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Gelatinization Characteristics of Glutinous Rice Varieties

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ABSTRACT

Gelatinization characteristics of 111 glutinous rice varieties were evaluated by Rapid Visco Analyzer. Gelatinization viscosity of glutinous rice tested varied with ecotypes or varietal groups: *indica, japonica,* and Tongil type. *Indica* rice showed the highest average value of initial pasting temperature. The average values for peak, hot, and cool viscosities were highest in Tongil-type rice, and lowest in *japonica* rice. *Japonica* showed the lowest breakdown and consistency, but the highest setback value. *Indica* was lower in alkali digestion value (ADV), and shorter in gel length after gelatinization than *japonica* and Tongil-type.

Glutinous rices tested could be divided into six groups by cluster analysis based on their gelatinization characteristics. Group I-A was mostly early maturing *japonica* varieties while I-B was mostly *indica* and Tongil-type rices. Groups Ⅱ-A and Ⅱ-B were consisted of very early maturing *japonica*, and Ⅲ-A and Ⅲ-B included medium or medium late maturing *japonica* varieties. Group Ⅲ-A showed the lowest average values of peak, hot, cool, and consistency viscosities, and also in breakdown and setback ratios. Group I-B revealed the highest values in peak, hot, cool, breakdown, and consistency viscosities. ADV was low in groups I-A, I-B, and Ⅱ-B, and gel consistency was not different among the six varietal groups. Principal component analysis using seven traits related with gelatinization produced four effective components, and the first and second components were highly correlated with all the gelatinization characters evaluated.

Key words : glutinous rice, gelatinization characteristics, ADV, gel consistency.

With the recent increasing interest in the cooking and processing qualities of glutinous rice, characteristics of glutinous rice starch have been extensively studied (Kim et al., 1983; Woo et al., 1985; Kim et al., 1985, 1992; Kim & Sohn, 1990; Kim & Chang, 1990; Kim et al., 1995). Since more than 90% of the dry matter of rice grain is starch and its major component in glutinous rice is amylopectin, glutinous rice differs from non-glutinous rice in viscosity and catabolic characteristics during cooking or processing.

When glutinous rice starch absorbs water and is heated, its water binding and swelling capacity decreases, while initial pasting temperature and solubility increases (Shin & Kim, 1990). The physiological change in glutinous rice starch might result from the increased molecular binding capacity during starch fusion by heating.

Variation in the degree of this change was also detected among the glutinous rice varieties. Tongil-type glutinous rice showed higher values of water binding capacity, amylogram viscosity, gelatinization viscosity in alkali solution, gelatinization temperature, and retrogradation degree compared with *japonica* glutinous rice. Starch granule of *japonica* glutinous rice is rounder and smaller than Tongil-type glutinous rice (Kim et al., 1983; Kim et al., 1985, 1992; Kim & Chang, 1990; Kim & Sohn, 1990).

Glutinous rice starch had the fastest gelatinization characteristic and the highest solubility at high swelling state, while its quality was very soft and sticky at the gel state (Woo et al., 1985). Also each glutinous variety showed the unique layer structure of starch. Tongil-type rice was higher in both inherent viscosity and water absorption rate than *japonica* rice (Kim & Sohn, 1990).

Though general and catabolic characteristics and processing adaptability of rice starch have been studied and reported so far, there are few studies on the grouping of glutinous rices by their gelatinization properties. In this study, gelatinization characteristics of 111 glutinous rice varieties were evaluated to determine the varietal variation and to classify varieties based on gelatinization properties of rice flour.

MATERIALS AND METHODS

One hundred and eleven glutinous rice varieties were grown at the experimental farm of Konkuk University. Seeds were sown in a box nursery bed on May 4 and seedlings were transplanted in the paddy field with 30× 15 cm distance with one plant per hill on June 1, 1996. The fertilizer was applied in the field at a ratio of 110-70-80kg/ha (N-P_2O_5-K_2O) and the other cultural practices followed the conventional method in the central region of Korea.

