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Genetic Analysis of Morphological Traits of Rice Grain and Their Inter-relationships

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ABSTRACT : Two rice varieties, 'Oochikara' with large grain and 'Hwayeongbyeo' and their progenies (F_1, F_2, B_1 and B_2) were tested to understand gene action of morphological traits of rice grain and their relationships. The evaluated traits were 1,000-grain weight, grain length, width, thickness, length-width ratio and chalkiness of brown rice. Correlation between grain weight and chalkiness was highly significant in the all progenies, and grain length were not associated with width and thickness in an F_2 population. Scaling test and jonit scaling test revealed that inheritance of grain traits were fitted to additive-dominance model without epistasis. Additive effects for the traits were much greater than the dominance effects.

Keywords : rice, grain size, grain shape, genetic analysis

Improvement of yield potential is one of the important objectives along with achievement of stability and high quality in rice breeding program, and grain yield is composed of yield components; panicle number per m^2, spikelet number per panicle, percentage of ripened grain and 1000-grain weight. The improvement of sink size through increasing panicle number per plant and grain number per panicle has been one of the major strategies to achieve the higher yield potential so far. Several varieties with large grain size have been developed as an way to improve sink size. For example, 'Oochikara', the high yielding rice variety with large grain, was released from the project, "Development of super high-yielding rice varieties and establishment of their cultivation methods (SHY)" initiated in 1982 in Japan (Miura & Kobayashi, 1991), and 'Daeribbyeo 1' was also released by the National Crop Experiment Station in Korea (Choi *et al.*, 1995).

The result of Takeda *et al.* (1987) in experiments using near isogenic lines, the plants with large grains were seldom outyielded those with small grains except certain location, In addition, the large grain-sized varieties show low level of grain ripening. In case of high yielding varieties with large grain, the high yield potential is due to large grain weight with a comparable percentage of ripened grain although the number of spikelets per m^2 is lower than that of rice varieties with normal grain size. The good ripening characteristics of 'Oochikara' were due to the higher percentage of grains on the primary rachis-branches (Wang *et al.*, 1997; Takita 1988). Since rice spikelets on primary rachis-branches generally bear fully filled grains, in contrast to spikelets on secondary rachis-branches.

Many studies have been done on inheritance of grain size. Generally, grain size in commercial varieties with normal grain size is controlled by polygenes and in mutant lines for grain size is controlled by major genes (Takeda, 1991). Choi (1980) and Kato (1989) reported that grain size was controlled by quantitative genes that adapt to the additive-dominance model in diallel analysis. However Buu and Hanh (1991) detect epistasis in triple testcross analysis of grain size. The Major genes controlling grain size are reported such as *Mi* controlling short kernel (Takeda & Saito, 1977), *Lk-f* controlling long kernel (Takeda and Saito 1980) and *lk-i* in the large grain variety 'IRAT13' (Takamure 1994).

The present study was undertaken to know the relationship among grain traits and to determine the inheritance of grain size.

MATERIALS AND METHODS

The experiment was conducted in the paddy field and glass house of the Yeongnam Agricultural Experimental Station from 1996 to 1997. Two rice varieties with different grain size and the populations derived form crosses between them were used. The parents were 'Oochikara' (P_1) from Japan and 'Hwayeongbyeo' (P_2), the leading variety of Korea. 'Oochikara' has high yield potential with large grain size, and 'Hwayeongbyeo' has normal grain size. Two parents were crossed in 1996 summer and backcross of each parent to F_1 plants were made in 1996 winter. The populations derived from these crosses, P_1, P_2, F_1, F_2, B_1 (P_1×F_1)

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and B_2 ($P_2 \times F_1$), were planted with 2 replications and measured for grain size to perform genetic analysis in 1997 summer. Numbers of plants measured in P_1, P_2, F_1, F_2, B_1 and B_2 were 15, 17, 19, 226, 97 and 103, respectively. The six populations were sown on April 20, 1997. Seedlings grown in a protected semi-irrigated rice nursery were transplanted to a paddy field on May 20 with a single plant per hill spaced at 30×15 cm. The amount of fertilizers applied by dressing was N; 11 kg, P_2O_5; 7 kg and K_2O; 8 kg per 10a.

