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Varietal Variations in Absolute Density of Rice Grain and Its Relations with Other Grain Characters

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米粒 絶對密度의 品種間 變異 및 몇가지 米粒形質과의 關係

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ABSTRACT : To investigate the varietal variations in absolute density of milled rice grain and its relations with other grain characters, the 235 rice varieties which consist of 30 Tongil type rices, 72 Japonica rices and 133 Indica rices were tested on grain size, volume, hardness, chalkiness and 1000 grains weight of brown rice, ADV, amylose content, starch composition on SEM and absolute density of milled rice grain using completely ripened grains. Average absolute density of milled rice grain was 1. 496g/㎤ in Tongil type rices, 1. 506g/㎤ in Japonica rices, and 1. 500g/㎤ in Indica rices. It was correlated positively with days to heading and grain hardness, and negatively with chalkiness, volume , grain weight and grain length of brown rice. Regression analysis indicated that grain volume and weight were the major characters affecting the density. However, since the absolute density of milled rice grain did not show great varietal variations it might not seem important as one of the characters contributing to the grain yield, while it could be a factor affecting the grain quality because there were definite varietal differences even though small. The microscopic feature of starch composition on SEM revealed differences between clear and chalky parts of the grain in shape and compactness of starch composition but did not discriminate between high and low-density grains.

Density of rice grain has been focused recently as one of the important characters for higher yield by increasing weight per grain. Venkteswarlu et al[4] and Vergara et al[5] reported that grain density varied among varieties and among locations of spikelets on the panicle within a variety. But, little research has been conducted on absolute density of completely ripened grains, which may be a prerequisite for breeding high-den-sity-grain varieties. Reyes et al[2] and Leach & Schoh[1] studied the absolute density of starch, however, they were only concerned with starch itself. The objective of this study is to investigate the varietal variations in absolute density of grain and the grain characters affecting the density.

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MATERIALS AND METHODS

The 235 rice varieties which consist of 30 Tongil type rices, 72 Japonica rices and 133 Indica rices were cultivated in paddy field using standard cultural practices in 1990. They were seeded on Apr. 27 and transplanted on Jun. 1 with one plant per hill by 30x15 cm of planting distance. Fertilizer was applied at the amount of 12-10-10 kg NPK/10a. After harvesting and hulling, completely ripened grains were selected by blowing, sieving and hand-working. Grain length, width and thickness were measured with Vernier Calipers, grain hardness with Kiya's Hardness Tester, amylose content and ADV by IRRI's method, and composition of starch granules with SEM (x1,500). Grain volume was measured by the volume increase of xylene in 5 ml pipette into which grains were put. Chalkiness was rated from 0(clear) to 7(completely chalky) for each grain and chalkiness of each variety was expressed by averaging the ratings of 30 randomly sampled grains. Absolute density of milled rice grain was calculated as follows;

$$\text{Absolute density of grain} = \frac{GW-(GW \times MC)}{GV-VW} \ (g/cm^3)$$

where, GW : grain weight
MC : moisture content
GV : grain volume
VW : volume of water contained in grains

Volume of water contained in grain was calculated by grain weight x moisture content on the assumption that density of water was 1. 0g/㎤ at room temperature.

RESULTS AND DISCUSSION

Varieties showed great variation in tested grain characters such as grain size and shape, chalkiness, hardness, amylose content and ADV, indicating that they could cover a large part of the rice germplasm and were thought to be a proper sample population for this study (Table 1). Absolute density of grain was shown in Table 2. The average grain density of Japonica rices was 1. 506 g/㎤, and those of Indica and Tongil type rices were 1. 500 g/㎤ and 1. 496g/㎤ respectively. The density of waxy rices was fairly lower than that of non-waxy ones, which was similar to the report on density of starch by Reyes et al(1965). Table 3 showed the correlation coefficients between the absolute density and other characters. The absolute density of rice grain was correlated positively with days to heading and grain hardness, and negatively with chalkiness, grain volume, grain weight and grain length.

Analysis of partial regression coefficients revealed that days to heading, grain hardness, chalkiness, grain volume and weight were associated significantly with the density (Table 4). The most important character affecting the grain density was found to be the grain size on the basis of standard partial regression coefficients measured on the five important characters (Table 5). This could be due to insufficient grain-filling in the larger grains compared with the smaller ones. The R^2 value was 0.6188 suggesting the good fitness of this 5-parameter equation.

