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Seed discoloration in rice: Causes and their effect on seed quality

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Abstract
Rice not only constitutes the most important staple food for half of the world's population, especially in Asia but is also an important export commodity. In India, rice crop is attacked by several bacterial, fungal, viral pathogens and pests. However, "grain discoloration" is a complex disease due to infection by certain microorganisms on the glumes, kernels, or both. In the recent years, it is emerging as a potent threat to rice crops. Seed discoloration is considered to affect the grain quality, breaking of rice grains during milling, weight loss, exports, post-harvest losses, crop yield and ultimately badly affect the economy. The present investigation was undertaken to determine the nature of seed discoloration, causes and their effect on seed quality, seed transmission, detection and identifications of different seed borne fungal pathogens associated with grain discoloration of rice. In the present study, seven types of seed discoloration namely; light to dark brown dot like spot, dark purple discoloration, light pink discoloration, eye shaped spots with ash grey center, ash grey discoloration marked by brown band and black discoloration were observed. However, light to dark brown dot like spots were found to be most predominant type of seed discoloration. Pant Basmati 1 variety exhibited maximum discoloration while, Pusa Basmati 1509 had minimum discoloration. Light pink discoloration was present only in three varieties namely; Sarju-52, Pusa Sugandh-5 and Pant Basmati-1, while, eye shaped spots with ash grey center type of discoloration was not observed in varieties Govind, Pusa basmati-1509 and Pant Dhan -21.

Keywords: seed discoloration, glume, pathogens, detection

1. Introduction
Rice (*Oryza sativa* L.) belongs to family Poaceae, is a self pollinated cereal crop. Twenty species of rice are known however, *Oryza sativa* and *O. glaberrima* havebeen cultivated. *O. sativa* is native to tropical and subtropical Southern Asia, while the African rice, *O. glaberrima* is native to West Africa (Habib *et al.*, 2012) [1]. *O. sativa* is divided into three sub-species namely; Indica, Japonica and Javanica. The varieties grown in India belong to sub-species *Indica*. This sub species is characterized by their leaves usually slightly pubescent and pale-green. The caryopsis is elongated, slightly flattened, thin and narrow. *Japonica* sub species is native to Japan, have mostly round or oval grains may be awned or awnless. The leaves are narrow and dark green colored. Whereas, *Javanica* sub species found mainly in Indonesia is characterized by long panicle having awned grains, plants with sparse tillering habit and stiff straw. These are long duration and have low sensitivity to differences in day light. *O. sativa* are more popular due to their higher yield, grain quality and worldwide distribution. For more than half of the world's population, it is one of the most important staple foods. The crop influences the economics and livelihoods of several billion people. Rice is primarily a high-energy food. It contains less protein compared to wheat and much of its fat is lost during milling. Its grain contains B group vitamins and low content of calcium. Rice bran (pericarp, seed-coat, nucellus and aleurone layer) accounts for about 8% of paddy weight and is used for variety of purposes such as poultry and cattle feed and oil extraction. Rice bran contains 15-20% oil. Of the total oil in grain, approximately 75% is present in bran itself. World rice bran oil production varies from 1-1.4 million tons. Of this, India accounts for 0.7-0.9 million tons (Garba *et al*., 2017) [2]. Rice hulls can be utilized in manufacturing insulation materials, cement, and card-board and as litter in poultry keeping. Rice straw can be used as cattle feed as well as litter during winter season. The total area under rice cultivation in the world is 158 million hectares with annual production of 759.6 million tons (Anonymous, 2018a) [4]. In India, rice is cultivated in the region between 8° to 34° N (Datta, 1981) [3]. More than 90 percent of the world's rice is grown and consumed in Asia. Rice and its derivatives account for 35 to 70 per cent of the calories consumed by more than 3 billion Asians and total calories consumption worldwide (Nandan *et al*., 2010).

India is second in terms of area and production of rice after China with an annual production of 102 million tons from an area of 46 million hectares (Anonymous, 2018b) [5]. The average yields of rice in India is2.22 tons per hectare against the world average of 4.80 tons per hectare. In Uttarakhand, rice is the most important kharif crop grown on 0.25 million hectare with a total production of 0.57 million tons at an average yield of 2.34 tons per hectare (Anonymous, 2018c). Non-adoption of modern cultivation technologies and losses caused by weeds, insect-pests, diseases etc. are some of the major factors which are responsible for low productivity of rice throughout the country.