Data were collected from each plant on the grain size related traits. The measured grain size related traits were 1,000-grain weight, length, width, thickness, length-width ratio and chalkiness of brown rice

Genetic analyses of these traits were conducted with scaling test and components of generation means proposed by Mather (1949), Hayman and Mather (1955) and Hayman (1958).

RESULTS AND DISCUSSION

Means of six populations (P_1, P_2, F_1, F_2, B_1, B_2), the scaling tests (A, B and C), the joint scaling tests and the esti-

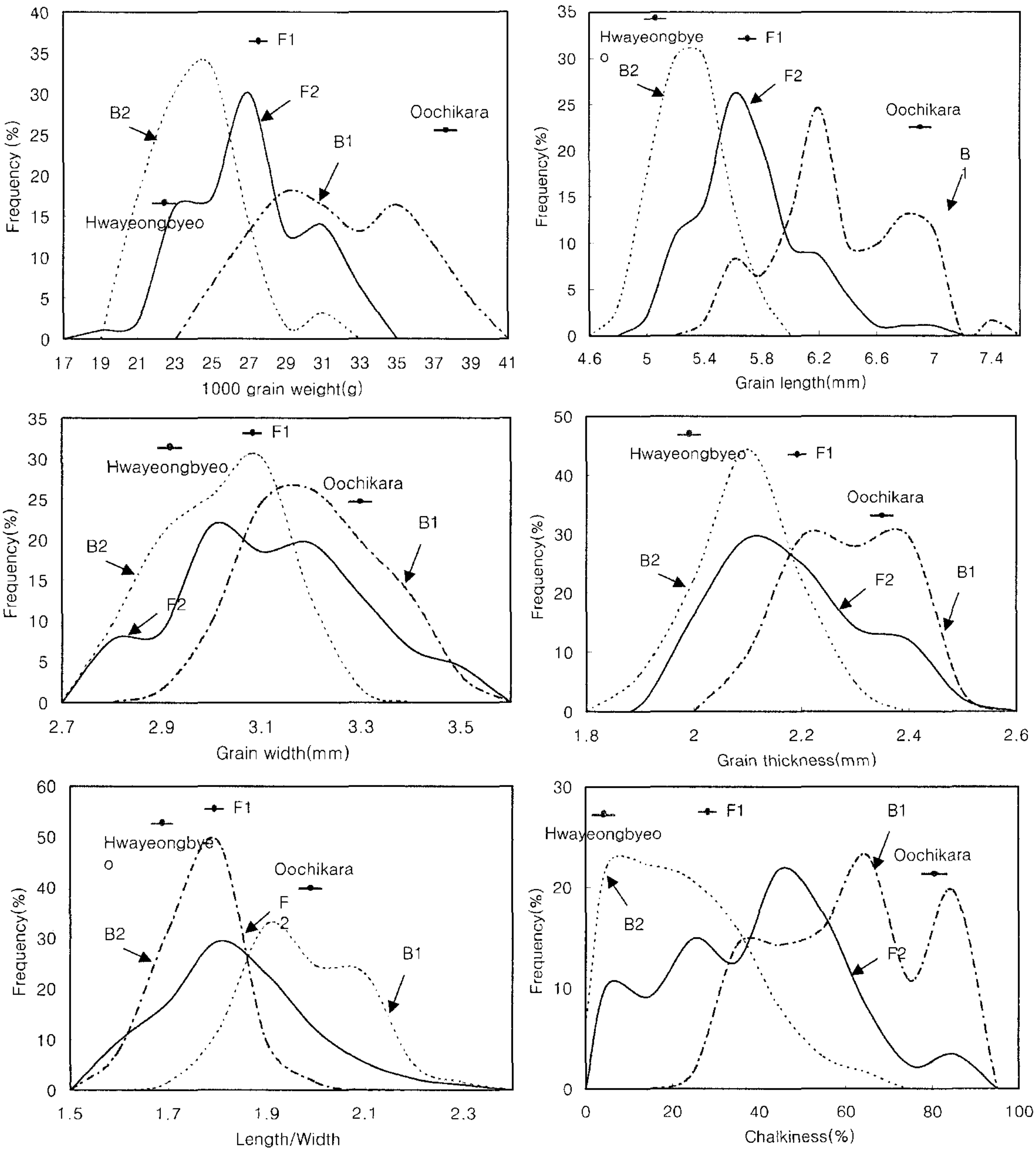

Fig. 1. Distribution of grain-size related traits in the F2, B1 and B2 population from the cross between 'Oochikara' and 'Hwayeongbyeo'.

mates of genetic parameters based on three or two parameter model for six traits were conducted to know genetic mode of grain size and shape. The relationship between grain size and shape was also estimated.

