Inheritance of Anthocyanin Pigmentation in Rice

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Abstract

Present study investigated genetic basis of anthocyanin pigmentation of four qualitative characters:y leaf sheath colour, leaf-blade colour, hull colour and pericarp colour. The experimental material consisted of 12 segregating F_2 populations for different characters. The segregating ratio revealed that purple leaf-sheath colour was governed by single dominant gene in the varieties Ram-laxaman and Dodana. Purlple leaf-blade in strain R714-2-9-3-2-2-2 was determined by inhibitory gene action determining green leaf blade. Purple hull colour was controlled trigenically involving two basic genes either of which complementing with one pigment localizing gene in the accession of wild species *O. officinalis* and an indigenous variety Mehar, whereas, in another indigenous variety Mainagali this trait was conferred by two independent genes, one dominant and other one recessive. A single recessive gene was responsible for light brown furrow on straw hull in the strain R714-2-9-3-2-2-2. Two independent recessive genes were responsible for expression of red hull colour (non-anthocynanin pigmentation) in the traditional varieties Kadam Phool and Suapankhi. But in in the varieties Karigilas, Roti and Mehar it was governed by a single dominant gene., In the variety Kaudidhul it was governed trigenically involving two dominant genes either of which complementing with another dominant gene. In an accession of *O. officinalis* this trait was governed trigenically involving two dominant complemetary genes and another independent recessive gene.

Rice (*Oryza sativa* L.) is one of the most important food crop for over 75% of Asian population and 2.4 billion of world population. This population will increase to over 4.6 billion by 2050 which demands greater crop production (Kush, 1996; Keshavarzi, 1999; Honarnejad *et al*., 2000).

The occurrence as well as distribution of anthocyanin pigmentation in different part of the rice plant are very variable and are a striking feature of the crop. This feature has been the subject of interest for several earlier studies. Such morphological variants with distinct phenotypic expression and simple inheritance pattern can be used to establish linkages and for indirect selection if found associated with useful traits (Reddy *et al.* 2008). Present study investigated genetic basis of anthocyanin pigmentation of four qualitative characters: leaf sheath colour, leaf-blade colour, hull colour and pericarp colour and its utilization in plant breeding.

Material and Methods

The experimental material consisted of twelve segregating F_2 populations using seventeen parents (supplementary Table 1) representing two crosses for leaf-sheath colour, one cross for leaf-blade colour, three crosses for anthocyanin pigmentation on hull colour, three crosses for non-anthocynanin pigmentation on hull colour and five crosses for pericarp colour. The observations on leaf-sheath colour (green or purple), leaf-blade colour (purple or green), hull colour (straw or purple/straw or red) and pericarp colour (white or red) recorded at appropriate stage of crop. The observations on the parents and F_1's were recorded on row basis, while F_2 population on individual plant basis. The data were analyzed independently for each trait to determine the fitness with diverse segregation ratios to determine mode of inheritance by χ^2 (Chi-square) test as suggested by Fisher (1936).

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Results and Discussion

The list of crosses and F_2 segregation pattern for different characters are given in Table 1.

1. Leaf-sheath colour: The F_1 plant derived from the cross R710-4-37-1-1-1-1 × Ram-laxaman and R710-4-37-1-1-1-1 × Dodana had purple leaf-sheath indicating this trait to be dominant over green leaf-sheath. The F_2 population segregated in 3:1 ratio revealing the presence of a single dominant gene in both the varieties Ram-laxaman and Dodana. Monogenic inheritance of leaf-sheath colour was also reported by earlier workers (Sathyanarayanaiah and Reddy, 1973 and Majumdaar, 1985). Misro (1981) designated this gene as Psh. However contrasting reports with monogenic, digenic (Panda & Mohapatra, 1997), trigenic (Pavithran *et al*., 1995 and Shukla, 1999) and tetragenic (Singh *et al*, 1990) control for this character have also been reported earlier in different crosses. This varied genetics may be due to multiple set of gene conferring the character in different source material used in these studies.

2. Leaf-blade Colour: Mode of inheritance of anthocyanin pigmentation on leaf-blade was studied in the cross R714-2-9-3-2-2-2 x Dokara-dokari. All the plants in F_1 generation of the cross were with green leaf-blade, indicating recessive nature of the trait. The F_2 population however segregated in the ratio of 3 purple : 13 green leaf-blade, which suggested inhibitory gene control with single major gene for green leaf. Earlier this gene has been designated as *Pl* (Kinoshita and Maekawa, 1985). Effect of *Pl* gene was inhibited by the inhibitory gene *I-Pl* when presented along with it and resulted in green colour (Nagao *et al.* 1962). Other workers (Qian *et al*., 1995; Tomar *et al*., 2000) also reported similar gene action for expression of purple pigmentation on leaf-blade.