The diseases such as blast, sheath rot, sheath blight, brown spot and bacterial leaf blight alone cause about 15-20 per cent yield loss in rice. Amongst, the diseases, seed discoloration also known as "Glume discoloration" and "Dirty panicle is one of the important diseases of rice (Datnoff *et al*., 1997) [6].

Seed discoloration is considered not only to affect the yield but it also affects the quality of grain, breaking of grains during processing, reduction in weight, losses during storage, ultimately greatly reduce the export resulting great economic loss (Ghazanfar *et al*., 2013) [7]. Since, rice is mainly grown during rainy season when high temperature and high humidity prevails.

Frequent and heavy rain falls and floods particularly near harvest in the different parts of the country, wet the crop and makes panicles more prone to invasion by fungal species. The seed discoloration of rice, earlier considered to be minor disease, is now gaining more importance due to its severity in rice growing areas. It is prevalent in moderate to severe form in almost all parts of the world (Zeigler and Alvarez, 1990 [9], Trung *et al*., 1993, Jeong *et al*., 2003, Chien and Chang, 1987 [12], Cottyn *et al*., 1996 [13], Rush *et al*., 1998 [14], Shahjahan *et al*., 2000, Narain, 1992) [11]. Seed discoloration affects the quantity and quality of the produce (Sumangata *et al*., 2009, Tariq *et al*., 2012) [16, 17] leading to loss in crop yield.

The seed discoloration has been shown to result in increase in chaffyness, loss in seed weight, deterioration in nutritional value, loss in viability, germination, reduction in market acceptability, etc. (Narain, 1992) [11]. Many types of seed discoloration are caused by several fungi in rice in different agro-climatic zones. The discoloration may be red, pink, orange, yellow, black or brown to dark brown depending upon the fungi. The extent of damage can also vary according to season, locality, seed microflora, host cultivar, their physiology, genetics and heavy nitrogenous fertilizer application.

2. Material and Methods

2.1: Collection of Seed Samples

Freshly harvested seeds of most popular rice varieties in the region were collected from Norman E. Borlaug Crop Research Center of G. B. Pant University of Agriculture and Technology Pantnagar, Udham Singh Nagar, Uttarakhand. Nine varieties representing bold grain (Sarju 52, Pant Dhan 10 and Pant Dhan 21), medium grain (PR 121, HKR 47 and Govind) and fine grain/basmati (Pusa Sugandh 5 or Pusa 2511, Pusa Basmati 1509 and Pant Basmati 1 were used in experiment.

A working sample of 200g of each variety was randomly collected from rice experiments as recommended by ISTA (1976) [8]. The samples were kept in cloth bags with proper labeling, and stored in the refrigerator at 5±1° C until used for subsequent studies.

2.2: Assessment of seed discoloration in popular varieties of rice.

Seed discoloration was determined by collecting discolored rice grain. Samples were categorized into different categories on the basis of symptom of the discolored grains.

3. Results and Discussion

Seed discoloration is one of the emerging diseases of rice which directly affects the quality of the produce. In Uttarakhand, rice is mainly grown in wet seasons where the flowering and post- flowering stages are exposed to high humidity and temperature conditions favors infection by different types of pathogens causing seed discoloration. Seeds play an important role in crop stand. The productivity and establishment of stands depends upon the quality of seeds used. As the loss of production and productivity of the crop is primarily due to the use of seeds of inferior quality, we should strive not only for improving seed quality but also for efficient utilization of seed through proper assessment of its quality.

3.1: Assessment of seed discoloration in popular varieties of rice

Seeds of nine popular varieties representing bold, medium and fine grains namely; Sarju-52, Pant Dhan-21, Pant Dhan-10, PR-121, HKR- 47, Govind, Pusa sugandh-5 (Pusa 2511), Pusa Basmati-1509 and Pant Basmati-1 were collected from N.E.B. Crop Research Center of G.B. Pant University of Agriculture & Technology, Pantnagar. The seeds were collected just before harvesting and seeds were further categorized into different types of discoloration on the basis of visual examinations (Plate 1).

3.1.1. Light to dark brown dots like spot.

The data presented in table 1 and 2 revealed that light to dark brown dots scattered all over the seed surface were observed in all the varieties. However, maximum (19.83%) was observed in fine grain variety Pant basmati 1 while, minimum (1.16%) was recorded in variety Pusa Basmati-1509 (Plate 2).

