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Seed Discoloration in Rice: A Threat to Rice Cultivation in India

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ABSTRACT: Several biotic and abiotic factors are responsible for seed discoloration in paddy (*Oryza sativa* L.). Among the biotic factors, several fungal pathogens play important role in producing the lusture less seeds with poor quality and such seeds are not preferred by the farming community. Some fungi responsible for discoloration in rice which produces toxins and lower down the seed as well as grain quality making unfit for human and cattle consumption. Paddy grain discoloration is an emerging threat which degrades the grain texture and quality. In the case of unpredictable climatic conditions across different ecological zones, severity of this disease also ranges from minor to major. Grain discoloration affects the grain morphology (size and shape of the grain) and significantly lower down the crop yield. Grain discoloration also affects the drying, shelling, milling and processing of the rice due to heavy weight loss. This malady causes weight loss in paddy grain that directly affects the post-harvest processing of the rice seeds and cooking quality. Now a days, Seed discoloration again proved to be a major recurring issue in the Indian coastal regions haltering the levels of desired grain production and also major challenge is to control the disease with minimal loss. In this review, we discuss the epidemiology, causes, symptoms and management of rice discoloration disease. Strategies such as better utilization of genetic resources, precise pathogen identification and improved agricultural practices should be developed and suggested to help cope up against this devastating problem.

Keywords: Seed discoloration, Rice, Integrated management, Seed borne disease, pathogen.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most commonly consumed grain in India, covering more than 60% of the population (Adam *et al*., 2018). It is major cereal crop that provides food security for more than two third of world population and is means of earnings which contributes in sustainable livelihood for millions of households. It is susceptible to a wide range of pathogens and pests affecting at all the stages of growth.

Among the diseases, seed discoloration is proved to be a chief recurring issue in most of the Indian regions affecting the levels of expected grain production. Though discoloration is a minor disease, has become more significant effect in agriculture. Consequence of global warming resulted in erratic hailstorms, delayed or minimum rainfall, higher temperatures and humidity levels especially after flowering stage, may also affects the rice production. Grain discoloration serves as a visible indicator of seeds having lower quality in association with microorganisms (Chandramani and Awadhiya 2014). It is a complex disease as several other pathogenic fungi infect rice grains in the experimental and farmers field (Patted *et al*., 2022).

A number of biotic and abiotic factors are accountable for seed discoloration in paddy. Seed discoloration is term for the variation in color of mature seed from its original color and seed possesses series of problems in seed certification programme. This disease affects the vigor and yield of the crop, thus reducing the economical and marketable value of the crop. Seed discoloration became a big concern may be due to prevalence of monoculture and the year-round development of only economically valuable crops like paddy and wheat (Bala and Pannu 2017). This is also owing to the numerous pests and pathogens that affects the crop very badly. Rice is such an important crop for mankind, needs to be research more for its development considering numerous fungal flora which might affect the vigor, production, morphology and constitution of newly introduced higher yielding/aromatic rice cultivars. Seed discolouration, also known as dirty panicle disease, is one of the emerging minor diseases, which is a serious problem in most of the rice growing areas around the world (Patted *et al*., 2022). The cause of such discoloration, whether pathological or non-pathological, isn't always obvious.

Discolored rice seeds are most commonly related with microorganisms, primarily fungi, though it can also occur as a result of insect bites, physiological and genetic factors. A researcher reported *Ustilaginoidea virens, Rhizopus oryzae, Bipolaris oryzae, Aspergillus niger*, *Aspergillus flavus, Pyricularia oryzae, Curvularia oryzae, Alternaria* spp., *Cercospora* spp. and *Penicillium* spp. from discolored seeds (Pantha *et al*., 2016). It is reported that seeds of all rice genotypes were infected with these fungi however frequency of these fungal association varied from one genotype to other. It is also found that the significant infectivity of *Fusarium moniliforme*, *Fusarium verticillioides*, *Trichothecium* spp. and *Curvularia lunata* were associated with grain discoloration (Agarwal and Singh 1974). The presence of different fungi (about ten genera) discovered in seed-borne mycoflora linked with seeds in fresh harvested rice varieties. Based on prevalence, these fungi are organized as *Alternaria, Curvularia, Fusarium, Helminthosporium, Nigrospora, Penicillium, Aspergillus, Sordida, Rhizopus* and *Chaetomium.*