Table 1 shows the list of varieties, their heading date and ecotype classified by origin and grain shape. Peak (P), hot (H), and cool (C) viscosity were measured using Rapid Visco Analyzer (RVA-3D Newport), and the viscosity and the ratio of breakdown (P-H, H/P), setback (C-P, C/P), and consistency (C-H, C/H) were calculated. ADV of milled rice grain was observed after 23 hours soaking in 8 ml of 1.4 and 1.7% KOH solution at 30℃ with 1 to 7 grade (Little et al., 1958). Evaluation of gel

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Table 1. Heading date and ecotype of 111 glutinous rice varieties used.

No.	Variety	Heading date	Type†	No.	Variety	Heading date	Type	No.	Variety	Heading date	Type
1	Sangnambatbyeo	Aug. 6	J	38	Nagabe 2	Aug.11	I	75	Sanhyeongdaem	July 31	J
2	Shinseonchalbyeo	Aug.14	J	39	Daejodo	Aug.22	J	76	Seosanna	Aug.11	J
3	Jinbuchalbyeo	Aug. 3	J	40	Mujudo	Aug.19	J	77	55061-6-6-2-2-2	Aug. 6	I
4	Nonglimna 1	Aug. 7	J	41	Sukna	Aug.25	J	78	wx126-12-12-18	Aug. 1	T
5	Daeripchalbyeo	Aug.15	T	42	Sulsuljo	Aug.20	J	79	wx185-29-1-3-3	Aug.18	T
6	Soripchalbyeo	Aug.16	J	43	Jangjo	Aug.10	J	80	wx185-29-1-3-3	Aug. 8	T
7	Hwaseonchalbyeo	Aug.15	J	44	Jeokdo	Aug.13	J	81	wx205-13-1-5-1	Aug. 2	T
8	Tatsumimochi	July 31	J	45	Jodo	Aug.12	J	82	wx207-2-9-5-3	Aug.10	T
9	Suweon 357	Aug. 9	J	46	Jinhwa	Aug.23	J	83	wx208-7-1-1-3	Aug.13	T
10	Baegunchalbyeo	Aug. 3	J	47	Hwanghaedo	July 29	J	84	wx195-22-11-6-2	Aug. 8	T
11	IR-3941-4-plp28	Aug. 6	I	48	Hangangchalbyeo	Aug.19	T	85	wx199-35-5-3-1	Aug.18	T
12	Daegoldo(chal)	Aug. 5	J	49	Cal. mochi	Aug. 4	J	86	S. 290-1-2-2-2	Aug.21	T
13	Gujungdo(chal)	July 29	J	50	Baekmang	Aug.18	J	87	wx134-2-10-3-2	Aug.17	T
14	EM 21(chal)	Aug.25	J	51	Baongok	Aug. 8	J	88	wx209-29-12-2-3	Aug. 4	T
15	Gujungdo(colored)	July 29	J	52	Buldo	July 29	J	89	wx209-29-7-2-1	Aug. 8	T
16	Nokdudo	Aug.15	J	53	Jeonjudo	Aug.11	J	90	wx216-10-5-1-3	Aug.21	T
17	Daigolmochi	Aug.18	J	54	Daeguna	Aug.15	J	91	wx223-9-9-6-1	July 31	T
18	Daegoldo	Aug. 4	J	55	Kangweonna	Aug.10	J	92	wx221-4-11-4-2	Aug.18	T
19	Danchalbyeo	Aug. 8	J	56	Gawichal	Aug. 1	J	93	HP301-8-13-16-1	Aug.15	T
20	Baekna	Aug.12	J	57	Keumdo	Aug. 3	J	94	wx219-3-5-5-2	Aug.18	T
21	Yangdo	Aug.20	J	58	Ggaebyeo	Aug.13	J	95	HP320-1-3-3-2	Aug.12	T
22	Yongcheon	Aug.13	J	59	Guju	Aug. 1	J	96	HP309-8-1-3-2	Aug.13	T
23	Inbujinado	Aug.12	J	60	Heukbal	Aug.15	J	97	Ishiokamochi 7	Aug.10	J
24	Janrubyeo	Aug.15	J	61	Hochokjindo	Aug.21	J	98	Ishiokamochi 11	Aug.12	J
25	Jangjo	Aug.13	J	62	Homina	Aug.11	J	99	Ishiokamochi 15	Aug.10	J
26	Jeokna	Aug.15	J	63	Hongdodo	Aug.22	J	100	Ishiokamochi 20	Aug.13	J
27	Jeokdo	Aug.10	J	64	Inbujido	Aug.16	J	101	Mangetsumochi	Aug.18	J
28	Jindo	Aug.20	J	65	Jeokbukna	Aug.12	J	102	Tatsumimochi	Aug. 7	J
29	Chanarak(A)	Aug.20	J	66	Jeokjo	Aug.14	J	103	Taichung Sen glutinous 2	Aug.27	I
30	Chanarak	Aug.20	J	67	Joshindo	Aug.11	J	104	Kamuimochi	July 19	J
31	Chalbyeo	Aug. 8	J	68	Kim-ir-seni	Aug. 3	J	105	Tannemochi	July 20	J
32	Hongjeong	Aug. 7	J	69	Kokionzindo	Aug.23	J	106	Wonsanchal	Aug.11	J
33	Heukgaeng	Aug.19	J	70	Manajo	Aug.10	J	107	Hangangchalbyeo	Aug.11	T
34	Samnambatbeyo	Aug. 4	J	71	Monggeunchalnar	Aug.16	J	108	Calmochi	Aug.11	J
35	Sanghaehyanghyeolla	Aug.20	I	72	Naengdo	Aug.18	J	109	Mokjeom 3	Aug.30	J
36	SX864	Aug.11	I	73	Namseon 212	Aug.19	J	110	Taichung Sen glutinous 1	Aug.18	I
37	HungTsan	Aug.13	I	74	Sangdo	Aug.13	J	111	IR29	Aug.23	I

