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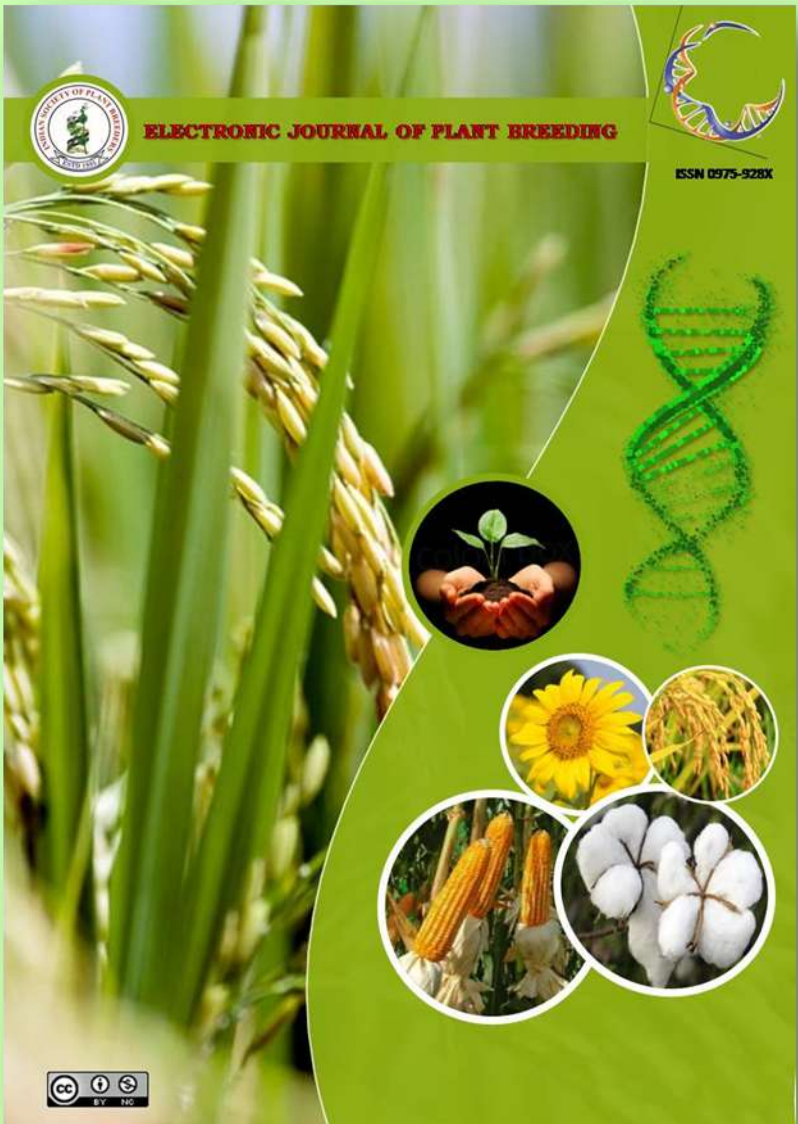

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Research Article

Genetics of awnness in the F_2 population of basmati crosses of rice

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Abstract
The present investigation was conducted to study the gene action of awn character in rice. Hybridization was done between four female parents' *viz*., ASD 16, ADT 37, MDU 6 and TKM 13 with one male parent *viz*., Improved Pusa Basmati 1. All the female parents are awnless, but the male parent is awned. F_1 of all the crosses except ADT 37 × Improved Pusa Basmati 1 exhibited awns. This result indicated that awn character was controlled by dominant gene in those three crosses. In the F_1 of the ADT 37 × Improved Pusa Basmati 1, awn expression was suppressed which indicated that suppressor or inhibitor gene may be present in ADT 37. All the F_1s were selfed and F_2 generation was obtained. F_2 population of all the four crosses *viz*., ASD 16 × Improved Pusa Basmati 1, ADT 37 × Improved Pusa Basmati 1, MDU 6 × Improved Pusa Basmati 1 and TKM 13 × Improved Pusa Basmati 1 were studied to know the inheritance pattern of awnness. Based on chi-square test it was found that inheritance pattern of awnness fit in the ratio of 9:7 (awned: awnless) in the F_2 generation of three crosses *viz*., ASD 16 × Improved Pusa Basmati 1, MDU 6 × Improved Pusa Basmati 1 and TKM 13 × Improved Pusa Basmati 1 and the awn character appeared to be governed by complementary gene action. In the cross, ADT 37 × Improved Pusa Basmati 1 showed a ratio of 7:9 (awned: awnless). The reason for the differences in gene action may be attributed to the presence of two different sets of genes in female parents of the crosses.

Keywords
Awn, complementary gene action, dominant gene, rice.

