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Inheritance of Apiculus Color, Awn, and Long Empty Glume in Korean Rice Collection

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ABSTRACT

Colored apiculus, awn, and long empty glume are indicators of wildness and are usually eliminated during rice domestication. Genetic analysis was conducted to clarify the inheritance patterns of awn, apiculus color, and long empty glume in Korean rice collection. Based on individual characterization of F_2 progenies derived from crosses between parents with colorless and purple apiculus, two (3 colored: 1 colorless) or three dominant genes (9 purple: 3 red: 4 colorless) are estimated as controlling this character by simultaneous complementary action. Different inheritance systems were detected between S237 and S245 of 'Shareibyeo' which belong to the weedy type. To determine the genes responsible in awning and long empty glume characters, the inheritance of landrace varieties of rice ('Naengdo' and 'Yuna') was investigated. In the crosses of awned landrace and awnless cultivar, three dominant genes are supposed to control the awning genetic system by 63 awned: 1 awnless individual. As for long empty glume, one recessive gene, *g-1* on the chromosome 4, was the one controlling the segregation ratio of 3 normal empty: 1 long empty glume. By analyzing the Korean rice collection, the inheritance systems of these wild characters may lead to a better understanding of rice domestication in the future.

Keywords : Rice, apiculus color, awn, long empty glume, inheritance

INTRODUCTION

Most rice varieties cultivated in Korea, except colored rice, are without awn, with yellowish white seed coat, and have green color in most parts of the plant. However, weedy rice such as 'Angmi' and 'Shareibyeo' and Korean landraces are usually characterized by the presence of awns. Many lines and varieties have awn, apiculus, glume, stigma, node, and leaf body in red, purple and black-purple colors which are characteristics of the wild type. Awn and color are not very useful characters in rice. Still, these characters are important in accelerating selection efficiency and early selection during seedling stage because various genetic information for the expression of these characters can be used as marker gene and as indicators for studying the origin of cultivated rice in Korea (Matsuo et al. 1997 ; Heu et al, 1986). Many researchers reported that the purple color in some parts of rice is caused by anthocyanin which generally contains

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apistasis among alleles '*C*', '*A*', and '*P*'(Matsuo et al. 1997). The gene *C* is involved in the formation of anthocyanin precursor, and the gene *A* is a catalyst which changes the metabolite for coloring into anthocyanin. The third gene, *P*, translocates anthocyanin to apiculus. There are nine, five, and three multiple alleles in the genes *C*, *A*, and *P*, respectively. Therefore, apiculus color is expressed by the various combinations of three multiple alleles. Currently, most cultivars developed by breeding do not have awns. However, this characteristic is frequently found in wild, landrace, and weedy rice. Appearance frequency and size of awns are influenced by environmental conditions and vary within the same plant and among varieties (Matsuo et al. 1997). Long empty glume is a characteristic which grows at about the same size as that of palea and outer glume. Length of empty glume in rice is about 1/3 - 1/5 of the total grain length. It was revealed that long empty glume is controlled by a gene of simple recessive allele, *g-1* (long sterile lemmas-1) on linkage group IV (Matsuo et al. 1997 ; Heu et al, 1986). This study investigated the inheritance patterns of characters such as awn, apiculus color, and long empty glume using artificial cross combinations between landraces and weedy rice in Korea.

MATERIALS AND METHODS

This experiment was carried out at the experiment station of the Kongju National University from 1999 to 2001. For the genetic analysis of the inheritance of apiculus color, two weedy accessions, S237 and S245(locally called "Shareibyeo" collected from Ganghwa Gun), were selected for artificial crosses. These two accessions are known to have characters such as awning and red or purple apiculus. Also, two landraces, 'Yuna' and 'Naengdo', were used for the genetic analysis of awning and empty glume. Both landraces have no awn and red apiculus. Maternal parents were 'Nonganbyeo', 'Daeyabyeo', and 'Seomjinbyeo' as bred varieties (Table 1). These bred varieties have no awn and no color on apiculus. The artificial crosses were conducted in 1999, and F_2 was developed in 2000. The plants for F_1, F_2 and parents were sown on April 20th, 2000 and transplanted to the paddy field on May 30th, 2000 with plant density of 15 × 30 cm. The observation of characters such as apiculus, awning, and the presence of empty glume was conducted with the segregating progenies of F_2 and followed the X^2-fitness test for the genetic analysis.