† J : *Japonica*, T : Tongil-type, I : *Indica*

consistency followed the modified Cagampang's (1973) method using rice gel cooled for two different periods, 20 minutes and 24 hours, at 4℃ after gelatinization of 140 mg rice flour in 2 ml of 0.2N-NaOH solution.

RESULTS AND DISCUSSION

Gelatinization characteristics of glutinous rice varieties

One hundred and eleven glutinous rice varieties used in this study include 80 *japonica*, 9 *indica*, and 22 Tongil-type rices. Average values of nine among ten visco-amylogram characters of rice flour were different among *japonica*, *indica*, and Tongil-type varieties tested (Table 2). Wide varietal variations were detected in hot, cool, setback, and consistency viscosities, and also in break-down and setback ratios. However, initial pasting temperature and consistency ratio showed a narrow range of varietal variation.

The initial pasting temperature was highest in *indica* rice. Tongil-type rices showed the highest average values for peak, hot, and cool viscosities, while *japonica* showed

Table 2. Visco-amylogram characteristics of glutinous rices tested.

Ecotype	No. of variety	Initial pasting temp. (℃)	Viscosity (RVU)						Break-down ratio (%)	Set-back ratio (%)	Consi-stency ratio (%)
			Peak	Hot	Cool	Break-down	Set-back	Consi-stency			
Japonica	71	68.9	194.7	61.7	80.6	133.0	−114.1	18.9	0.317	0.415	1.316
Indica	18	69.7	255.9	91.1	122.2	164.8	−133.8	31.1	0.351	0.470	1.345
Tongil	22	68.1	318.2	111.7	148.0	206.5	−170.3	36.2	0.352	0.466	1.332
Mean		68.9	229.1	76.4	100.7	152.7	−128.4	24.3	0.330	0.434	1.324
CV (%)		3.5	15.9	28.5	27.1	19.4	22.7	30.5	26.4	24.6	4.2
LSD (5%)		1.3	20.1	11.9	15.0	16.3	16.1	4.1	0.048	0.059	0.030

the lowest values. Average values of both breakdown and consistency were highest in Tongil-type, and lowest in *japonica* varieties tested. But the setback value was highest in *japonica* and lowest in Tongil-type. The ratios for average breakdown, setback, and consistency were lowest in *japonica* rices.

