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Shattering Grain Loss in Relation to the Impulse During Harvest and Year-Variation of Grain Tensile Strength in Rice

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벼 收穫時 衝激에 의한 脫粒 損失과 脫粒性의 年次間 變異

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ABSTRACT

Tensile strength and shattering losses of rice grains in a binder harvest and in a free falling test were examined. Indica x Japonica varieties, Milyang 23, Hangangchal, and Taebaek, and a Japonica variety, Jinheung were used for this study. The average tensile strength varied with varieties, showing 0.743N (Newton) in Milyang 23, 1.078N in Hangangchal, 1.573 N in Taebaek, and 1.775 N in Jinheung. Extrapolation of the average tensile strength for the zero field loss of grain indicated about 1.7 N. Moisture content of straw at the cutting position in a binder harvest was 76.0 to 86.7% in culm and 76.7 to 77.8% in leaf sheath. The percent loss of grains occurring in binder barvest in the field was equivalent to the degree of shattering in the panicle-falling test onto the concrete floor at the height of about 40cm. The grain shattering ($\hat{Y}$) was closely related to the impulse (X), the change in momentum: $\hat{Y} = -25.73+4958.4X$, ($r^2=0.987$) for Milyang 23, $\hat{Y} = -12.97+2258.3X$, ($r^2=0.979$) for Hanagangchal, $\hat{Y} = -5.24+840.4X$, ($r^2=0.976$) for Taebaek. The tensile strengths of grains and their variance varied singnificantly yearly even in the same variety. The magnitude of year-variance was somewhat smaller for the easily shattering variety.

INTRODUCTION

Minimizing the grain loss of high yielding Indica x Japonica varieties during harvest stands out as an important issue in Korea. The field loss of rice grains during harvest has been reported to be about 180 to 300kg/ha in the varieties[1,8]. Generally self-feeding type combines and the binders popular in Korea have been developed for the Japonica varieties, but the agronomic characteristics are very different between Japonica varieties and high yielding Indica x Japonica varieties. Of the critical differences between them grain shatterability is the most important factor in relation to grain loss during harvest.

In our previous studies[3,12] major rice cultivars showed different degrees of grain shattering, different tensile strengths of grain, and different degrees of field loss of grains during harvest. It was also revealed that temperature condition during grain ripening was the major factor affecting shatterability of grains in the thermophilic Indica x Japonica varieties.[11] Kawamura and Horio[5] re-

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ported that threshing force measured by centrifugal force was 1.510 to 1.990 Newton for Japonica varieties. Singh and Burkhardt[12] showed that the mean values of spikelet attachment in tensile were 0.333 to 2.412 Newton. Lee and Hur[10] studied the difference in the force to detach grains according to orientation of the force applied and reported that the mean threshing force was about 196g in Japonica varieties and 113g in Indica x Japonica varieties when the force was loaded in the direction parallel to the grain, and that the threshing force bent to the grain was about 59.8 to 115 g in Japonica and 9.8 to 28.2 g in Indica x Japonica varieties.

The present study aimed at further clarification of the relationship between the degree of shattering under free-falling test in the laboratory and that of field loss in binder harvest. Also tried was elucidation of the relationship between the impulse which the grains in a bundle receives in binder harvest and the degree of shattering. As our study on grain shattering has been continued, year to year variation in grain shattering are documented.

MATERIALS AND METHODS

Four varieties, Milyang 23, Hangangchal, Taebaek and Jinheung, differing seizably in tensile strength of grain, were used for this study in 1982. The panicles detached from the plants at the paincle neck were dropped onto the concrete floor at the heights of 25, 50, 75, 100, 150 and 200 cm. Then, the ratio of the number of shattered grains to the total number of grains in the dropped panicle was expressed as the degree of grain shattering. Falling test at each height and variety was replicated five times. The mass of each panicle dropped, tensile strength on rice shattering tester (Kiya No. 150, Tokyo, Japn), and field loss of grain in binder harvest were measured. The binder used was a rice binder harvester, Model KB 602, Kukje Machinaries Co., Korea.