3.1.2. Dark purple discoloration

As evident from the Table 1 and 2 that dark purple discoloration was also recorded in all the nine varieties. This type of discoloration ranged from 1.40 to 10.30 per cent, being maximum in Pant Basmati-1 and minimum in Pusa Basmati-1509 (Plate 2).

3.1.3. Light pink discoloration

Interestingly, light pink discoloration was observed only in the seeds of varieties Pusa Sugandh-5 (Pusa 2511), Pant basmati 1 and Sarju-52. However, it was maximum in Pant Basmati-1 (2.25%) while minimum in Sarju-52 (2.00%) (Plate 2 and Table 1&2).

3.1.4. Eye shaped spot with ash grey center

Oval to eye shaped spots with ash grey center and dark brown margins were observed in all the varieties except in Govind, Pusa Basmati-1509 and Pant Dhan-21. The center of the spot also exhibited dark minute fruiting bodies. This type of discoloration ranged from 0.18% to 2.60%.Maximum discoloration was recorded in variety HKR-47(2.60%) while, minimum (0.18%) in variety Pant Pasmati-1 (Table 1 & 2 and Plate 2).

3.1.5. Ash grey discoloration marked by brown band

Ash grey discoloration marked by brown band was observed in all the varieties. This type of discoloration ranged from 0.47% to 5.78%, being maximum in variety Govind and minimum in Pusa Basmati 1509 (Table 1 & 2, and Plate 2).

3.1.6. Dark brown spot

Small irregular spots of dark brown color were observed in all the varieties under study. It was maximum (26.82%) in Pant Basmati-1, while, minimum (4.25%) was recorded in Pusa Basmati-1509 (Table 1 & 2 Plate 2).

3.1.7. Black discoloration

Black discoloration appeared in the form of general seed blackening on the glumes while in severe infection blackening covered entire seed surface (Plate 2). All the varieties showed black discoloration. It was maximum (5.92%) in Govind while minimum (1.70%) in Pant Dhan-21 (Table 1 & 2,). It is evident from the results that the varieties under study exhibited seven types of discoloration namely; light to dark brown dot like spot, dark purple discoloration, Light pink discoloration, eye shaped spots with ash grey center, ash grey discoloration marked by brown band and black discoloration. Perusal of were found to be most prominent type of discoloration whereas, light pink was least prominent discoloration. Of the nine varieties, Pant Basmati 1 showed maximum discoloration while Pusa Basmati 1509 showed minimum discoloration. It was interesting to note that light pink discoloration was present only in three varieties namely; Sarju-52, Pusa Sugandh-5 and Pant Basmati-1, while eye shaped spots with ash grey center type of discoloration was not observed in varieties Govind, Pusa basmati-1509 and Pant Dhan-21. Light to dark brown dot like spot, dark purple discoloration, light pink discoloration eye shaped spot with ash grey center, ash grey discoloration marked by brown band, dark brown spot and black discoloration types of discolorations observed in the present studies have also been reported by Rawte (2013), Khanzanda *et al*., (2002), Bateman and Kwasna (1999), Sachan and Agrawal (1995), Ibrahim and Danab (2014). Various types of seed discoloration and their causes have been reported by workers all the world. Some of the major discolorations include; red (Uyeda, 1901) and yellow discoloration (Vander Wolk, 1922), chestnut brown to white spots
(Marchionatto, 1943), black flecks (Tanaka and Inagaki, 1957), black dots (Hora, 1959), black and brown spot (Ranganathaiah, 1985) and pale brown spot on glumes (Singh, 1987). Besides the above mentioned categories of rice seed discoloration, general discoloration and spotting on rice seed also have been reported (Upadhyay and Dwivedi, 1984). Likewise, Rawte (2013) reported ashy grey discoloration, black discoloration, dark brown spots and light to dark brown dot like spots in the seed coat and endosperm of discolored seed, eye shaped spots, pink discoloration and light brown discoloration. Seed discoloration on rice seeds is reported to be due to seed infection by different fungi (Agrawal *et al.*, 1989, Misra *et al*., 1994).

