

Identification of QTLs Affecting Physical Traits of Cooked Rice

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ABSTRACT

This study was conducted to ascertain the chromosomal locations and effect of quantitative trait loci (QTL) associated with the physical traits of rice (*Oryza sativa* L.) eating quality. One hundred sixty four recombinant inbred lines (MGRILs) of F₁₁ were derived from the cross between Milyang 23 (Tongil type) and Gihobyeo (*japonica* type). They were evaluated for six physical traits of cooked rice.

Transgressive segregation was observed for all examined traits. Significant QTL were detected (LOD \geq 2.0) in three traits, including single QTL for adhesiveness, gumminess, and chewiness of cooked rice, respectively. Phenotypic variation explained by each QTL ranged from 6.3% to 14.6%. However, no significant QTL was detected for hardness, cohesiveness, and elasticity of cooked rice. Pleiotropic effects of single QTL on different traits are observed.

Key word : rice, molecular map, QTL, recombinant inbred line, physical trait.

The use of a molecular map provides the resolution of complex polygenic traits into discrete Mendelian factors (Tanksley, 1993). In rice, several research groups have made a saturated genetic map (Causse et al., 1994; Cho et al., 1998; McCouch et al., 1988; Saito et al., 1991) and analyzed QTLs associated with agronomic traits including yield and its components (Kang et al., 1998a; Lin et al., 1996; Wu et al., 1996; Xiao et al., 1996). Also, previous efforts have been focused on major quantitative genes associated with plant morphological traits (Lin et al., 1996; Wu et al., 1996; Xiao et al., 1996). There are only a few reports about QTL analysis of eating quality traits in rice (Ann et al., 1992; 1993). The primary components of eating quality in cooked rice are flavor, texture, and aroma. Many researchers have worked on relationships between eating quality and physical traits in cooked rice using texture analyzer (Yang, 1994; Lim, 1994). It has been suggested that low degrees of hardness, adhesiveness, elasticity, and gumminess are related with good eating quality. However, it is not clear yet how to determine the effects of physical traits of cooked rice on eating quality. Evaluation of eating quality is usually difficult, time consuming and very laborious. In addition, experimental error is quite dependent on individual testers.

Therefore indirect selection for eating quality-related characteristics using marker tools would be preferable. The prerequisite for marker-assisted selection is the accurate mapping of loci controlling the eating quality traits.

The present study was conducted to locate QTLs associated with physical traits of cooked rice measured by texture analyzer and to estimate the contribution of each QTL in rice genome.

MATERIALS AND METHODS

Plant materials

Two elite rice cultivars, Milyang 23 (Tongil type) and Gihobyeo (*japonica* type) were crossed at the National Institute of Agricultural Science and Technology in 1988. Milyang 23 has poor eating quality with a high degree of hardness of cooked rice. However, Gihobyeo displays good eating quality with a low degree of hardness of cooked rice. Development of population from F₁ plants was conducted by the single seed descent (SSD) method. The population at F₉ generation was transplanted at National Honam Agricultural Experiment Station (NH-AES), on southwest side of Korea in 1993. The material (F₁₁) used in this experiment was harvested at NHAES in 1995.

Analysis of physical traits

The milled rice was cooked according to the instructions given by the rice producer, i.e., by using the recommended excess water method (20g milled rice was cooked with 27 ml water for 30 minutes). After 20 minutes in room temperature, the mechanical hardness, adhesiveness, cohesiveness, elasticity, gumminess, and chewiness of cooked rice were measured using an Texture Analyzer (TA-XT2, Stable Microsystems, England) according to the standard procedure (Endo et al. 1976). Cooked rice was tested within a maximum delay time of 2 minutes. after completion of the cooking process. The physical properties of the cooked rice were based on the force (in Newtons) required to express the cooked rice through the plunger of the Texturometer.

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RFLP map and QTL analysis

RFLP map construction and QTL analysis method has been described previously (Kang et al., 1998b). According to the published rice RFLP map (Kang et al., 1998b), the MAPMAKER (Lander et al., 1987) program was used to establish a RFLP map at a minimum LOD value of 3.0 and recombination fraction expressed in centiMorgan (cM) was calculated by Kosambi mapping function (Kosambi, 1944). The analysis of QTL associated with each trait was performed using two different procedures: one-way analysis of variance (ANOVA) using PROC GLM procedure in Statistical Analysis System (SAS), (SAS Institution, 1988) and interval mapping in MAPMAKER/QTL (Lander & Bostein, 1989). In interval mapping, a LOD score of 2.0 was used as the threshold for detecting QTL.