It is the impulse that shatters grains from the bundle discharged from binder, when the bundle collides with ground. The impulse, the product of average force and the colliding time (Ft), equals the change in momentum (mass times velocity). That is,

$$Ft = mv' - mv \text{ (g.cm/sec)} \quad \ldots\ldots\ldots\ldots (1)$$

m = the mass of the panicle (g)

v = the velocity of the panicle just before collision with the ground (cm/sec)

v' = the velocity of the panicle after collision (cm/sec)

t = the colliding time (sec)

F = the average force ($g \cdot cm/sec^2$)

Because the velocity of the panicle after collision is zero, the impulse (Ft) equals the mass times velocity.

$$Ft = -mv \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The velocity of the falling panicle at the ground was calculated by means of the energy conservation law as follows:

$$(Ek = \tfrac{1}{2} mv^2) = (mgh = Ep) \quad \ldots\ldots\ldots\ldots (3)$$

$$v = \sqrt{2gh} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where Ek: the kinetic energy at the ground

Ep: the potential energy at the falling height

g : the gravitational acceleration

h : the falling height

Thus, the impulse (Ft) is calculated from the equation (2).

RESULTS

Tensile strength and field loss: The average tensile strength of grains of the four varieties varied, showing 0.743N (Newton) in Milyang 23, 1.078 N in Hangangchal, 1.573 N in Teabaek and 1.775 N in Jinheung (Table 1). The highest field loss of grain during binder harvest took place in Milyang 23 (4.63% of grain yield). The percentage of grain loss was related to the tensile strength. The smaller was the tensile strength, the higher was the field loss of grain (Table 1).

Fig. 1 shows the relationship between average tensile strength and field loss of grains in binder harvest. Extrapolation of the average tensile strength for the zero loss of grain gives us about 1.7 Newton.

Table 1. Varietal differences in the tensile strength and the field loss of grains in binder harvest.

Variety	Average tensile strength (Newton)	Field grain loss (%)
Milyang 23	0.743	4.63
Hangangchal	1.078	2.25
Taebaek	1.573	0.13
Jinheung	1.775	0.00

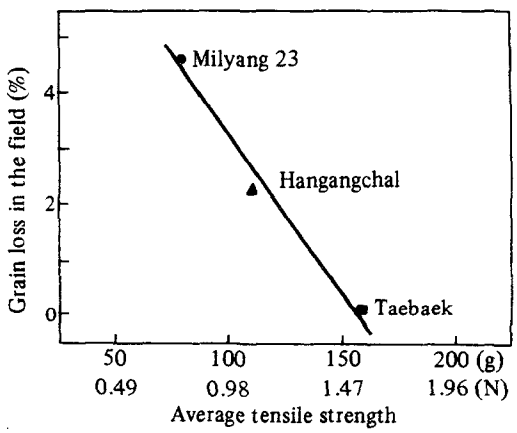

Fig. 1. Relationship between the average tensile strength and the field grain loss in harvest with binder.

This result is in agreement with our previous report[8].

Moisture content of the cutting position: Lee and Hur [10] reported that the shear force of a Japonica variety, Iri 345, was on average *ca.* 1.54 N and an Indica x Japonica variety, Taebaek, on average *ca.* 1.01 N. The value might be affected by the stem moisture content. The moisture content of straw at cutting position at 45 days after heading varied among varieties. They were about 76.0-86.7% in culm and 76.7-77.8% in leaf sheath (Table 2).

Table 2. Moisture content of rice plants at the cutting position in binder harvest.