The frequency distribution of grain size shape related traits, 1000-grain weight, grain length, grain width, grain thickness, grain shape (length/width), and chalkiness, were given in Fig. 1. The segregations of populations, F_2, B_1 and B_2, on all tested traits were a quantitative mode, and the population means of backcrossed plants were closely located to the recurrent parent. The range for 1,000-grain weight of 226 F_2 individuals was 22.1 to 33.6 g without any transgressive segregation compared to parents; grain weight of 'Oochikara' and 'Hwayeongbyeo' was 38.5 and 21.3 g respectively. Backcross populations also could not find transgressive segregation. Other traits were similar trend of segregation with exception of length-width ratio. The F_2 plants of length-width ratio transgressed both the parental limits.

The relationship among grain size and shape related traits in the F_2 progeny is shown in Fig. 2, and the comparison of grain shape and size of P_1 ('Oochikara'), P_2 ('Hwayeongbyeo'), F_1 and F_2 plants was given in Fig. 3. The correlation between grain weight and chalkiness was highly significant (r= 0.83**, n=226). It is suggested that selection for both large grain and clearness is quite difficult. Grain size may be indicated by weight, and the weight is determined by length, width and thickness. These traits are the commonly used indicators for grain shape. There were highly significant positive correlations between grain width and thickness in the F_2 progeny. However, the relationship of grain length with width and thickness progeny were not found in F_2 progeny (Fig. 2). As shown in Fig. 3, rice grain with various size and shape were observed. Slender type of rice grain compared to the grain shape of parents were found, and boll type of grain also found. Transgressive segregation in grain shape was due to the no relationship between grain length and width which are component of grain shape. These were the same result in an experiment by Takeda (1986) in which correlations of length with width and thickness were not significant in the used sample of 88 rice varieties with a very wide range of