Table 1: Type of seed discoloration on different varieties of rice

S. no	Varieties	Types of discoloration						
		Light to Dark brown dot like spot	Dark purple discoloration	Light pink discoloration	Eye shaped spot with ash grey center	Ash grey discoloration by marked brown band	Dark brown spot	Black discoloration
Bold								
1	Sarju-52	+	+	+	+	+	+	+
2	Pant Dhan 21	+	+	_	_	+	+	+
3	Pant Dhan 10	+	+	_	+	+	+	+
Medium								
1	Pr 121	+	+	_	+	+	+	+
2	HKR 47	+	+	_	+	+	+	+
3	Govind	+	+	_	_	+	+	+
Fine								
1	Pusa Sugandh 5 (Pusa-2511)	+	+	+	+	+	+	+
2	Pusa Basmati-1509	+	+	_	_	+	+	+
3	Pant Basmati-1	+	+	+	+	+	+	+
Note:	**+ (Present) & – (Absent)**							

Table 2: Incidence of seed discoloration in different varieties of rice

Sl. No.	Varieties	Type of discoloration							Total
		Light to dark brown dot like spot	Dark purple discoloration	Light pink discoloration	Eye shaped spot with ash grey center	Ash grey discoloration marked by brown band	Dark brown spot	Black discoloration	
Bold									
1	Sarju-52	12.72	2.73	2.00	1.37	0.70	5.56	3.29	28.37
2	Pant Dhan 21	8.93	1.78	0.00	0.00	1.76	7.30	1.70	21.47
3	Pant Dhan 10	14.62	2.35	0.00	0.70	1.55	7.22	3.88	30.32
Medium									
1	Pr 121	14.70	2.27	0.00	1.14	1.58	11.18	3.96	34.83
2	HKR-47	15.33	4.82	0.00	2.60	5.75	5.90	3.42	37.82
3	Govind	7.77	3.82	0.00	0.00	5.78	8.76	5.92	32.05
Fine									
1	Pusa Sugandh 5	9.40	7.85	2.17	1.56	1.85	10.10	5.73	38.66
2	Pusa Basmati 1509	1.16	1.40	0.00	0.00	0.47	4.25	2.30	9.58
3	Pant Basmati-1	19.83	10.30	2.25	0.18	2.72	26.82	2.30	64.40

Total		104.46	37.32	6.42	7.55	22.16	87.09	32.50	
	S.E.m%	0.33	0.26	0.97	0.13	0.22	0.59	0.27	
	CD at 5%	0.98	0.79	0.28	0.39	0.67	1.76	0.82	
	CV	4.98	11.23	23.59	23.59	16.14	11.25	13.20	

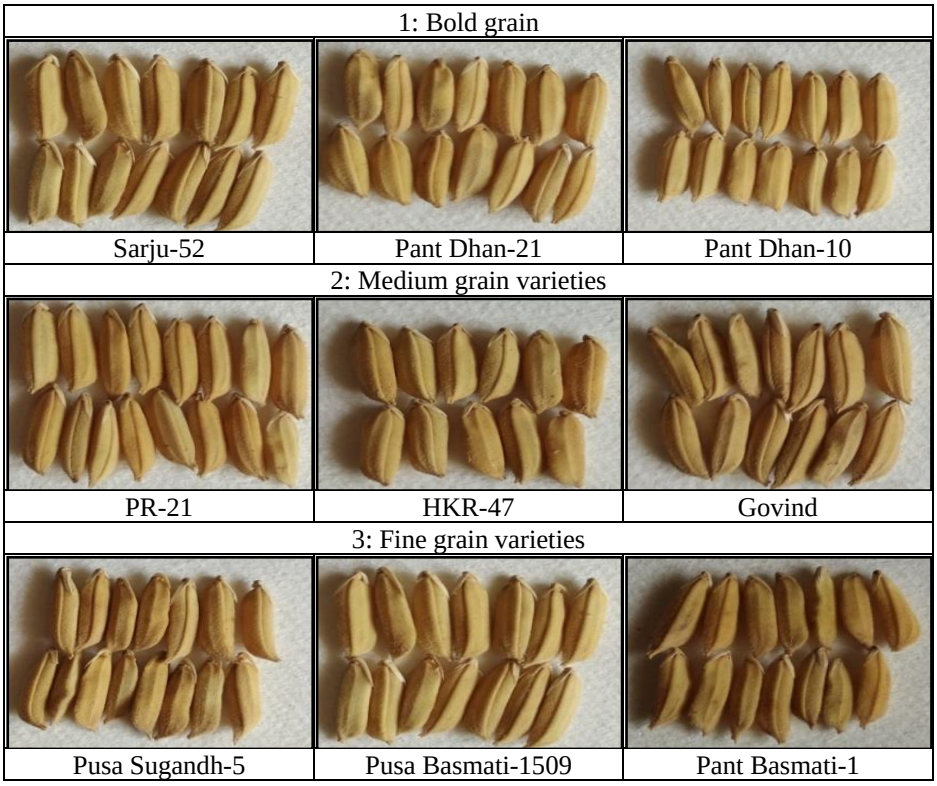

Plate 1: Healthy grains of different types of bold, medium, and fine grain varieties of rice.