The results of this study are in agreement with those of other reports that the peak viscosity of Tongil-type glutinous variety "Hangangchalbyeo" was higher than that of *japonica* varieties "Shinsunchalbyeo" and "Jinbuchalbyeo" (Lim et al., 1995; Kim et al., 1995).

The mean alkali digestion values (ADV) of three rice ecotypes at different KOH levels are presented in Table 3. *Indica* rice showed the lower average values for ADV at both KOH 1.4% and 1.7% levels than those of *japonica* and Tongil-type rices. The result obtained in this study that *indica* varieties showed high initial pasting temperature and low ADV supports the idea well that ADV is an indicative character which is inversely proportional to the gelatinization temperature of rice starch (Bhattacharya & Sowbhagya, 1972; Little et al., 1958).

It is reported that varietal variation of ADV is smaller in glutinous rice than in non-glutinous rice (Kim & Yoon, 1994), and the difference of ADV at various KOH concentrations was informative for estimating the eating quality of non-glutinous rice varieties (Choi & Sohn, 1993). Similar results were obtained in this study that the coefficients of variation of ADV were 15.7 and 14.8% at KOH concentrations of 1.4 and 1.7%, respectively. The difference of ADV between two levels (1.4 and 1.7%) of KOH concentrations showed high coefficient of variation as much as 36.7%, and this result seemed to indicate that wide varietal variation in the difference of ADV at two KOH levels exists.

Gel consistency of rice flour is used to differentiate among high amylose rice varieties with contrasting amylograph pasting viscosities (Cagampang et al., 1973). Because gel consistencies of glutinous rice did not reveal much difference due to extremely low amylose content, the method to evaluate gel consistency was modified in this study in which the amount of sample rice flour was increased and cooling time after gelatinization was adjusted.

The average gel length of *indica* varieties was shorter than that of *japonica* and Tongil-type rices (Table 3). However, most of the glutinous rices tested showed gel length over 60 mm when measured after cooling for both 20 minutes and 24 hours at 4℃ after gelatinization. The coefficient of variation was less than 10% regardless of the cooling time, which means that all of the glutinous rice belong to soft in gel consistency.

Variety grouping by cluster analysis

Cluster analysis was conducted to classify the glutinous rice varieties based on seven gelatinization characters; initial pasting temperature, peak, hot and cool viscosities, and breakdown, setback and consistency ratios. The

Table 3. Alkali digestion value (ADV) and gel consistency of glutinous rice varieties used.

Ecotype	No. of variety	ADV (1~7)			Gel length (mm)		
		KOH 1.4% (A)	1.7% (B)	B-A	20 min.† (C)	24 hr.‡ (D)	D-C
Japonica	71	3.6	5.4	1.8	68.8	72.1	3.3
Indica	18	3.2	5.0	1.8	66.2	66.8	0.6
Tongil	22	3.6	5.5	2.0	70.1	73.0	3.0
Mean		3.5	5.4	1.8	68.7	71.7	2.9
CV(%)		15.7	14.8	36.7	7.8	9.4	242.3
LSD(5%)		0.1	0.2	0.2	2.3	2.9	3.1

† and ‡: cooling time after gelatinization.

varieties were classified into three groups (Ⅰ, Ⅱ, and Ⅲ) at a similarity coefficient of 0.20, and each group was divided into two subgroups (A and B) at a similarity coefficient of 0.15 (Fig. 1).

The group I-A was consisted of 24 varieties which were mostly early maturing *japonica* varieties including Sangnambatbyeo. The group I-B included 32 glutinous rice varieties which were mostly *indica* and Tongil-type, and showed wide distribution in the heading date (Table 4). Eight and three varieties in each Ⅱ-A and Ⅱ-B were *japonica* varieties including Calmochi developed in California, and they had extremely early maturity with heading in July. And 18 varieties of Ⅲ-A and 28 of Ⅲ-B were medium or medium-late maturing *japonica* varieties.