Variety	Moisture content (%)	
	Culm	Leaf sheath
Milyang 23	86.7 ± 2.05	77.8 ± 3.90
Hangangchal	76.0 ± 2.26	76.7 ± 2.51
Jinheung	84.3 ± 0.92	76.8 ± 6.35

The impulse and shattering: The impulse which is incurred when a bundle is discharged from

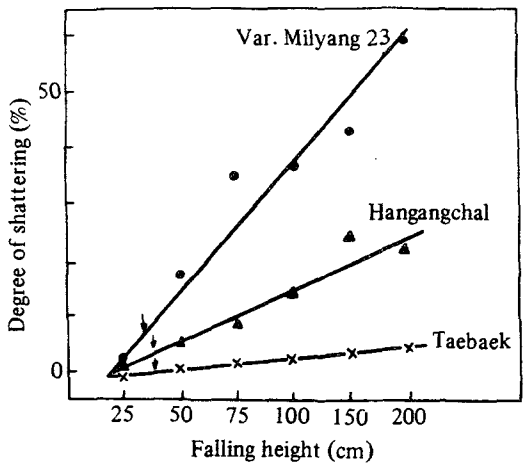

Fig. 2. Relationship between the degree of shattering and falling height (↓ indicates the degree of shattering in binder harvest in the field).

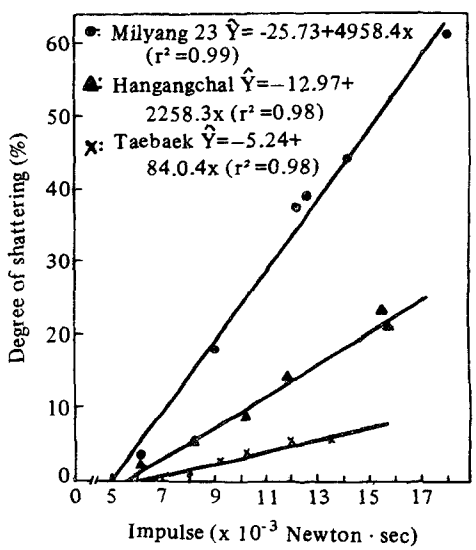

Fig. 3. Relationship between the degree of grain shattering and the impulse to shatter the grains.

binder and drops onto the ground is a major factor of grain loss during harvest. Fig. 2 shows the relationship between falling height and degree of grain shattering. Of the varieties tested Jinheung did not shatter even when the panicle was dropped onto concrete floor at the height of 200 cm. The degree of grain shattering in the three varieties tested increased rather linearly with the increase in falling

height. The percent loss of grains in binder harvest in the field shown in Table 1 was equalized to the degree of shattering in the panicle-falling test at the height of about 40 cm.

The effect of the impulse on grain shattering is shown in the Fig. 3. Tendency in the relationship between the impulse to shatter grains and the degree of grain shattering is similar to that in the Fig. 2. The minimum impulse to shatter grains in the extrapolation on the regression equations was 5.15 N·sec. in Milyang 23, 5.74 N·sec. in Hangangchal and 6.24 N. sec. in Taebaek. The increments in gran loss with the increase in the impulse by 1/1000 Newton. sec. are 4.96% in Milyang 23,2.2% in Hangangchal and 0.84% in Taebaek.

The year variation in tensile strength: Table 3 shows the year variation in average tensile strength and its variance at 40 days after heading. The average tensile strength of grains and its variance varied significantly yearly in the same varieties. However, the yearly change in tensile strength of easily shattering variety, Milyang 23, was smaller than that of the non-shattering variety, Jinheung.

Table 3. Year-variation in the tensile strength of grains and its variance at 40 days after heading.

Variety	Year	Average tensile strength (g)	Coefficient of variance	Standard deviation	Standard error	Number of grains tested
Milyang 23	1978	75.6	33.4	26.2	1.80	200
	1981	89.3	34.7	31.7	2.32	187
	1982	65.8	21.7	14.3	1.43	100
Jinheung	1978	205.6	14.8	30.3	2.13	200
	1981	220.9	15.2	33.1	2.87	132
	1982	180.9	7.4	12.2	1.22	100

DISCUSSION

Two ways are conceivable for reducing field grain loss during harvest. Development of non-shattering variety is the fundamental way of reducing field loss. Table 1 shows the fact that the shatterability varies among varieties. The varietal difference in shatterability has been well documented by the authors for the Indica x Jaonica varieties and by others for Japonica or Indica varieties[4, 6, 7, 8, 9, 10, 11]. It implies that the field loss during harvest can be reduced by breeding varieties having greater grain tensile strength. In our previous paper [8] the threshold average tensile strength of grains giving no shattering was about 180g (*ca.* 1.764 Newton). In the present study Jinheung of which average tensile strength was 1.776 Newton did not shatter in binder harvest and falling test at the height of 200 cm.

