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Dr. Anita Chandrabhan Solanke
Assistant professor,
Dept of Genetics & plant breeding, college of Agriculture, NAU, Waghai, Gujarat, India

Dr. PB Patel
Associate professor, Main Rice Research station, NAU, Navsari, Gujarat, India

Pooja K Patel
Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Dr. Anita Chandrabhan Solanke
Assistant professor,
Dept of Genetics & plant breeding, college of Agriculture, NAU, Waghai, Gujarat, India

Inheritance of aroma in aromatic rice (*Oryza sativa* L.) genotypes

Dr. Anita Chandrabhan Solanke, Dr. PB Patel and Pooja K Patel

Abstract
The inheritance pattern of aroma in aromatic rice (*Oryza sativa* L.) was carried out in the four crosses among seven diversified aromatic and non-aromatic elite lines of. In four crosses viz., GR-104 × IET-26215, IET-24617 × NWGR-9081, IET-26214 × GAR-1 and IET-26215 × GNR-2, the parents viz., GR-104, IET-26215, NWGR-9081, IET-26214 and GAR-1 were aromatic, while IET-24617 and GNR-2 were non-aromatic. All the F1 plants of the four crosses were non-aromatic indicating that the gene controlling aroma in the donor parents was recessive. F_2 generations of all crosses segregated into different aromatic and non-aromatic plants. The segregation ratio of non-aromatic to aromatic plants was 3:1 in F_2 plants confirming the monogenic inheritance of aroma. These showed that there would be a high probability of success in selecting for aroma using pedigree breeding in early segregating generations of F_2.

Keywords: Aroma, aromatic rice, *Oryza sativa* L., genotypes

Introduction
Aromatic rice is also named as fine rice, scented rice or fragrance rice. Aromatic rices constitute a small but an important sub-group of rice. These are rated best in quality and fetch much higher price than high quality non-aromatic rice in international market. India produces some of the best quality rice in the world.

The major concern in rice grain quality for aromatic rice is their unique aroma or flavors. Several chemical constituents are related to the aroma or fragrance of cooked rice (Cordeiro *et al*., 2002). Yajima *et al*. (1979) [2, 7] have detected a total of 114 different volatile compounds in rice fragrance. Whereas, Nijssen *et al*. (1996) [4] reported more than 200 volatile compounds in cooked rice. Among them, a "popcorn" like flavour compound, 2-acetyl-1-pyrroline (2AP) stands out as the main aroma compound in basmati-style rice varieties.

Low-yielding aromatic rices have been the major casualty of green revolution where the main emphasis was on yield rather than quality. A large number of aromatic rices have already been lost and many are at the verge of extinction. It is truer for the small and medium-grained aromatic rices which are mostly cultivated for home consumption than the long-grained basmati types which form the bulk of rice export. Some of the small and medium-grained aromatic rices possess excellent aroma and other quality traits like kernel elongation after cooking, taste etc. These could be excellent sources for improving quality in high yielding varieties. Therefore, there is a strong need to conserve whatever aromatic rice germplasms are left. Keeping in view the above mentioned facts, present investigation was formulated to study inheritance of aroma in aromatic rice genotypes.

From many investigations in the past, aroma in rice is known to be genetically controlled and its genetic behaviour is summarized as follows: Sood & Siddiq reported, aroma is monogenic recessive to non-aromatic and Kadam & Patankar reported it to be monogenic dominant. Patil *et al* (2012) [5] reported the F_1 plants of the four crosses were non-aromatic indicating that the gene controlling aroma in the parents was recessive. The segregation ratio of non-aromatic to aromatic plants was 3:1 in F_2 plants confirming the monogenic inheritance of aroma. The present investigation was formulated to the nature of inheritance of aroma that may be useful in breeding and development of aromatic rice varieties.