The major factor for the grouping of the 111 varieties used was ecotype and the one for *japonica* rices was heading date. It was interesting to note that *indica* varieties were in the same group with Tongil-type varieties.

Gelatinization characteristics of variety groups divided

Table 5 shows the average values of gelatinization characters of six variety groups classified by cluster analysis. The initial pasting temperature was lower in the groups I-B, Ⅲ-A, and Ⅲ-B than in the groups I-A, Ⅱ-A, and Ⅱ-B. Group Ⅱ-B showed the highest pasting temperature. Group Ⅲ-A including the medium and medium-late maturing *japonica* varieties was lowest in peak, hot, cool, and consistency viscosities, and also in breakdown and setback ratios. Group I-B, consisting of *indica* and Tongil-type varieties, showed the highest values in peak, hot, cool, breakdown, and consistency viscosities.

Based on the fact that viscosity characteristics during gelatinization of early maturing *japonica* rice in group I-A differed from those of medium and medium-late maturing

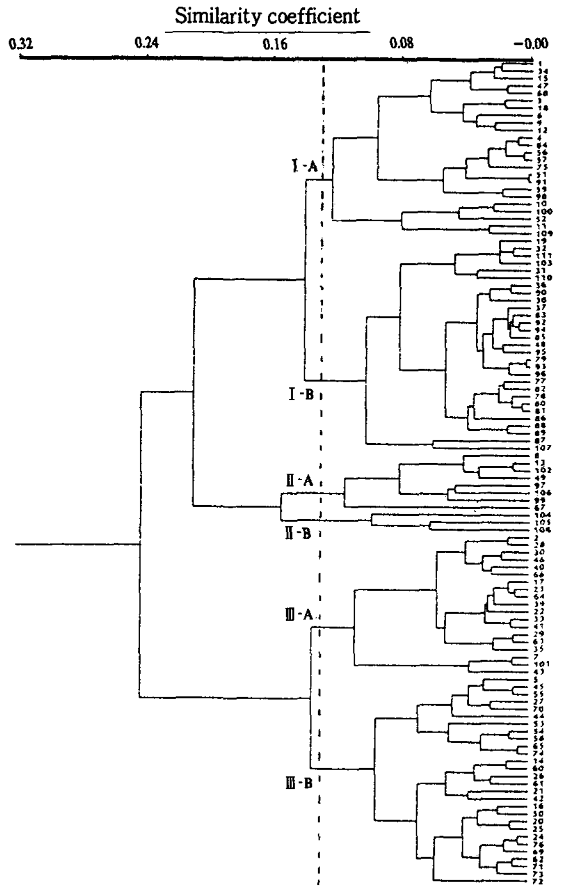

Fig. 1. Dendrogram of 111 glutinous rice varieties classified by gelatinization characteristics measured by Rapid Visco Amylogram.

Table 4. Corresponding rice varieties of six groups classified by cluster analysis.