The second way is to reduce grain losses as much as possible in the harvesting processes. Chung and Ryu[2] reported that the shattering loss at the height of 80 cm was 6.3 to 7.3% which was three times of the discharge loss 2.1 to 2.4% in binder harvest and explained that the difference in grain losses between the field and laboratory tests might be due to the difference in the size of bundle. The difference in the size of bundle, however, seems not to account fully for the difference in grain loss: the bundle discharged from the binder consisted of average 10 to 15 hills which was 5 to 8 times heavier than the bundles used in the laboratory tests. The impact force will be a function of the mass of bundle. Some other factors contributing to the above difference appear to exist. Fig. 3 shows that the degree of grain shattering increases linearly with the increase in the impulse. The grain shattering of individual panicle was mainly caused by the impulse: r^2 ranges from 0.976 to 0.987. A great portion of grain losses in binder harvest incurred when the bundle discharged from a binder collided with ground[2]. The impulse consists of

the mass times the colliding time (Ft = mv). It is thought that in easily shattering varieties almost all the grains which collide directly with ground would shatter, but the other grains which do not have impact would not shatter due to the buffering effects of the culms, branches, pedicels and so on.

From the results of Fig. 3, it is obvious that shattering loss of grain during harvest will be decreased by reducing the impulse. The impulse will be lessened by reducing the mass and velocity of the bundle. Field drying of the plants for harvest is one method to reduce the mass of bundle. In our previous studies tensile strength increased somewhat with drying of the panicle in the field [6,8]. Since the dried bundle consists of more hills than the moistened bundle in given diameter and mass, the panicles which collide directly with ground will be decreased in a unit area.

The velocity of a free falling bundle and the colliding time are important factors for lessening the impulse. If the free falling bundle is slipped at its middle position in height by an accessary of the binder before colliding, a great deal of velocity could be reduced, resulting in seizable reduction in field loss of grains.

摘　　要

密陽 23 號, 漢江찰벼, 太白벼 및 振興을 供試하여 벼알의 引張強度를 測定하고, binder 收穫時 圃場損失과 地上 25, 50, 75, 100, 150 *cm* 및 200 *cm*에서 콘크리트 바닥에 이삭을 落下시켜 落下높이별 脫粒率을 調査하여 衝激力과 脫粒率과의 關係를 구하고 引張強度의 年次變異를 調査하여 다음과 같은 結果를 얻었다.

1. 平均引張強度는 密陽 23 號 0.743 Newton, 漢江찰벼 1.078 N, 太白벼 1.573 N, 振興 1.775 N이었다.

2. 引張強度가 낮을수록 binder 收穫時 脫粒損失이 많았으며 脫粒損失이 없는 引張強度는 약 1.7 N 이상이었다.

3. 벼의 binder 切斷部位의 水分含量은 葉鞘가 76.7 ~ 77.8 %, 稈이 76 ~ 87 %이었다.

4. Binder 收穫時의 圃場損失率은 한 이삭을 약 40 *cm* 높이에서 콘크리트 바닥에 떨어뜨렸을 때의 脫粒率과 같았다.

5. 衝激力(x, Newton · Sec)과 脫粒率($\hat{Y}$, %) 과의 關係는 密陽 23 號에서 $\hat{Y} = -25.73 + 4958.4x$ ($r^2 = 0.987$), 漢江찰벼에서는 $\hat{Y} = -12.97 + 2258.3x$ ($r^2 = 0.979$), 太白벼에서 $\hat{Y} = -5.24 + 840.4x$ ($r^2 = 0.976$) 이었다.

6. 引張強度는 同一品種에서도 年次間에 有意的 變異를 보였는데 그 變異幅은 脫粒性이 큰 品種에서 작았다.

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