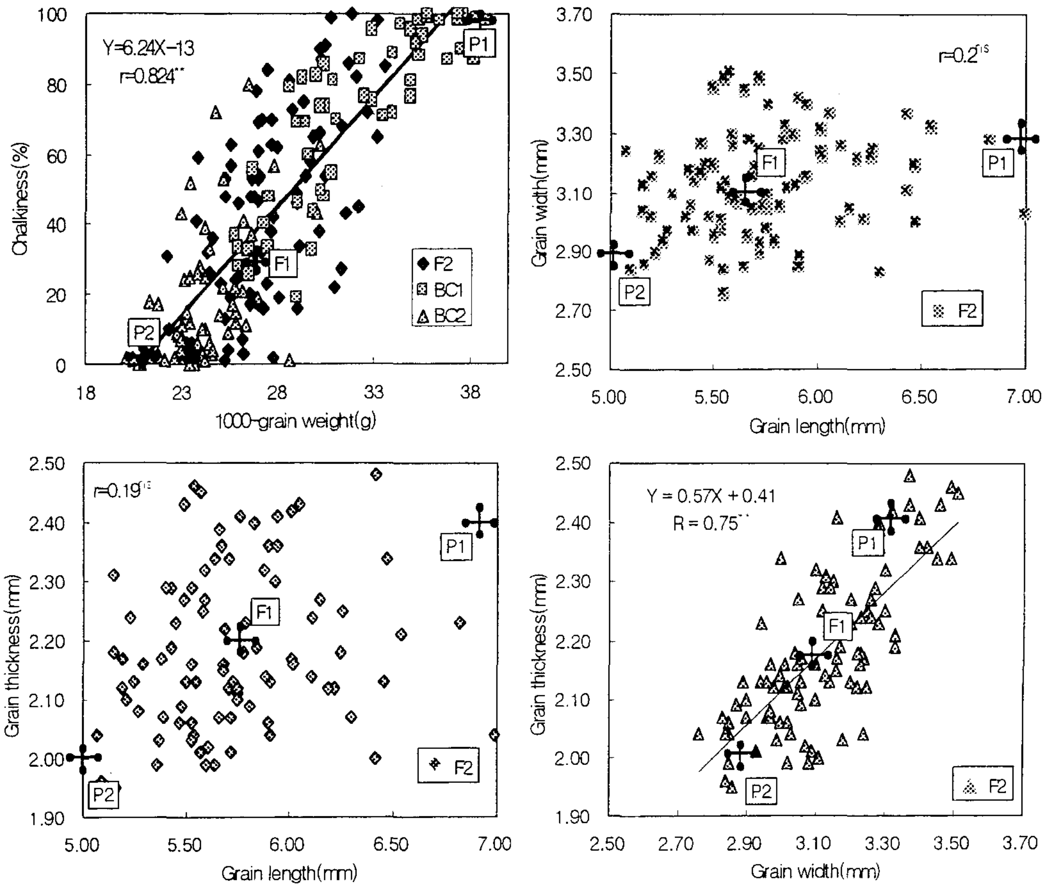

Fig. 2. Relationship among grain-size related traits in segregating populations. The abbreviation of P1 and P2 indicate Oochakara and Hwayeongbyeo, respectively.

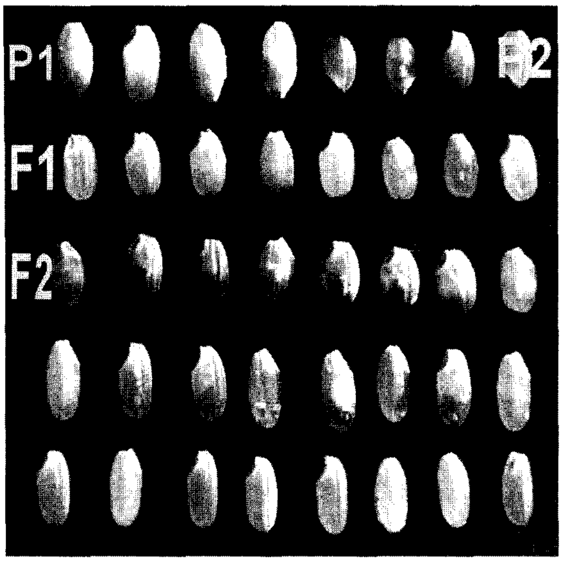

Fig. 3. Variation in size and shape of brown rice in the two parents, 'Oochikara' (P1) and 'Hwayeongbyeo' (P2), and in the F_2 population.

variation in grain size and shape. Choi (1980) reported that grain length showed low relationship with width and thickness in segregating population of F_3. Choi (1979) reported a similar result about chalkiness of large rice grain. It was suggested that large grain with clearness will be rather difficult to select for considering the fact that the chalkiness had highly positive correlations with grain volume and 1,000-grain weight from six crosses.

Means of six generations (P_1, P_2, F_1, F_2, B_1 and B_2), the scaling test (A, B and C) and joint scaling test for cross between 'Oochikara' and 'Hwayeongbyeo' are presented in Table 1 and Table 2. In the scaling test, the values of A, B and C should be zero within the limits of their standard error. Significance of any one of these scales is considered to indicate the presence of non-allelic interaction; C indicates *l* type of interaction, and A and B tests provide evidence on *i*, *j* and *l* type of gene interaction. In the absence of interactions as indicated by non-significance of scale test, three or two parameter models were used for estimation of genetic components of variances. Joint scaling tests were used to conform absence of any interaction with n-parameter model. In the scaling tests, the values of A, B and C for six traits (1,000-grain weight, grain length, grain width, grain thickness, length-width ratio and chalkiness) were not significantly different from zero. Therefore three parameter (M, [d] and [h]) model without epistasis parameter (*i*, *j* and *l*) was chosen for estimation of genetic components in 1,000-grain weight, grain length and chalkiness. The two-parameter model (M and [d]) was found to be adequate for grain width, grain thickness and length-width ratio which revealed significant estimates of mean(M) and additive([d]) effect. The [d] component was positive in all six traits. The [h] component was negative in the 1,000-grain weight, grain length and chalkiness, but zero in the grain width, grain thickness and length-width ratio. The average degree of dominance ([h]/[d]) was less than unity for all six traits (Table 1). The joint scaling test of three or two parameter model was used to know fitness of the parameter (Table 2). The results of chi-square test of the deviation of the observed mean from the expected mean for each progeny were found non-significance which proves that employment of the genetic analysis for all six traits is adequate. The heritabilities of 1,000-grain weight, grain length, grain width, grain thickness, length-width ratio and chalkiness were highly estimated as 0.89, 0.89, 0.81, 0.65, 0.88 and 0.97, respectively. The estimates of gene effects by fitting three or two parameter showed the

Table 1. Scaling test and estimates of gene effects of the grain size for six populations from the cross between 'Oochikara' and 'Hwayeongbyeo'.