Variety group	No. of variety	Variety number (Ecotype)	Heading date range
Ⅰ-A	24	1(J), 3(J), 4(J), 6(J), 9(J), 10(J), 11(I), 12(J), 15(J), 18(J), 34(J), 47(J), 51(J), 52(J), 56(J), 57(J), 59(J), 68(J), 75(J), 84(T), 91(T), 98(J), 100(J), 109(J)	July 29~Aug. 9†
Ⅰ-B	29	19(J), 31(J), 32(J), 36(I), 37(I), 38(I), 48(T), 77(I), 78(T), 79(T), 80(T), 81(T), 82(T), 83(T), 85(T), 86(T), 87(T), 88(T), 89(T), 90(T) 92(T), 93(T), 94(T), 95(T), 96(T), 103(I), 107(T), 110(I), 111(I)	Aug. 1~Aug. 27
Ⅰ-A	8	8(J), 13(J), 49(J), 67(J), 97(J), 99(J), 102(J), 106(J)	July 29~Aug. 11
Ⅱ-B	3	104(J), 105(J), 108(J)	July 19~Aug. 11
Ⅲ-A	19	2(J), 7(J), 17(J), 22(J), 23(J), 28(J), 29(J), 30(J), 33(J), 35(I), 39(J), 40(J), 41(J), 43(J), 46(J), 63(J), 64(J), 66(J), 101(J)	Aug. 10~Aug. 23‡
Ⅲ-B	28	5(T), 14(J), 16(J), 20(J), 21(J), 24(J), 25(J), 26(J), 27(J), 42(J), 44(J), 45(J), 50(J), 53(J), 54(J), 55(J), 58(J), 60(J), 61(J), 62(J), 65(J), 69(J), 70(J), 71(J), 72(J), 73(J), 74(J), 76(J)	Aug. 10~Aug. 25

† Four varieties(No. 6, 98, 100 and 109) headed after August 10.

‡ Heading date of variety No. 41 was August 25.

Table 5. Mean values of gelatinization characters of six glutinous rice variety groups.

Variety group	Initial pasting temp. (℃)	Viscosity (RVU)						Break-down ratio (%)	Set-back ratio (%)	Consi-stency ratio (%)
		Peak	Hot	Cool	Break-down	Set-back	Consi-stency			
Ⅰ-A	71.0	225.9	97.5	127.0	128.3	−98.8	29.5	0.432	0.562	1.300
Ⅰ-B	68.4	310.0	107.0	142.6	203.0	−167.4	35.6	0.346	0.461	1.339
Ⅱ-A	71.6	156.9	60.1	78.1	96.8	−78.8	18.0	0.382	0.497	1.302
Ⅱ-B	73.9	146.0	73.0	93.3	73.0	−52.7	20.3	0.500	0.639	1.278
Ⅲ-A	67.3	169.4	36.7	50.1	132.6	−119.3	13.3	0.217	0.296	1.365
Ⅲ-B	67.5	218.1	58.4	76.3	159.7	−141.8	17.9	0.268	0.350	1.312
Mean	68.9	229.1	76.4	100.7	152.7	−128.4	24.3	0.330	0.434	1.324
LSD (5%)	1.6	26.9	12.1	15.0	19.3	16.9	5.4	0.032	0.037	0.050

Table 6. Mean values of ADV and gel consistency of six glutinous rice groups.

Variety group	ADV (1~7)			Gel length (mm)		
	KOH 1.4% (A)	1.7% (B)	B-A	20 min. †(C)	24 hr. ‡(D)	D-C
Ⅰ-A	3.4	4.7	1.6	69.2	70.2	1.0
Ⅰ-B	3.5	5.5	2.0	69.1	71.5	2.4
Ⅱ-A	3.2	4.9	1.6	67.8	70.6	2.8
Ⅱ-B	3.3	4.2	0.9	65.5	70.0	3.5
Ⅲ-A	3.8	5.7	1.9	68.6	75.3	6.6
Ⅲ-B	3.7	5.7	2.0	68.5	71.7	3.2
Mean	3.6	5.4	1.8	68.7	71.7	2.9
LSD(0.05)	0.5	0.3	0.3	5.1	6.3	6.5

† and ‡: cooling time after gelatinization.

japonica in groups Ⅲ-A and Ⅲ-B, it is inferred that the ripening environment affected the gelatinization viscosity characteristics of glutinous rice. However, the viscosity characteristics of *japonica* rices in the groups Ⅲ-A and Ⅲ-B were also different, although they had the same maturity. This result seemed to indicate that the varietal genetic background also affects the viscosity characteristics.

