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Genetic Control of Seed Dormancy in Basmati Rice

M. Kumar[1], D. Rajpurohit[1], P.O. Basha[1], A. Bhalla, G.S. Randhawa and H.S. Dhaliwal*
[1]Contributed equally to the paper, Department of Biotechnology,
Indian Institute of Technology, Roorkee-247 667, Uttarakhand

Seed dormancy in rice (*Oryza sativa* L.) is important to avoid losses due to germination rains during harvesting. Four *indica* type rice cultivars (Basmati 370, Type 3, P2 and PR106), as well as F_3 seeds obtained from a cross of Basmati Type3 with seed dormancy and non-dormant and non-basmati P2, were used to investigate the genetic control of seed dormancy at different temperatures and days after harvesting (DAH). The seeds of non-basmati rice cultivars germinated immediately after harvesting, while seeds of the traditional Basmati cultivars, Basmati 370 and Type 3 remained dormant. Seed dormancy in Basmati cultivars was hull-imposed, and could not be overcome by the usual heat treatment of seeds at 45^{0}C for 72. Both the Basmati cultivars continued to have a dormant seeds up to 50 DAH. The F_3 seeds from 160 F_2 plants from a cross of Basmati Type 3 with non-Basmati P2 were investigated for genetics of seed dormancy. The F_3 seeds of F_2 plants segregated for dormant: non-dormant seeds at 50 DAH at room temperature in 13:3 ratio, suggesting that two genes one dominant and another recessive controlled seed dormancy in Basmati cultivars. For heat-treated seeds at 50 DAH, a 1:3 ratio of dormant: non-dormant F_2 plant/F_3 seeds was observed and this response ratio was maintained up to 100 DAH without heat treatment, indicating the long term effectiveness of the recessive gene controlling the seed dormancy. The dormancy conditioned by the dominant gene was overcome by heat treatment whereas the part controlled by the recessive gene continued to be effective.

Key words: *Oryza sativa,* basmati rice, germination, heat treatment, seed dormancy

Seed dormancy is defined as the temporary inability of a viable seed to germinate upto a specific period of time under favourable conditions. This is an adaptive trait that promotes the survival of many plants in nature (Simpson, 1990). There are two ways by which seed dormancy is imposed: seed coverings (*e.g.* pericarp, testa and in some cases the endosperm) and in other cases the embryo itself (Bewley and Black, 1994). A dormant seed would continue its state until a specific environment overcomes its dormancy (Simpson, 1990) and this condition is known as after-ripening seed dormancy. In general, freshly harvested seeds of *indica* rice cultivar are dormant while that of *japonica* rice cultivars are non-dormant (Hartman *et al.,* 1997; Ellis *et al.*, 1983).

Seed dormancy in wild species has been found to be primitive trait of rice (Takahashi, 1984) which was lost during domestication. Vearsey *et al.*, (2004) found lower intensity of seed dormancy of the cultivated species of rice compared to its wild species. Seed dormancy is common in grasses like *Hordeum vulgare, Avena spp., Secale cereale* (Simpson, 1990). The QTLs (quantitative trait loci) associated with pre-harvest sprouting resistance genes have been identified in barley (Prada *et al.*, 2004), sorghum (Lijavetzky *et al*., 2000) and wheat (Kulwal *et al.*, 2004). The QTLs controlling seed dormancy have been reported in cultivated *O. sativa* (Dong *et al.,* 2002; Miura *et al.*, 2002; Wan *et al.*, 1997), in wild rice, O. *rufipogon* (Cai and Morishima, 2000) and in weedy rice, *O.sativa* (Gu *et al.*, 2004).

Self-sown Basmati rice plants were observed in the wheat experimental material in March, 2005 in the field plots at the Indian Institute of Technology, Roorkee, where two traditional Basmati cultivars Type3 and Basmati 370 were grown from July to October, 2004. The plants from the self-sown seeds were tall, photosensitive and had typical grain characteristics similar to that of Type 3 and Basmati 370, suggesting that the basmati cultivars had strong after-ripening seed dormancy up to 100 days under low temperature (4-25ºC) field condition in winter. This article deals with the study of genetics of seed dormancy in a traditional Basmati rice cultivar Type 3.

Materials and Methods

The plant material consisting of two traditional Basmati cultivars, Basmati 370 and Dehraduni Basmati (Type 3) and non basmati *indica* rice cultivars were obtained from the Punjab Agricultural University, Ludhiana.

Hulled and dehulled seeds of freshly harvested grains of two traditional Basmati cultivars, Basmati 370 and Type 3 and two non-basmati semi-dwarf

*Corresponding author email : hsdhaliwal07@gmail.com,

indica rice cultivars PR106 and P2 (PR106 with bacterial leaf blight resistance genes *xa5, xa13* and *Xa21* pyramided) were harvested and threshed gently by hand. The harvested seeds were tested for germination 10 days after harvesting (DAH) in Petri plates at room temperature with and without heat treatment. For breaking the seed dormancy, the hulled grains were treated at 45ºC for 72 h. The hulled grains were tested for germination at room temperature (25ºC) with and without heat treatment at 15, 40, 50 and 100 DAH.