Introduction

Awn is a hair like structure or bristle-like appendage extending from the primordial tip of the lemma. Awns in cultivated rice have been partially or completely eliminated by artificial selection for the convenience of agricultural practices. Presence of awn protects the grains against animal predation and facilitates seed dispersal. Long awns in closed panicles significantly decrease the outcrossing rate. Long and burry awns of wild rice are vital for propagation. Process of awn development is controlled by multiple genes. Sahu *et al*. (2018) reported that presence of awns influences the physical and morphological characteristics of the grains. In contrast to barley awns, which are capable of photosynthesis during grain-filling, rice awns lack chlorenchyma and hence cannot contribute to photosynthesis (Yoshika *et al*., 2017). Luo *et al*. (2013) reported that round rice awn contains only one vascular bundle and may not contribute to photosynthesis. In tetraploid wheat the total surface area of awn is more than that of leaf blade and more than half of the total number of stomata of wheat spikelets is present in the awn (Yoshioka *et al*., 2017). The genus *Oryza* has two independently domesticated species: cultivated Asian rice (*Oryza sativa*) and cultivated African rice (*Oryza glaberrima*). Most varieties of both species are awnless whereas their ancestral species, *O. rufipogon* and *O. barthii*, possess long awns. Most of the basmati varieties are awned. In this study the basmati variety, Improved Pusa Basmati 1 which has awns was used as male parent and four awnless varieties were used as female parents. Hybridization was carried out and F_1 and F_2 generations were raised to know the inheritance pattern of awnness.

Material and Methods

Hybridization was done between four female parents *viz*., ASD 16, ADT 37, MDU 6 and TKM 13 with one male parent *viz*., Improved Pusa Basmati 1 at Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai during *Kharif*, 2017. Selected lines, ASD 16 and ADT 37 are high yielding and belong to short bold grain type. TKM 13 and MDU 6 are high yielding varieties with medium and long slender grain types respectively. All the female parents are awnless. The male parent, Improved Pusa Basmati 1 is an extra-long slender aromatic rice variety with high linear elongation ratio and long awned variety. Emasculation and crossing was done as per Ramaiah method. Panicles on the 3rd or 4th day of its blooming were selected; top and lower spikelets were removed leaving only the middle spikelets which were covered with a wet cloth and hot air was blown from mouth in order to facilitate opening of spikelets. After 2-3 minutes, the wet cloth was removed and spikelets were found to be open. Then, all the six anthers were removed. Pollen of Improved Pusa Basmati 1 was collected and dusted on female parents. F_1s of all the four crosses *viz.*, ASD 16 × Improved Pusa Basmati 1, ADT 37 × Improved Pusa Basmati 1, MDU 6 × Improved Pusa Basmati 1 and TKM 13 × Improved Pusa Basmati 1 were evaluated by Randomized Block Design with three replication during *Rabi*, 2018. All the F_1s were selfed to raise the F_2 generation during *Kharif*, 2018.

Segregation of the F_2 population for the awned trait was tested for goodness of fit using chi-square test. The observation was classified into two groups. The expected ratio was calculated by using the following formula for more than 1 degree of freedom.

$$\chi^2 = \frac{\Sigma (O - E)^2}{E}$$

Where, 'O' is the Observed frequency and 'E' is the Expected frequency.

Results and Discussion

For the awned trait, chi-square tests for the deviation from the expected genetic ratios of the segregating generation of four crosses were worked out and results presented in Table 2. F_1 of three crosses *viz*., ASD 16 × Improved Pusa Basmati 1, MDU 6 × Improved Pusa Basmati 1 and TKM 13 × Improved Pusa Basmati 1exhibited awns. This result indicated that awn character was controlled by dominant gene in these three crosses. The same results were reported by Bharadwaj *et al*. (2007) in Pusa Basmati 1 cross, Tomar *et al*. (2000) and Deepak *et al*. (2016) for the awn character. However, in ADT 37 × Improved Pusa Basmati 1 cross, F_1 was awnless. Even though the male parent in this cross was Improved Pusa Basmati 1 which is fully awned, expression of awn was suppressed in F_1 and this is the first report of its kind. All the F_1 plants of four cross combinations were forwarded to F_2 generation (Fig. 1).

In F_2 population of ASD 16 × Improved Pusa Basmati 1, 196 segregants were obtained. Among the 196 segregants, 123 segregants were awned and remaining were awnless. In ADT 37 × Improved Pusa Basmati 1, totally 219 plants were obtained; of which 94 were awned and 125 were awnless. In MDU 6 × Improved Pusa Basmati 1, out of 212 segregants, 124 segregants were awned and 88 segregants were awnless. In TKM 13 × Improved Pusa Basmati 1, out of 223 segregants, 120 were awned and 103 were awnless.