3. *Hull colour:* Genetics of purple hull character was studied in three crosses R710-4-37-1-1-1-1 / *O. officinalis*, R710-4-37-1-1-1-1 / Mehar and Mahamaya / Mainagali. The F_1 plants of first two crosses were observed to have purple hull, indicating dominant nature of trait. The F_2 population of both crosses segregated into ratio of 45 purple hull : 19 straw hull which indicated that the trait was controlled by three genes, two basic genes either of which complementing with the third pigment localizing gene in the accession *O. officinalis* and variety Mehar. But the proportion of purple hull and straw hull plants in the F_2 population of the cross Mahamaya / Mainagali closely fitted to the ratio of 13 purple : 3 straw hull. This result revealed that anthocyanin pigmentation on lemma palea in the variety Mainagali was due to two independent genes, one dominant and other one recessive (Pr-1, pr-2) Earlier Nagao and Takahasi (1963) designated these genes as A, C and *Pr*, respectively. Nadaf *et al.* (1995) studied inheritance of purplish-black hull and noted the six gene ratio for presence vs. absence of the trait with the involvement of one basic gene for the trait expression and five inhibitory duplicate genes, this character was monogenic dominant in the absence of the inhibitory genes.

The inheritance study of light brown furrows on straw hull was studied in the cross R714-2-9-3-2-2-2/ Safri deshi. The phenotype of F_1 of this cross suggested recessive nature of the trait. Proportion of plants with light brown furrows on straw hull and straw hull in the F_2 population agreed with the ratio of single recessive gene (designated as *bf1*) for this trait in the strain R714-2-9-3-2-2-2. Genetics of red hull colour (non-anthocyanin pigmentation) was studied in two crosses representing in Table 1. The F_1s in both crosses were found to have straw hull, indicating recessive nature of the trait (red hull). The F_2 population of both crosses segregated into ratio of 7:9 red hull to straw hull, indicating two independent recessive genes responsible for expression of red hull colour in the varieties Kadam Phool and Suapankhi (*hr1* and *hr2*).

4. Pericarp colour: The mode of inheritance of red pericarp was studied in five crosses R710-4-37-1-1-1-1 / Karigilas, R304-34 / Roti, R710-4-37-1-1-1-1 / Mehar, R714-3-103-1-3-2/ Kaudidhul and R710-4-37-1-1-1-1 / *O. officinalis.* The F_1s of first three crosses were found to have red pericarp. Proportion of plants with red and white pericarp in F_2 population closely fitted in the ratio of 3:1, indicating that red colour of pericarp in the varieties Karigilas, Roti and Mehar was governed by single dominant gene. rlier this gene has been designated as *Rd* (Nagao and Takahasi, 1963). Sastry (1978) and Sahu (1991) also reported similar gene action for the red pericarp. In the other cross R714-3-103-1-3-2 / Kaudidhul the F_1 plants were found to have red pericarp, indicating dominant nature of the trait. The F_2 population of this cross segregated into ratio of 45:19 (red to white pericarp), suggesting that expression of red pericarp colour in the

Table 1: Segregation for four qualitative pigmentation characters in F_2 population in rice