Alkali digestion value and gel consistency of six glutinous rice groups are presented in Table 6. Groups Ⅰ-A, Ⅱ-A, and Ⅱ-B showed lower ADVs at KOH 1.4 and 1.7% concentration levels compared with those of groups Ⅲ-A and Ⅲ-B. The maturity of variety groups I-A, Ⅱ-A, and Ⅱ-B was early or extremely early, and their ADVs were lower than those of medium or medium-late maturing variety groups Ⅲ-A and Ⅲ-B. This result seemed to indicate that ADV was closely associated with maturity. Kim & Oh (1992) reported that ADVs of early maturing non-glutinous cultivars were lower than those of medium-late maturing cultivars.

No difference in gel consistency among the six variety groups was detected and this implies that gel consistency does not differ among glutinous rice varieties.

Principal component analysis

Principal component analysis was conducted using seven gelatinization viscosity characters. Among the seven principal components obtained the first two principal components explained 85.4% of the total variation, and the accumulative contribution of up to the fourth component was 99.8%.

Correlation coefficients between principal components and gelatinization characters are shown in Table 7. The first and second principal components were closely correlated with all the gelatinization characters, the third one with three characters, and the fourth one with only two characters. The fifth to seventh components did not

Table 7. Correlation coefficients between principal components and gelatinization properties.

Variable	Z1	Z2	Z3	Z4	Z5	Z6	Z7
Initial pasting temp.	0.626**	−0.643**	0.251**	−0.364**	−0.003	−0.000	0.000
Peak viscosity	0.538**	0.816**	−0.145	−0.139	−0.070	−0.008	0.000
Hot viscosity	0.924**	0.369**	−0.076	−0.019	0.065	−0.019	0.004
Cool viscosity	0.898**	0.435**	0.042	−0.009	0.030	0.029	−0.005
Breakdown ratio	0.913**	−0.361**	0.062	0.176	−0.016	−0.023	−0.006
Setback ratio	−0.368**	0.465**	0.805**	0.023	0.004	−0.007	−0.000
Consistency ratio	0.911**	−0.295**	0.212*	0.192*	−0.035	0.016	0.006

*, ** : significant at 5% and 1% levels, respectively.

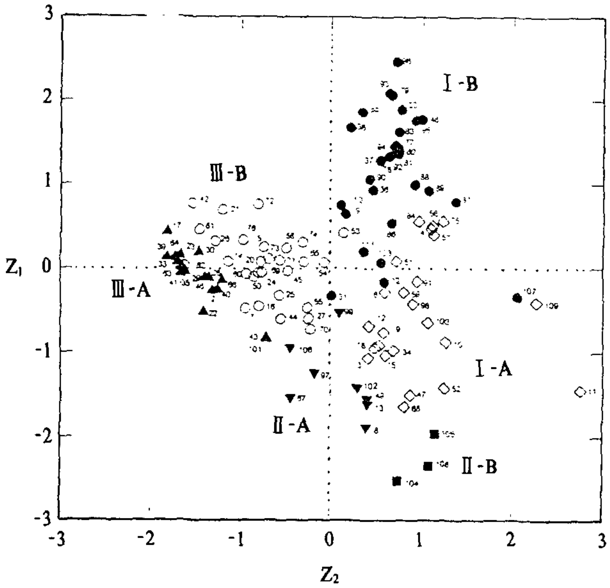

Fig. 2. Scatter diagram of 111 glutinous rice varieties on the plane of the first and second principal components. I-A : ◇, I-B : ●, II-A : ▼, II-B : ■, III-A : ▲, III-B : ○.

show any significant correlations with gelatinization characters.

The first and second components were highly correlated with seven characters, but were different in the direction of relationship with initial pasting temperature, breakdown ratio, setback ratio, and consistency ratio. The third component showed positive correlation with initial pasting temperature, setback ratio and consistency ratio. The fourth component was negatively correlated with initial pasting temperature and positively with consistency ratio.

Fig. 2 is the scatter diagram of 111 glutinous rices based on the first and second components calculated. Varieties in the same group based on the cluster analysis (Table 4) were closely positioned. Exceptional varieties such as varieties numbered 11, 31, 43, 99, 107 or 109 were located apart from their expected positions. This is because only the first and second components among the four effective principal components were considered in Fig. 2.

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