RESULTS AND DISCUSSION

Transgressive segregation of traits

The frequency distribution of phenotypes for each trait in the F₁₁ MGRILs is shown in Fig. 1. Normal distributions were observed in all traits. Milyang 23 and Gihobyeo had almost identical values for cohesiveness of cooked rice. However, phenotypic values of some F₁₁ MGRILs were beyond the ranges of parental means (e.g., transgressive segregants) for all traits. The occurrence of such transgression could be associated with the interaction of complementary QTL alleles from two parents or overdominance of a gene. In cohesiveness of cooked rice, the value of the parents is similar but the segregation shows a very wide range. It possibly resulted from the interaction of complementary genes.

Correlation of traits

Correlations between traits were evaluated by regressing phenotypic values of one trait on those of another trait. The correlation coefficients among traits are presented in Table 1. For most of the correlations, the direction (+ or -) and degree of correlations were consistent with other observations (Yang, 1994).

QTLs for traits

For each trait, the association of QTLs with DNA markers was assessed by single-point analysis and interval mapping. Both analyses gave almost similar results in identifying QTLs for each trait. Only the results from the

Table 1. Correlation coefficients among physical traits of cooked rice.

	HAR	ADH	COH	ELA	GUM	CHE
Hardness (HAR)		0.380**	-0.102	0.501**	0.950**	0.932**
Adhesiveness (ADH)			0.059	0.514**	0.262**	0.347**
Cohesiveness (COH)				-0.222**	0.151	-0.266**
Elasticity (ELA)					0.427**	0.655**
Gumminess (GUM)						0.936**
Chewiness (CHE)						

** : Significant at 5% and 1% level, respectively

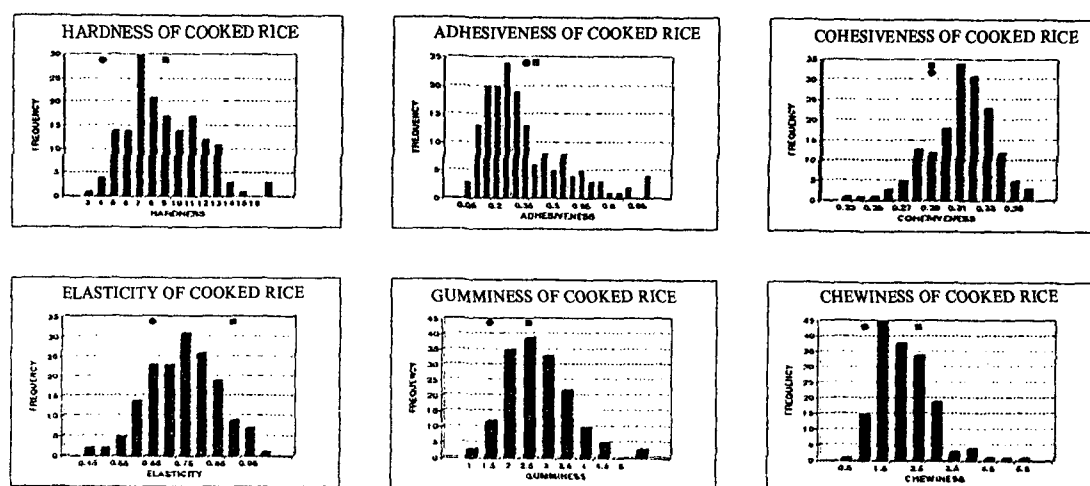


Fig. 1. Frequency distributions of physical traits in F₁₁ MGRILs.

■ : Milyang 23 ● : Gihobyeo

Table 2. Characteristics of QTLs affecting physical traits of cooked rice in F₁₁ MG RILs.

Trait	QTL	Chr. no.	Marker bordering the QTL	Peak LOD	%Var. †	Phenotypic effect ‡
Adhesiveness	ADH1	1	RZ14–RG109	4.71	14.6	–0.17
Gumminess	GUM1	4	BCD135–RG620	2.07	7.6	0.08
Chewiness	CHE1	4	BCD135–RG620	2.24	7.6	0.46

† : Percentage of variance explained by each QTL.