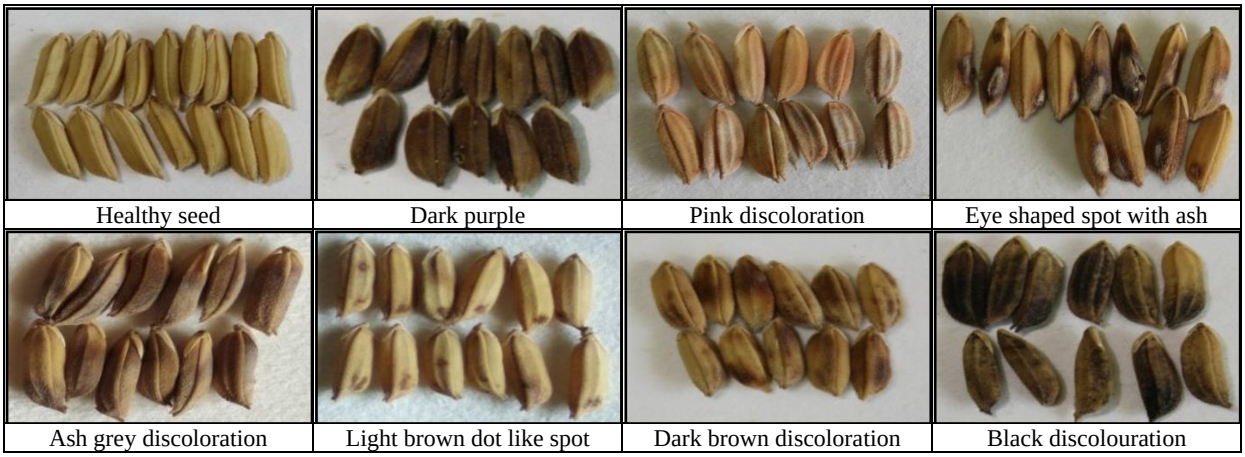

Plate 2: Different types of seed discoloration in rice

4. Summary and Conclusion

Rice is the one the most important food crops in Indian agriculture and is grown all over the word. The total area under rice cultivation in the world is 158 million hectares with annual production of 759.6 million tons. India is second largest in terms

of area and production of rice after China with an annual production of 102 million tons from an area of 46 million hectares. The average yield of rice in India is 2.22 tons per hectare against the world average of 4.80 tons per hectare. The attack of the sect-pests and diseases in rice crop is considered as one of the most important factors attributing to low yields in rice. Amongst the disease of rice, grain discoloration is the major constraints in production of rice. Seed discoloration is considered to affect the grain quality, breaking of rice grains during milling, weight loss, exports, post-harvest losses, crop yield and ultimately badly affect the economy. The present investigation was undertaken to determine the nature of seed discoloration, causes and their effect on seed quality, seed transmission, detection and identification of different seed borne fungal pathogens associated with grain discoloration of rice. Findings of the present study are summarized below: Seven types of seed discoloration namely; light to dark brown dot like spot, dark purple discoloration, Light pink discoloration, eye shaped spots with ash grey center, ash grey discoloration marked by brown band, dark brown spot and black discoloration. Light to dark brown dot like spots was found to be most predominant type of discoloration. The variety Pant Basmati 1 exhibited maximum discoloration while Pusa Basmati 1509 had minimum discoloration. Light pink discoloration was present only in three varieties namely; Sarju-52, Pusa

Sugandh-5 and Pant Basmati-1, while eye shaped spots with ash grey center type of discoloration was not observed in varieties Govind, Pusa Basmati-1509 and Pant Dhan-21.

The study has shown that seed discoloration is major constraint in production of quality seeds of rice. Therefore, the farmers should be trained regarding production and post-production activities for healthy, disease free quality seed and to minimize crop failure.

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