	1000-grain weight	Grain length	Grain width	Grain thickness	Length / Width	Chalkiness
Scaling test						
A	-2.2 ± 7.8	0.1 ± 0.9	0.1 ± 0.4	0.0 ± 0.1	0.1 ± 0.2	7.2 ± 35.4
B	-0.2 ± 4.6	-0.1 ± 0.5	0.0 ± 0.3	0.0 ± 0.0	0.0 ± 0.2	4.3 ± 30.4
C	-5.6 ± 12.0	-0.4 ± 1.6	0.0 ± 0.7	-0.1 ± 0.3	-0.1 ± 0.6	4.4 ± 81.2
Estimates of gene effects						
M	29.9 ± 0.6**†	45.1 ± 1.9**	3.1 ± 0.1**	2.2 ± 0.1**	1.9 ± 0.0**	45.1 ± 1.9**
[d]	8.6 ± 0.6**	37.2 ± 1.9**	0.2 ± 0.1**	0.2 ± 0.0**	0.2 ± 0.0**	37.2 ± 1.9**
[h]	-2.7 ± 1.2*	-13.0 ± 4.9**	-	-	-	-13.0 ± 4.9**
[h]/[d]	0.31	0.31	0.02	0.15	0.47	0.35
Heritability	0.89	0.89	0.81	0.65	0.88	0.97

†*,**Significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Generation means and joint scaling test of the grain size for six populations form the cross between 'Oochikara' and 'Hwayeongbyeo'.

Generation	1000-grain weight(g)	Grain length (mm)	Grain width (mm)	Grain thickness (mm)	Length / Width	Chalkiness(%)
P_1	38.5† ± 0.9 (38.5‡)	6.9 ± 0.1 (6.9)	3.3 ± 0.07 (3.3)	2.4 ± 0.08 (2.4)	2.1 ± 0.06 (2.1)	82.2 ± 2.5 (82.3)
P_2	21.3 ± 0.1 (21.3)	5.0 ± 0.1 (5.0)	2.9 ± 0.07 (2.9)	2.0 ± 0.07 (2.0)	1.7 ± 0.05 (1.7)	7.8 ± 2.8 (7.9)
F_1	27.3 ± 1.1 (27.2)	5.7 ± 0.1 (5.7)	3.1 ± 0.09 (3.1)	2.2 ± 0.08 (2.2)	1.8 ± 0.04 (1.8)	31.9 ± 4.6 (32.1)
F_2	27.2 ± 2.9 (28.5)	5.7 ± 0.4 (5.8)	3.1 ± 0.17 (3.1)	2.2 ± 0.13 (2.2)	1.8 ± 0.14 (1.9)	39.5 ± 20.1 (38.8)
B_1	31.8 ± 3.8 (32.8)	6.3 ± 0.4 (6.3)	3.2 ± 0.18 (3.2)	2.3 ± 0.11 (2.3)	2.0 ± 0.14 (1.9)	60.6 ± 17.5 (57.2)
B_2	24.2 ± 2.2 (24.2)	5.3 ± 0.2 (5.4)	3.0 ± 0.12 (3.0)	2.1 ± 0.09 (2.1)	1.8 ± 0.08 (1.8)	22.0 ± 15.0 (20.0)
$x^2_{(3)}$	$0.092^{ns§}$	0.003^{ns}	0.000^{ns}	0.000^{ns}	0.002^{ns}	0.437^{ns}

†Observed means, ‡Expected means
§ns, *,**non-significant, significant at 0.05 and at 0.01 probability levels, respectively.

adequacy of the additive-dominance model without epistasis for all six traits of the cross. The additive effects exceeded the corresponding dominance effects for all six traits which indicated the presence of either partial dominance or no dominance. Choi (1980) reported similar result that incomplete dominant gene was related to grain weight, and small grain was dominant to large grain, but the gene effect appeared to be largely additive than dominant. The distribution of 1000-grain weight in F_1 and F_2 showed normal curve with the plants by falling between parents, and the transgressive segregations were not found toward to the 'Oochikara'. Hwang *et al.* (1987) also showed similar result about grain size and shape that short and small grain had partial dominance and the degree of dominance, and grain size and shape related traits were mainly controlled by additive gene effect with highly estimated heritabilitis in diallel analysis. Dikshit and Mani (1988) published different result that dominance effects were more pronounce than the additive effects in grain weight. This difference appeared to be due to different environment and crosses.