To know the genuine differences in absolute grain density regardless of other grain characters which might affect the density, 16 Indica varieties which showed no chalkiness, slender shape and similar size were tested on absolute grain density as shown in Table 6. The absolute density of grain in selected varieties ranged from 1.4959 to 1.5244 g/㎤, on the other hand in all varieties tested it ranged from 1.4358 to 1. 5256 g/㎤. The coefficient of variation in 16 Indica varieties was about one-tenth of that in all varieties. This means that the genuine differences in absolute grain density caused by different genotypes is very small, amounting to only 2% so far as other grain characters such as grain size and chalkiness could be controllable genetically. It could

Table 1. Varietal distribution on some grain characters

Days to heading (days)

No. of varieties tested	65----	80	85	90	95	100	105	110	115	120	125	Mean
235	2	4	4	18	49	41	45	48	15	9	1	102.0

Grain length (mm) of brown rice

	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	-----	10.5	Mean
235	1	16	46	70	45	24	30	1	1		1	6.00

Grain width (mm) of brown rice

	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	Mean
235	1	3	13	31	29	79	41	28	8	2	2.69

Grain thickness (mm) of brown rice

	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	------	2.7	Mean
235	4	14	25	70	54	38	21	7	------	2	1.93

Ratio of L/W of brown rice

	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	4.1	Mean
235	17	41	35	52	22	30	11	11	12	1	2	1	2.27

1000 grains volume (㎤) of brown rice

	7	9	11	13	15	17	19	21	23	25	-----35	--- 43	Mean
235	1	1	14	48	84	52	19	7	2	4	------1	--- 1	14.8

1000 grains wt.(g) of brown rice

	12	15	18	21	24	27	30	33	36	---51	--60	Mean
235	1	17	42	81	62	18	7	2	3	---1	--1	21.3

Chalkiness

	0	1	2	3	4	5	6	7	Mean
218[a)]	21	51	33	46	27	22	5	1	2.5

Hardness(kg/grain)[b)] of brown rice

	4	5	6	7	8	9	10	11	12	13	14	15	Mean
235	1	4	14	27	42	43	41	29	21	8	3	2	9.2

ADV (1-7)

	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	Mean
235	30	24	12	13	6	2	2	4	7	21	44	42	28	4.5

Amylose content (%)

	7	-10	-14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Mean
218[a)]	3	-1	-1	3	6	9	14	33	33	19	21	16	12	115	18	10	2	1	1	21.2

a) Waxy varieties were excluded.

b) Measured by Hardness Tester made by Kiya Seisakusho Ltd. (Japan)

be concluded that significant yield improvement might not be expected through the selection of high absolute density grain because of its narrow genetic variation, and breeding efforts rather be concentrated on the selection of varieties with good and uniform grain-filling characteristics. However the possible relevance to physicochemical properties and qual-

Table 2. Varietal distribution on the absolute density of milled rice grain

Varietal type	Waxiness	Absolute density of grain (g/cm³)											Total
		1.44	1.45	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	Mean	No. of Culti.
Tongil type	WxWx				1	1	7	11	3			1.496	23
	wxwx			1	4	2						1.470	7
Japonica	WxWx	1			3	2	6	14	21	18	2	1.506	67
	wxwx					2	3					1.485	5
Indica	WxWx	1		1	5	6	19	48	33	15		1.500	128
	wxwx					4	1					1.485	5
Total	WxWx	2	0	1	9	9	32	73	57	33	2	1.501	218
	wxwx			1	4	8	4					1.479	17

Table 3. Correlation coefficients between absolute density of milled rice grain and grain-related characters

Grain-related characters	Correlation coefficients
Days to heading	0.275**
Grain length	-0.246**
Grain width	-0.047
Grain thickness	-0.065
L/W ratio	-0.101
1000-grs. wt.	-0.280**
Grain volume	-0.319**
Chalkiness	-0.526**
ADV	0.124
Amylose content	-0.011
Grain hardness	0.268**

ity of grain is remained to be studied since there were found to be definite varietal differences in absolute grain density even though small.

The microscopic feature of starch composition on SEM was compared in between low and high-density grain, and between normal and chalky part of endosperm (Fig. 1 & 2). Remarkable differences between low and high-density grain was not found, while starch granules in the chalky part showed somewhat rounder shape and looser packing, probably resulted from limited grain-filling, than those in the normal part of endosperm. Similar observations was reported by Tashiro & Ebata[3].

摘 要

벼 品種間 米粒 絶對密度의 變異와 그에 영향하는 米粒關聯形質들을 究明하기 위하여 統一型 30, Japonica型 72 및 Indica型 133 計 235 品種에 대해 米粒의 絶對密度와 모양 및 크기, 硬度, 心腹白, ADV, amylose 含量, 澱粉構造를 조사하고 그들 간의 關係를 檢討한 결과는 다음과 같다.