To study the genetics of seed dormancy, 160 F_3 progenies (seeds obtained from the F_2 plants) from a cross of Basmati Type 3 with dormant seeds and non-dormant and non-basmati P_2 *indica* rice cultivars were tested for germination at 50 DAH and 100 DAH with and without heat treatment. Different germination percentage cut-off points were taken to classify the dormant vs. non-dormant progenies depending upon the parental seed germination under different conditions.

Table1. Germination of hulled and dehulled seeds of traditional basmati and non-basmati *indica* rice cultivars with and without heat treatment

Cultivar	Germination % without heat treatment at 10 DAH		Germination % with heat treatment at 10 DAH	
	With Hull	Without Hull	With Hull	Without Hull
Basmati 370	12	95	32	95
Type 3	16	85	26	85
P2	76	86	92	90
PR106	85	90	80	90

Results and Discussion

Germination of PR106 and P2 with and without hulls at 10 DAH with heat and without heat treatment was 76-90%, indicating that there was little seed dormancy in these non-basmati cultivars. In both the traditional basmati cultivars, the germination of hulled seeds was 12 and 16% without heat treatment and 32 and 26% with heat treatment, respectively, indicating that the recommended heat treatment could break the dormancy only partially and not completely (Table1). However, there was 80-90% seed germination in basmati and non-basmati without hulls, irrespective of the heat treatment, indicating that the hull imposed seed dormancy upon traditional basmati cultivars to a major extent. The hull-conditioned dormancy could not be effectively overcome by the recommended heat treatment.

Seed germination of non-dormant cultivars PR 106 and its near isogenic line P2 improved steadily from 70% (15 DAH), 85% (50 DAH) to above 90% (100 DAH) whereas the seed of self-sown Basmati 370/Type 3, Basmati 370 and Type 3 had no germination till 50 DAH (Table 2). The heat treatment of hulled seed could only slightly enhance germination from 0-20% (15 DAH), and 50% (50 DAH) and not overcome completely. The maximum germination of Basmati cultivars with and without heat treatment was 60-70% even at 100 DAH. Lower seed germination (<70%) in basmati cultivars even after heat treatment at 100 DAH indicated the presence of residual dormancy which is not overcome by the recommended heat treatment.

The frequency distribution of germination of different F_3 seeds under three different germination conditions is given in Figure 1. Considering that the Type 3 seeds would start germinating between 50-100 DAH and by taking 35% germination as the cut-off point between dormant and non-dormant F_3 seeds at 50 DAH, the F_2 plants segregated into 129 dormant: 31 non-dormant in 13:3 ratio ($\chi 2$ = 0.041, P<0.05) (Fig. 1a), indicating that the hull imposed seed dormancy is controlled by two genes, one dominant and the other recessive. Shenoy (1993) in his study on the genetics of hull imposed dormancy in rice seeds, obtained 9:7 ratio between dormant vs. non dormant seeds upon fixing 80% germination cut-off. After heat treatment at 50 DAH, the majority of the progenies had above 50% germination, the maximum germination of Basmati 370 after heat treatment at 50 DAH. The progenies segregated in a ratio of 36 dormant to 124 non-dormant progenies in 1:3 ratio ($\chi 2$ =0.53, P<0.05) (Fig.1b), suggesting that a recessive gene controlled residual dormancy. The dormancy conditioned by the dominant gene was overcome by heat treatment, whereas the part controlled by the recessive gene continued to be expressed.

The germination of Type 3 at 100 DAH without heat treatment was over 60%. Taking 65% germination as the cut-off point between partially dormant: non-dormant progenies at 100 DAH without heat treatment, there were 43 dormant and 114 non-dormant progenies which segregated in 1:3 (c2 =0.477, P<0.05) (Fig.1c) ratio, confirming that a recessive gene in Type 3 still controlled partial dormancy even 100 DAH and that this residual dormancy could not be overcome by heat treatment. It probably would require still longer heat treatment

Table 2. Germination of hulled seeds of self-sown Basmati 370/Type 3, traditional basmati and non-basmati rice cultivars at different DAH

Rice Cultivars	Germination % without heat treatment				Germination % after heat treatment			
	15 DAH	40 DAH	50 DAH	100 DAH	15 DAH	40 DAH	50 DAH	100 DAH
Self-sown Basmati370/Type 3	0	0	0	60	10	15	45	60
Basmati 370	0	0	0	70	20	30	50	70
Type 3	0	0	5	60	10	20	45	60
P2	70	80	80	95	75	85	95	100
PR106	70	75	85	100	70	85	90	100