Materials and Methods
The material comprising of seven diversified aromatic and non-aromatic elite lines of rice (GR-104, IET-26215, IET-24617, NWGR-9081, IET-26214, GAR-1 and GNR-2). The four crosses (GR-104 x IET-26215, IET-24617 x NWGR-9081, IET-26214 x GAR-1 and IET-26215

x GNR-2) obtained by crossing of seven diverse parents during summer 2017 at Main Rice Research Centre, Navsari Agricultural University, Navsari. Backcrossing was done in *kharif*-2017 with its respective parents. Selfing of F_1s was done in the same season (kharif-2017) to get F_2s. The evaluation trial was conducted in *kharif*-2018 at Main Rice Research Centre, Navsari Agricultural University, Navsari. The experimental material consisting of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of each of the four crosses were sown during *kharif*-2018 in compact family block design with three replications. Each replication was divided in four compact blocks. Each four crosses consisting of six generations were randomly allotted to each plot within a block. Each plot consisted of one row (10 plants) of parents and F_1s, two rows of the backcrosses and four rows of the F_2 generations of each cross.

Aroma in rice is a sensory character. It is essential for rice breeders to develop reliable, fast and cost-effective evaluation for rice aroma in breeding programs. As sensory quality has always been an important consideration in rice improvement. Aroma was estimated by procedure given by Azam *et al* (Indian Institute of Rice Research) by sensory evaluation only. Procedure for aroma estimation is as follow.

Procedure

1. Add 15 ml of water to 5 g of rice sample in test tube and soak for 10 minutes.
2. Cook the sample in water bath for 15 minutes.
3. Transfer the cooked rice into a petri dish.
4. After bringing the sample to room temperature, keep it in the refrigerator for 20 minutes.
5. Open the petri plates and smell the content. The samples possessing the scent, produce recognizable aroma. Score the samples as following;

SS= Strongly Scented; MS=mild scented; NS=Non scented

Results and Discussion

In four crosses viz., GR-104 × IET-26215, IET-24617 × NWGR-9081, IET-26214 × GAR-1 and IET-26215 × GNR-2, the parent's *viz*., GR-104, IET-26215, NWGR-9081, IET-26214 and GAR-1 were aromatic, while IET-24617 and GNR-2 were non-aromatic. The data obtained on the presence and absence of aroma of F_2 generations in each of four crosses is presented in Table 2. In the cross GR-104 × IET-26215, 200 out of 263 were non aromatic and 63 were aromatic. The cross IET-24617 × NWGR-9081 having 230 non aromatic out of 315 and 85 were aromatic.246 plants out of 326 were non aromatic and 80 were aromatic in cross IET-26214 × GAR-1. Similarly, 160 out of 210 were non aromatic and 50 were aromatic in cross IET-26215 × GNR-2.

In all the aromatic x non-aromatic crosses, all F_1 hybrids were non-aromatic indicating recessive nature of the character. The F_2 population segregated into the ratio of 3 non aromatic: 1aromatic offspring indicating a monogenic Mendelian ratio. The calculated chi-square values were not differing from the table values fitting a monogenic Mendelian ratio at a very high level. The results showed that the aroma was controlled by a nuclear recessive gene which agreed with those reported by Berner and Hoff Vivekanandan and Giridharan and Lorieux *et al*. The calculated value of *chi-square* of all four crosses is less than the table value (3.84) the results are non-significant indicating the deviation to be due to chance only. Therefore, the null hypothesis is accepted, and it is concluded that observed data are in agreement with the 3:1 expected ratio.

Table 1: Number of plants expressing aromatic and non-aromatic grain type according to sensory evaluation

Parents	No. of plants tested	No. of plants	
		Aromatic plants	Non-aromatic plants
GR-104	10	10	0
IET-26215	10	10	0
IET-24617	10	0	10
IET-26214	10	10	0
NWGR-9081	10	10	0
GAR-1	10	10	0
GNR-2	10	0	10
F_1 hybrids			
GR-104 × IET-26215	10	0	10
IET-24617 × NWGR-9081	10	0	10
IET-26214 × GAR-1	10	0	10
IET-26215 × GNR-2	10	0	10

Table 2: Inheritance pattern of aroma in all four F2 populations of rice

Crosses	No. Of plants tested	No. of plants				Ratio	Chi-square	*p* value (5%)
		Non-aromatic plants		Aromatic plants				
		Observed	Expected	Observed	Expected			
GR-104 × IET-26215	263	200	197.25	63	65.75	3:1	0.153	3.84
IET-24617 × NWGR-9081	315	230	236.25	85	78.25	3:1	0.661	3.84
IET-26214 × GAR-1	326	246	244.5	80	81.5	3:1	0.037	3.84
IET-26215 × GNR-2	210	160	157.5	50	52.5	3:1	0.159	3.84

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