1. 白米의 絶對密度는 平均的으로 統一型 1.496 g/cm³, Japonica型 1.506 g/cm³, Indica型 1.500 g/cm³ 이었고, 出穗까지의 生育日數 및 玄米의 硬度와는 正의 相關을 心腹白, 玄米의 부피 및 1000粒重, 粒長과는 負의 相關을 보였다.

2. 偏回歸分析 결과 米粒의 크기가 絶對密度에 가장 크게 영향하는 것으로 나타났다.

3. 絶對密度의 高. 低에 따른 澱粉結晶構造의 差異는 鑑別할 수 없었으며, 心腹白의 경우 正常胚乳部分에 비해 澱粉粒子가 둥글고 그 結晶組織이 느슨하였다.

4. 米粒의 크기가 비슷하고 心腹白이 없는 경우 絶對密度의 品種間 差異는 微微한 것으로 나타나서 收量性에는 크게 영향하지 못할 것으로 생각되

Table 4. Partial regression coefficients of some grain characters on absolute density of grain(Y)

	Parameter estimate	Standard error	Significance	Character
$\hat{Y}=$	1.41447	0.02801	***	Intercept
	+0.00022	0.00007	**	Days to heading
	+0.00108	0.00032	**	Grain hardness
	−0.00003	0.00030	ns	Alkali digestibility value
	+0.00047	0.00027	ns	Amylose content
	−0.00257	0.00046	***	Chalkiness
	−0.00420	0.00404	ns	Grain length
	+0.01141	0.00920	ns	Grain width
	+0.01324	0.00651	ns	Grain thickness
	+0.00981	0.00924	ns	Ratio of L/W
	−0.03390	0.00290	***	Grain volume
	+0.02343	0.00210	***	1000-grains weight

R^2=0.6464***

Table 5. Standard partial regression coefficients of some grain characters on absolute density of grain

Character	D.F.	Standardized estimate
Days to heading	1	0.103924
Grain hardness	1	0.152547
Chalkiness	1	−0.277442
Grain volume	1	−9.270652
Grain weight	1	9.113244

R^2=0.6188***

Table 6. Varietal variation of absolute density of rice grain

Cultivars	Absolute density Min.(A)	Max.(B)	Mean	C.V.	(B/A)x100
	g/cm^3			%	
Total	1.4358	1.5256	1.5014	0.572	106.3
Indica (fine grain)	1.4959	1.5244	1.5056	0.058	102.0

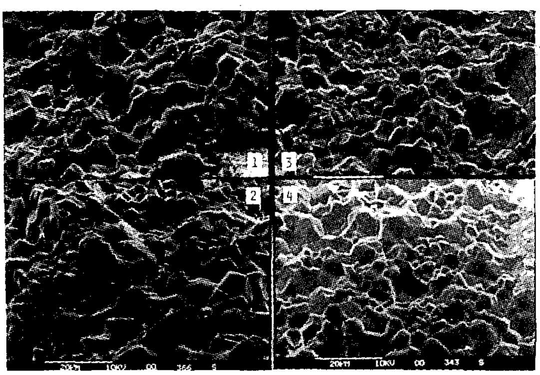

Fig.1. Starch granules of high (1&3) and low (2&4)-density grains exposed by SEM (x1500)---1 : Shingwangbyeo, 2 : Josaengtongil, 3 : Geumobyeo, 4 : Daegwanbyeo.

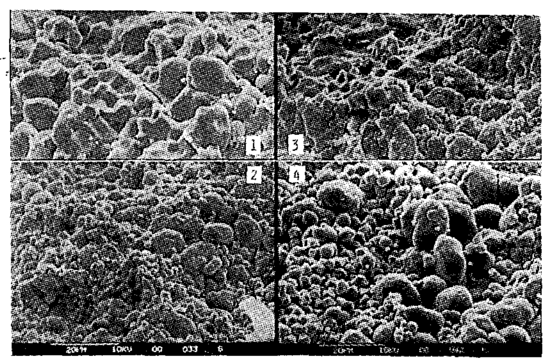

Fig.2. Starch granules of chalky endosperm exposed by SEM (1&2 : white core of Cselzaz, 3&4 : white belly of *D zhan B*, 1&3 : border between chalky and normal endosperm, 2&4 : center of the chalky endosperm)

나, 米質의 側面에서는 檢討되어져야 할 것이다.

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