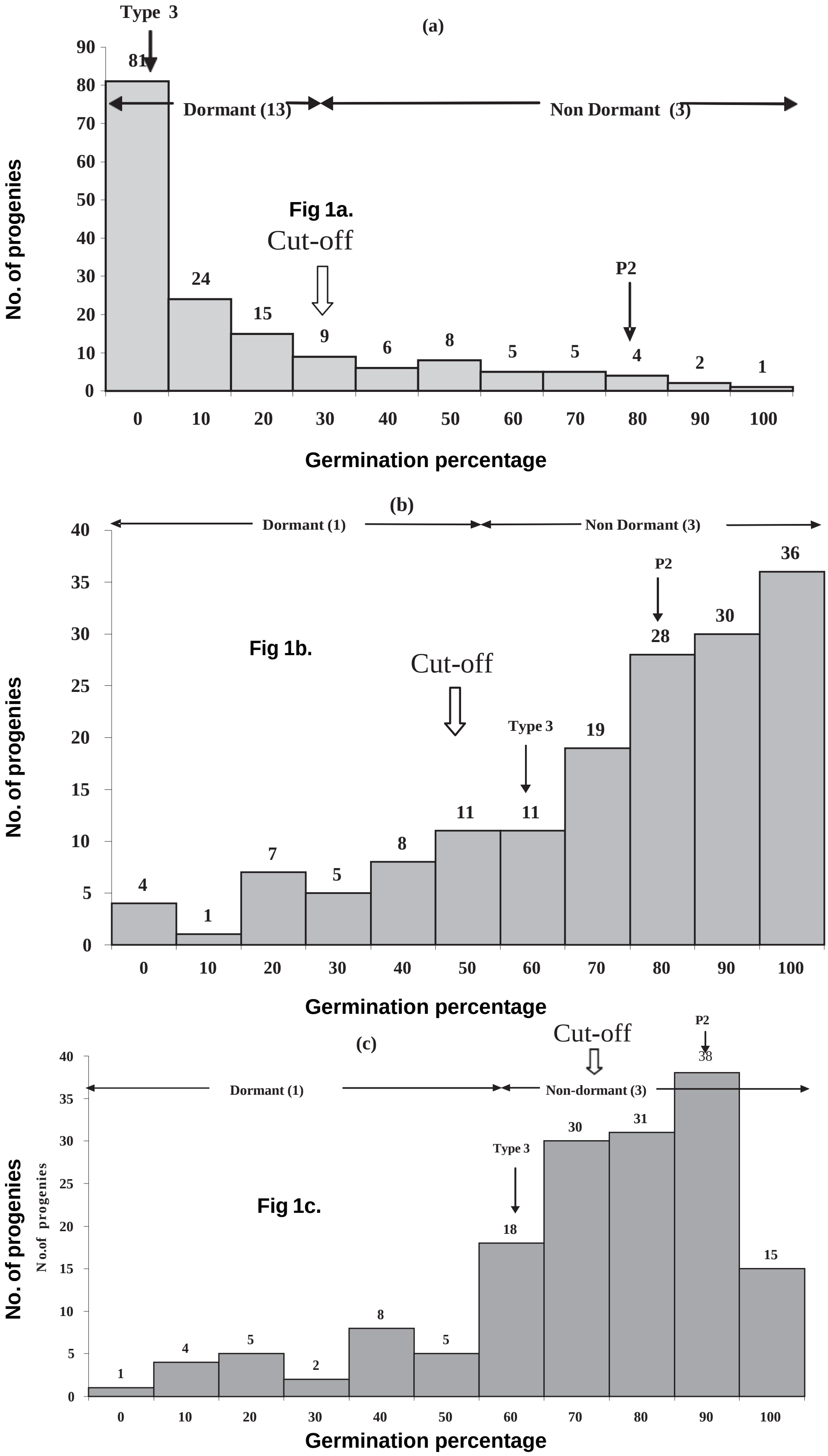

Figure 1. Frequency distributions of seed germination of 160 F3 progenies of Type3 Basmati/P2 cross at 50 and 100 DAH. The black arrows denote the germination levels of the parents. Cut-off points between dormant and non-dormant seeds in all three conditions have been marked by vertical arrow lines. Approximate proportion of dormant and non-dormant progenies in each condition has been shown in parentheses. a. 50 DAH without heat treatment, b. 50 DAH after heat treatment. c. 100 DAH without heat treatment.

or additional time for restoring complete germination. Das (1985), in his study on the genetics of dormancy in rice, also found an epistatic (13:3) and 3:1 ratio of dormant vs non-dormant seeds at 5 DAH and 35 DAH, respectively. Takahashi (1962) found complementary dominant gene interaction for seed dormancy in certain rice cultivars. Gu *et al.* (2003) found the ratio of the low and high germination plants in weedy and non-weedy rice crop as 9:7, suggesting a digenic model for controlling seed dormancy. Seed dormancy is reported to be controlled by several QTLs.

From the results of this investigation, it can be concluded that seed dormancy of traditional basmati cultivars, Basmati 370 and Type 3 (Dehraduni basmati) is imposed by hull and controlled by the interaction of at least one dominant and one recessive gene. The effect of the dominant gene could be overcome by heat treatment, whereas the one controlled by recessive gene resisted the heat treatment and continued for much longer time. The hull imposed seed dormancy in traditional Basmati cultivars probably provided protection against preharvest sprouting as the photosensitive traditional basmati were adapted for cultivation in flood prone low lying areas of Northern India. The tagging and transfer of seed dormancy genes will be useful for marker assisted selection in non-basmati cultivars to avoid losses due to rain and lodging during harvesting.

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