S. No.	Plant characters / crosses	$P_1 \times P_2$	F_1 Phenotypes	F_2 observations		χ^2 ratio	χ^2_{Value}	P value
1.	**Leaf Sheath colour**			**Purple**	**Green**			
	R710-4-37-1-1-1-1-1 x Ram-laxaman	Green × purple	Purple	470	161	3:1	0.089	0.80-0.70
	R710-4-37-1-1-1-1-1 x Dodana	Green × purple	Purple	504	198	3:1	3.19	0.10-0.05
2.	**Leaf-blade colour**			**Purple**	**Green**			
	R714-2-9-3-2-2-2-2 x Dokara-dokari	Purple × green	Green	137	614	3:13	0.127	0.80-0.70
3.	**Hull colour**							
				Purple	**Straw**			
	R710-4-37-1-1-1-1-1 x *O. officinalis*	Straw × purple	Purple	245	97	45:19	0.287	0.70-0.50
	R710-4-37-1-1-1-1-1 x Mehar	Straw × purple	Purple	564	240	45:19	0.010	0.95-0.90
	Mahamaya x Mainagali	Straw × purple	Purple	635	151	13:3	0.109	0.80-0.70
				Light brown furrow	**straw hull**			
	R714-2-9-3-2-2-2-2 x Safri Deshi	Light brown furrow × straw hull	straw hull	208	575	1:3	1.021	0.50-0.30
				Red	**Straw**			
	R710-4-37-1-1-1-1-1 x Kadam Phool	Straw × red	Straw	245	361	7:9	2.715	0.10-0.50
	IR-64 x Suapankhi	Straw × red	Straw	294	373	7:9	0.028	0.90-0.80
4.	**Pericarp colour**			**Red**	**White**			
	R710-4-37-1-1-1-1-1 x Karigilas	White × red	Red	583	222	3:1	2.85	0.10-0.50
	R304-34 x Roti	White × red	Red	631	190	3:1	1.513	0.30-0.20
	R710-4-37-1-1-1-1-1 x Mehar	White × red	Red	603	214	3:1	0.620	0.50-0.30
	R714-3-103-1-3-2 x Kaudidhul	White × red	Red	541	237	45:19	0.338	0.70-0.05
	R710-4-37-1-1-1-1-1 x *O. officinalis*	White × red	Red	231	110	43:21	0.047	0.90-0.80

variety Kaudidhul was imparted by three genes involving two major genes either of them complementing with another dominant gene, to be responsible for the trait. Pavithran *et al.* (1995) reported similar gene interaction for expression of red pericarp colour.

The F_1 plants of the fifth cross R710-4-37-1-1-1-1 / *O. officinalis* were observed to have red pericarp, indicating dominant nature of red pericarp trait. The proportion of plants with red and white pericarp in the F_2 population fitted well with the ratio of 43:21, indicating that red pericarp in the accession of wild species *O. officinalis* was governed by three genes involving two dominant complementary genes and another independent recessive gene. Tomar *et al.* (2000) reported that three dominant complementary genes controlled the red colour.

Pigmentation of various parts of the rice plant involves a complicated system of the gene interaction, ranging from epistasis to pleiotropic effects (Chang, 1960). Our results also indicated involvement of one to three genes with various interactions determining pigmentation of leaf sheath, leaf blade, hull and pericarp. Genetic diversity was also evident with the choice of the parental lines. However, no allelism studies were conducted to check if the reported genes are same as noticed in the present work.

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Supplementary Table 1 : Details of genotypes and their characteristics undertaken in the present study

S. No.	Name of the genotypes/ Acc. Nos.	Place of origin	Place of collection Distt. / Block	Traits studied
1	*Ram-laxaman (R:358)	India	Raigarh/ Gharghoda	pigmentation on leaf-sheath
2	*Dodana (D:612)	India	Bilaspur/Bilaspur	-- do --
3	***O. officinalis* (Asian wild species) [Allotetraploid, genome-BBCC]	India	Coimbatore (Tamil Nadu)	red pericarp and purple hull
4.	*Kadam Phool (K:2382)	India	Bastar/Bijapur	Red hull
5.	*Karigilas (K:760)	India	Bastar/Charama	Red pericarp
6.	*Mehar (DPM 3/1/10)	India	Bastar/Bastanar	Purple hull, red pericarp
7.	*Roti (R:299)	India	Bastar/Bastar	Red pericarp
8.	*Suapankhi (S:1634)	India	Seoni/Seoni	red hull
9.	*Mainagali (M:926)	India	Raigarh/ Dharamjaigarh	purple hull
10.	*Kaudidhul (K:1849)	India	Raigarh/ Dharamjaigarh	Red pericarp
11.	R714-2-9-3-2-2-2 (purple, dwarf)	India	IGAU, Raipur	Purple pigmentation on leaf-blade, light brown furrows on straw hull
12.	*Dokara-dokari (D:520)	India	Raipur/Fingeshwar	Normal parent
13.	*Safri Deshi (S:99) (tall)	India	Bilaspur/Masturi	--do--
14.	R 714-3-103-1-3-2 (semi dwarf)	India	IGAU, Raipur	--do--
15.	Mahamaya (semi dwarf)	India	IGAU, Raipur	--do--
16.	IR 64 (semi dwarf)	Philippines	IGAU, Raipur	--do--
17.	R 710-4-37-1-1-1-1 (semi dwarf)	India	IGAU, Raipur	--do--

* - Indigenous varieties ** - Wild species