In summary, the close correlation between gain weight and chalkiness assume that breeding for large grain rice varieties with clear grain will be rather difficult. The low correlations of grain length with grain width and thickness give some possibility of releasing japonica rice variety with long grain. Predominance of additive gene effects without epistasis and highly estimated heritability suggested that the selection would be effective in earlier generations for 1,000-grain weight, grain length, grain width, grain thickness, length-width ratio and chalkiness.

REFERENCES

Buu, B. B. and T. T. Hanh.. 1991. Some quantitative characters of rice *Oryza stiva* L. studied by triple testcross analysis. *Rice Genetics* 766-767.

Choi, S. J. 1979. Studies on inheritance and selection efficiency of endosperm chalkiness of rice kernels. *The Reports, ORD* 21(C) : 209-234.

Choi, S. J. 1980. Diallel analysis of grain weight and inter-relationships between components of grain size. *Korean J. Breed.* 12(1) : 13-18.

Choi, H. C., Y. G. Kim, S. Y. Cho, H. P. Moon, N. K. Park, K. W. Kim, Y. S. Kim, S. N. Ahn, Y. G. Choi, R. K. Park, Y. S. Kim and C. Y. Cho. 1995. A large-grain new rice variety 'Daeribbyeo 1'. *RDA. J. Agri. Sci.* 37(1) : 59-66.

Dikshit, H. K. and S. C. Mani. 1988. Genetic analysis of yield components and related agronomic characters in rice(*Oryza sativa* L.). *SABRAO J.* 20(2) : 101-107

Hayman, B. I. and Mather, K. 1955. The description of genetic interaction in continuous variation. *Biometrics* 11 : 69-82

Hayman, B. I. 1956. The separation of epistatic from additive and dominance variation in generation means. *Heredity* 12 : 371-390.

Hwang, H. G., J. K. Sohn and S. K. Lee. 1987. Studies on the yield potential increment by grain weight in rice . Genetic study on the grain weight and length. *Korean J. Breed.* 19(2) : 151-157.

Kato, T. 1989. Diallel analysis of grain size of rice(*Oryza sativa* L.). *Jpn. J. Breed.* 39 : 39-45

Mather, K. 1949. Biometrical Genetics. Dover Publication, Inc., New York.

Miura, K. and A. Kobayashi. 1991. Oochikara : A rice cultivar in Japan with large-sized grains. *JARQ* 25 : 154-158.

Park, N. B., M. S. Ko. 1995. Genetic analysis of resistance according to the race of bacterial leaf blight in japonica rice(*Oryza* *sativa* L.). *The Journal of the Institute of Agriculture and Fishery Development.* 14 : 81-94.

Takamure, I. 1994. Genetic studies on several mutants related to morphological and physiological characters in rice. *Mem. Fac. Agric. Hokkaido Univ.* 19 : 151-202.

Takeda, K. and K. Saito. 1977. The inheritance and character expression of the minute gene derived from a rice genetic tester "Minute". *Bull. Fac. Agric. Hirosaki Univ.* 27 : 1-29.

Takeda, K. and K. Saito. 1980. Major genes controlling grain size of rice. *Jpn. J. Breed.* 30 : 280-282.

Takeda, K. 1986. Gene symbols for grain size and shape. *Rice Genet. Newsl.* 3 : 14-15

Takeda, K., K. Saito, K. Yamazaki, T. Mikami. 1987. Environmental response of yielding capacity in isogenic lines for grain size in rice. *Jpn. J. Breed.* 37 : 309-317.

Takeda, K. 1991. Inheritance of grain size and its implications for rice breeding. Rice Genetics : 181-189.

Takita, T. 1988. Grain ripening of hig yielding rice cultivar with very large grains. *Jpn. J. Breed.* 38 : 443-448.

Wang, Y., E. Kuroda, M. Hirano and T. Murata. 1997. Analysis of high yielding mechanism of rice varieties belonging to different plant types. *Jpn. J. Crop Sci.* 66(22) : 293-299.