) Digestibility

In addition to the palatability, digestibility is the most important character for the quality of grass varieties. Near infrared reflectance spectroscopy (NIRS) could successfully predict cellulase degradability of unknown samples of orchardgrass, and NIRS was considered to be one of the most effective methods to improve the digestibility in grass breeding[8,15].

2) Proposed model for breeding

A model for developing new varieties with a high palatability was proposed[15] (Table 6), in which 3 stages were designed for 2 regions in Japan. For the breeding of varieties suitable for the cool region, promising plants in the original population could be selected based on winter hardiness and resistance to diseases, and their seeds would be harvested as maternal lines in Stage 1. Then, superior maternal lines could be selected based on the flexibility of leaf and stem and the Ca concentration in Stage 2. Finally, new varieties could be selected through the evaluation of palatability measured by using cattle from the final candidate lines in Stage 3.



▲: Akimidori. ●: Lude.
(1): DMI of Akimidori = −44.72+1.79 DMD.
(2): DMI of Lude = −41.23+1.79 DMD.

Fig. 2. Relationship between dry matter intake (DMI) and predicted dry matter digestibility (DMD)[a] in 2 varieties of orchardgrass

a): *In vivo* DMD (Y, %) was predicted from the following equation:
$Y = 25.1 + 0.917 \times$ (DM degradability by 1% cellulase solution for 48 h, %).
According to the t-distribution, the regression coefficient of the original equations on Akimidori and Lude can be pooled statistically to the value 1.79, but the intercept of the regression line on (1) and (2) is significantly different at 5% level.

For the breeding of varieties suitable for the warm region, variety Lude would be one of the most important breeding materials. Promising plants in the original population could be selected based on summer productivity and resistance to summer blight to breed maternal lines in Stage 1. Then, superior maternal lines could be selected based on the digestibility by using a cellulase solution or by NIRS in Stage 2. Finally, new varieties could be selected through the evaluation of palatability measured by using cattle in Stage 3.

Table 6. Proposed model for breeding scheme to improve palatability of orchardgrass for 2 regions in Japan

Adaptation area in Japan	Main breeding materials	Characters to be selected	Stage for selection 1	Stage for selection 2	Stage for selection 3
			5,000 plants → 100 to 200 plants	100 to 200 lines → 5 to 10 lines	5 to 10 lines → 1 to 2 varieties
Cool region (Hokkaido and Tohoku)	Winter-hardy type varieties	1. Palatability[a]	–	–	◎
		2. Flexibility[b]	–	◎	–
		3. Ca concentration	–	◎	–
		4. Digestibility[c]	–	–	○
		5. Winter hardiness	◎	○	–
		6. Disease resistance	◎	○	–
		7. Other agronomic traits[d]	–	◎	○
Warm region (Kanto to Kyushu)	Lude and Japanese varieties	1. Palatability[a]	–	–	◎
		2. Digestibility[c]	–	◎	○
		3. Resistance to summer blight	◎	○	–
		4. Resistance to other diseases	○	–	–
		5. Summer regrowth	◎	○	–
		6. Other agronomic traits[e]	–	◎	○

◎ : Main characters to be selected at the given stage. ○ : Characters to be selected at the given stage.
a): Evaluated by cattle. b): Measured by hand-touching. c): Measured by NIRS or cellulase solution.
d): Including yield and persistency. e): Including yield, persistency and competitive ability with weeds.

This model was the first to be proposed for the improvement of both palatability and quality, which includes digestibility and mineral-balances in forage breeding in Japan.

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