‡ : The signs; + (omitted) and –, preceding phenotypic effect, represent that the J alleles in homozygous state had higher phenotypic effects and that the M alleles in homozygous state had higher phenotypic effects, respectively (J, M alleles represent the alleles of the locus originated from Gihobyee and Milyang 23, respectively).

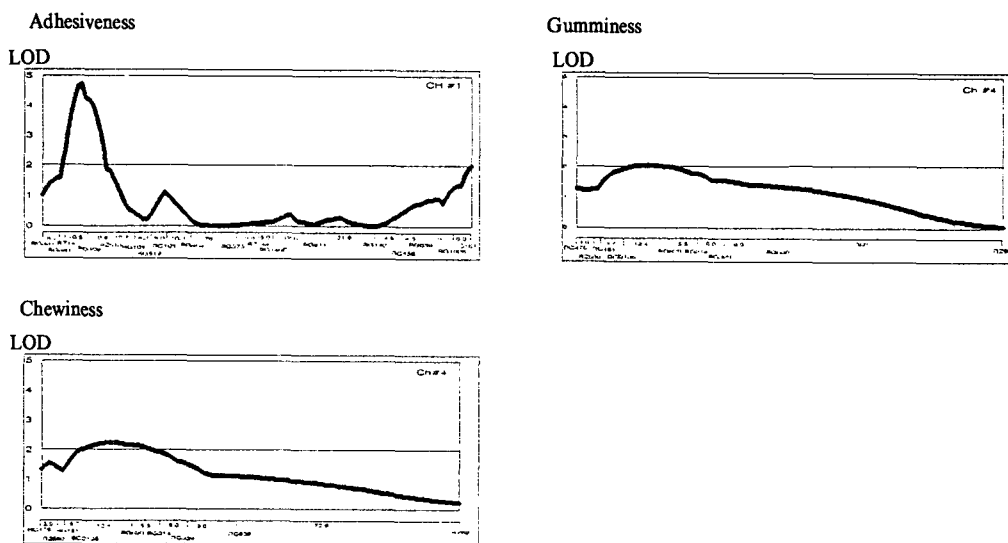


Fig. 2. QTL Likelihood plots indicating LOD scores and chromosome number for each quantitative trait related to physical traits of cooked rice.

interval mapping analysis are presented here. The QTLs for each trait are shown in Table 2 and their likelihood plots are shown in Fig. 2.

Adhesiveness of cooked rice

Only one QTL designated as ADH1 on chromosome 1 was significantly associated with adhesiveness of cooked rice. The individual M allele, originated from Milyang 23, increased adhesiveness by 0.17. This QTL explained 14.6% of the total phenotypic variation.

Gumminess of cooked rice

Only one QTL designated as GUM1 was detected on chromosome 1 for gumminess of cooked rice. J alleles, originated from Gihobyee, increased gumminess of cooked rice and this QTL accounted for 7.6% of the total phenotypic variation.

Chewiness of cooked rice

One QTL designated as CHE1 was identified on chromosome 4 for chewiness of cooked rice. J alleles increased this trait at CHE1 and this QTL explained 7.6% of the total phenotypic variation.

mosome 4 for chewiness of cooked rice. J alleles increased this trait at CHE1 and this QTL explained 7.6% of the total phenotypic variation.

Hardness, cohesiveness, and elasticity of cooked rice

No significant QTLs were detected for hardness, cohesiveness, and elasticity of cooked rice, respectively. More saturated frame map is thought to be required to detect QTLs for these traits. Hardness of cooked rice is highly correlated with gumminess and chewiness of cooked rice. However no significant QTL was detected. It is possible that the detected QTLs have a low LOD score. That is to say, hardness of cooked rice shows a slightly elevated LOD score on chromosome 4 but has no significance. These factors should be verified by further studies.

Correlated traits often have QTLs sharing similar genomic location

As demonstrated by Paterson et al. (1991), and Xiao et al. (1996), QTLs associated with some highly correlated traits were mapped at the same chromosomal locations.

A similar trend was observed in our study. For example, correlation of gumminess and chewiness is very high (0.936**) and the chromosomal location is almost the same. Trait correlations may result from either pleiotropic effects of single genes or tight linkages of several genes controlling the traits (Lin et al. 1996). Pleiotropy was suggested at the chromosome 4 region in our study.

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