Table 1. Characteristics of varieties used as cross parents

Variety	Origin	Days to heading	Plant organs		
			Awn[1)]	Apiculus color	Empty glume length
Nonganbyeo	Korea	121	-	white	normal
Daeyabyeo	Korea	120	-	white	normal
Seomjinbyeo	Korea	124	-	white	normal
Yuna	Korea	119	-	red	long
Naengdo	Korea	124	+++	red	normal
S237[2)]	Korea	119	++	purple	normal
S245[3)]	Korea	120	++	purple	normal

1) - : awnless, +, ++, +++ : amount of awn

2) S237 → Shareibyeo 124-1-B, 3) S245 → Shareibyeo 132-1-B

Table 2. Cross combination and their segregation patterns for the inheritance of apiculus color in F_2 populations

Cross combination	F_1	F_2 segregation		Total	Ratio	Goodness of fit	
		Colored	Colorless			X^2	P
Daeyabyeo / S237	Red	169	215	384	27:37	0.523	0.5-0.25
Seomjinbyeo / S237	Red	158	187	345	27:37	1.843	0.25-0.1
Daeyabyeo / S245	Purple	245	90	335	3:1	0.622	0.5-0.25
		(178P, 67R)			(9P:3R:4W)[1]	(1.324)	(0.25-0.1)
Seomjinbyeo / S245	Purple	326	117	443	3:1	0.470	0.5-0.25
		(237P, 89R)			(9P:3R:4W)	(1.373)	(0.25-0.1)

1) P:Purple, R:Red, W:White(colorless)

RESULTS AND DISCUSSION

1. Inheritance of the gene for apiculus

Cross combination and their segregation patterns for the inheritance of apiculus color in F_2 populations are shown in Table 2. The F_1 plants from the crosses between two bred varieties and two weedy accessions had red or pink apiculus. Red color was expressed in F_1 of cross combination with S237, whereas, purple with S245. Based on the F_2 progenies from the cross combination of Daeyabyeo/S237 and Seomjinbyeo /S237, the segregation has a 27:37 ratio, indicating that three dominant genes may be involved by way of complementary action in controlling the color expression of apiculus. Different inheritances were shown in the cross combination of Daeyabyeo/S245 and Seomjinbyeo/S245. The ratio of F_2 progenies was 9 purple: 3 red: 4 colorless. This indicates that two dominant genes were involved in this character by way of complementary action. If both genes are present, the purple apiculus is expressed and, if one of the two genes is working, red color is turned on. The double recessive combination of these two genes is estimated as colorless in apiculus. Color of apiculus is known to be controlled by three different genes, *C, A,* and *P*. Various colors such as colorless, pale purple, reddish purple, deep purple, pale brown, brown, and deep brown were expressed with diverse segregation ratios of 3: 1, 13: 3, 9: 7, 15: 1, 27: 37, 39: 25, and 9 purple: 3 red: 4 colorless (Mori and Takahashi, 1981; Sahu and Sahu, 1989; Tsunoda and Takahashi, 1984; Matsuo et al. 1997 ; Heu et al, 1986; Jeong, 1993; Chung, 1994; Hue and Kim, 1975). The expression may also be controlled by the interaction of genes and linkage relationship among them (Dhulappanavar et al., 1973).

2. Inheritance of awning in landraces

Awning character is slightly influenced by environmental factors and genetic inheritance by different cultivars. So far, dominant genes are expected to express awning. Four different genes have been identified from different linkage groups in rice (Matsuo et al. 1997). Two bred varieties, Daeyabyeo and Seomjinbyeo, have not shown awning at all. Target

Table 3. Cross combination and their segregation patterns for the inheritance of awning in F_2 populations

Cross	F_1	F_2 Segregation		Total	Ratio	Goodness of fit	
		Awned	Awnless			X^2	P
Daeyabyeo / Naengdo	Awned	427	11	438	63:1	2.564	0.25-0.1
Seomjinbyeo / Naengdo	Awned	402	4	406	63:1	0.880	0.5-0.25

Table 4. Segregation mode of empty glume length in F_2 population

Cross	F_1	F_2 segregation		Total	Goodness of fit		
		Long	Normal		Ratio	X^2	P
Nonganbyeo / Yuna	Normal	92	276	368	1:3	0.000	1.00
Daeyabyeo / Yuna	Normal	92	276	368	1:3	0.000	1.00
Seomjinbyeo / Yuna	Normal	65	216	281	1:3	0.523	0.95-0.75

landrace, Naengdo, has relatively long awn (5 cm long) of yellowish white color. All the F_1 progenies have awns from two cross combinations (Daeyabyeo/ Naengdo and Seomjinbyeo/Naengdo). The segregation ratio of F_2 was 63:1(Table 3). Hence, three different dominant genes among four genes may be involved in controlling this character on the condition expressed by independent mode of gene action.

3. Inheritance of long empty glume

Long empty glume can have the same size as that of palea or outer glume. So far, three genes, *g-1* on chromosome 4, *G-2* and *Su-g-1*, have been identified for controlling this character (Matsuo et al. 1997). The gene, *g-1*, was estimated as located on Linkage group IV, and *G-2* is a kind of incomplete dominant gene. The three bred varieties, Nonganbyeo, Daeyabyeo, and Seomjinbyeo, are carrying normal empty glume, whereas, Yuna, a landrace, has long empty glume. All the F_1 progenies have normal glumes. The segregation ratio for F_2 progenies was 3 normal: 1 long(Table 4), indicating that *g-1* on Linkage group IV is involved in expressing long empty glume in Yuna.

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