The chi-square test for the expected ratio of 9:7 (awned: awnless) was significant in the F_2 population of the crosses *viz*., ASD 16 × Improved Pusa Basmati 1, MDU 6 × Improved Pusa Basmati 1 and TKM 13 × Improved Pusa Basmati 1. The segregation of awn trait appeared to be governed by digenic complementary interaction and the ratio of 9:7 (awned: awnless) was obtained. This may be due to the presence of similar set of genes in ASD 16, MDU 6 and TKM 13 which may be complementary to the Improved Pusa Basmati 1 leading to 9:7 ratio in F_2 generation. Shobha Rani *et al.* (2005) reported that expression of awned trait was governed by complementary genes with a dihybrid segregation ratio of 9:7 (awned: awnless) in F2 generation. For awned trait, monogenic – 3:1 (Ramiah, 1993), digenic – 9:7 and 15:1 (Mitra and Ganguli, 1992) and trigenic – 63:1 (Sethi, 1997) gene action were also reported. Takano *et al*. (2001) and Kurakazu *et al*. (2002) reported the dominant nature of awning over awnlessness.

The F_2 generation of ADT 37 × Improved Pusa Basmati 1 showed a ratio of 7:9 (awned: awnless) which may be due to the presence of suppressor or inhibitor gene in the female parent, ADT 37. Toriba and Hirano (2014) identified and mapped more than 10 loci for awn suppression using F_2 population involving awned wild rice species and awnless japonica strains. Though the four crosses had the same male parent (Improved Pusa Basmati 1), two different types of gene action were noticed. The reason for the differences in gene action may be attributed to the presence of two different sets of genes in female parents of the crosses.

The earlier reports on awning by various workers are contradictory. Nadaf *et al.* (1995) reported awning behaviour as recessive trait. Sahu *et al*. (2018) reported that segregation ratio of awn closely fitted with 13 long awned : 3 awnless, indicating that two independent genes (designated as *An-a* and *An-b*) governed long and fully awned character in the F_2 involving accessions of wild species, *O. officinalis.* Awnedness was found to be governed by three genes with duplicate gene action (63:1) (Deepak *et al*., 2016).

Ntakirutimana and Xie (2019) found observed *an1* allele in *O. sativa* inhibited awn differentiation. This indicated that the absence of awns in cultivated rice may be caused by the mutation in *AN1* during awn elongation. In wheat, awn development was controlled by three dominant inhibitors *viz.*, *Hooded* (*Hd*), *Tipped1* (*B1*) and *Tipped2 (B2)*. Full-awned phenotypes carry three homozygous recessive alleles *viz.*, *hd*, *b1* and *b2* and awnless phenotypes possess two dominant alleles and one recessive allele (Yoshika *et al*., 2017). Ben *et al*. (2016) found that dominant alleles of *Awn3-1* and *Awn4-2* confer the awned trait which confirmed that the presence of two dominant genes with additive effects is responsible for awned trait.

Awn is an important trait in rice evolution and production. Rice awnness is a complicated trait regulated by multiple genes, and their expression is affected by environment. Study of gene action provides clues on breeding procedures to be followed for genetic improvement of specific characters. In this study, it was observed that the awned trait of rice was governed by complementary gene action.

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Table 1. Details of the parents

Parents	Parentage	Special features
ASD 16	ADT 31/CO 39	Short bold, semi dwarf erect, high yielding variety and resistant to blast.
ADT 37	BG 280-12/ PTB 33	Short bold, semi dwarf, semi erect, resistant to blast, brown spot, brown plant hopper and moderately resistant to bacterial leaf blight and rice tungro virus.
MDU 6	MDU5/ACM 96136	Long slender, moderately resistant to leaf folder, stem borer and green leafhopper.
TKM 13	WGL32100/Swarna	Medium slender fine grain, moderately resistant to leaf folder and stem borer.
Improved Pusa Basmati 1	Pusa150/Karnal local	Long slender grain type with high linear elongation ratio and suitable for export. Developed through marker assisted selection for Bacterial Leaf Blight resistance with *xa*13 (recessive) and *Xa* 21 (dominant) genes.

Table 2. Segregation pattern of awn character in F_2 population

Cross	No of Plants tested	Observed values		Expected Ratio	Chi –square values	P value
		Awned	Awnless			
ASD16/Improved Pusa Basmati 1	196	123	73	9:7	3.37	3.84
ADT37/Improved Pusa Basmati 1	219	94	125	7:9	0.06	
MDU6/Improved Pusa Basmati 1	212	124	88	9:7	0.43	
TKM13/Improved Pusa Basmati 1	223	120	103	9:7	0.053	

Fig. 1. Awnness in F_1 hybrid of Basmati crosses

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