Curvularia launata is the most common genus, accounting for 29 percent of total fungal isolates, and affected 59.5 percent of the rice grains (Islam *et al*., 2012). On the samples of rice seed, the frequency of *Penicillium* spp., *Aspergillus* spp., *Trichoconis padwickii, Curvularia lunata* and *Bipolaris oryzae* (BR11) are examined using the blotter paper technique which varied from 0.0-4.0 percent,0.9-19.5 percent, 1.2-21 percent, 16-48 percent, and 0-64 percent, respectively. *Curvularia* isolates inoculated to rice cultivars in pot resulting in typical grain discoloration symptoms such as light brown, dark brownspots and lesions, whereas rice seed husk possesses light to deep black-colored patches (Gopalakrishnan *et al*., 2010). On workout of seven fungi, *Curvularia* spp. was predominant followed by *Curvularia lunata, Sarocladium oryzae, Alternaria alternate, Aspergillus niger, Helminthosporium oryzae and Fusarium* spp. (Ibrahim and Abo Dabab 2014). It was found that *Bipolaris oryzae* is the most frequent fungus responsible for grain discoloration causing light black to brown spots in rice varieties, followed by *Alternaria padwickii* which was liable for causing spots varying from light pink, dark brown, ash grey, pale yellow to light brown, whereas the genus *Fusarium* caused pale yellow to light pink spots and *Alternaria alternata* led to ash grey spot seeds.

Among the fungal diseases, seed discoloration is one of the major limiting factors in paddy production and is caused by *Alternaria padwickii*, *Cochliobolus miyabeanus*, *Drechslera* spp., *Pyricularia oryzae*, *Gibberella fujikuroi, G. zeae, Nigrospora* spp., *Epicoccum* spp., *Curvularia* spp., *Helicoceras oryzae* and *Alternaria* spp. (Ou, 1985). Different methods have been used for control of diseases in which chemical control has been the most widely adopted in many countries. However, injudicious use of plant protection chemicals has caused environmental hazards and it is preferable to find alternate sources (Tarr, 1972). Seed-borne mycoflora related with grains of different varieties of rice using towel paper (blotter paper) method and reported that incidence of different fungal mycoflora in the seeds of aromatic rice varieties only (Butt *et al*., 2011). Different chemicals were used to control seed borne fungi in rice (Habib *et al*., 2013). Arshad *et al*. (2009) tested different fungicides against fungi isolated from discolored seed of different rice varieties. Use of single foliar spray with Propiconazole 25 EC, Trifloxystrobin 25% + Tebuconazole 50 %, Kresoxim methyl, Tricyclazole 75 WP and Carbendazim 50 WP at milking to dough stage effectively reduces the discoloration in rice (Said *et al*., 2015).

Causes of Seed Discoloration. Seed discoloration is caused by a combination of biotic and abiotic factors such as fungal, bacterial and viral attack, with high humidity and moisture content along with increased temperature, high failure and weak plant defense system. *Aspergillus* is known to decrease the percent of seed germination in the Poaceae family. Grain discoloration reduces the production and size of paddy grains, resulting in significant qualitative and quantitative failures in the paddy crop (Yan *et al*., 2010; Ashfaq *et al*., 2013). Seed discoloration, foot rot, stem rot and seedling blight in rice have been linked to a variety of seed-borne fungi, including *Helminthosporium oryzae, Fusarium moniliforme* and *Penicillium* spp. (Ashfaq *et al*., 2017). Climate change and biotic stress, could have a negative impact on plant physiology and growth characteristics. The consequences on the rice crop may vary depending upon the amount, timing, and severity of rainfall (Modarresi *et al*., 2015). An increase in rainfall during the harvesting stage could result in discolored seeds and lower agricultural yields. A high incidence of the disease is correlated with a wider temperature range during the flowering stage. Paddy discoloration typically begins at the heading stage and persists till maturity and is worsened in a humid atmosphere. Rainfall and rice grain fertility were found to have a negative relationship. As a result, delaying in harvest can result in more empty grains. Frequent and heavy rainfall, creates a flood-like environment during the harvest stage, can make the crop damp, making the panicles more susceptible to pathogen invasion (Reddy *et al*., 2004).

The seed germination percentage reduced when the moisture percentage of the seeds in storage increased due to which an increase in fungal infection which may lead to grain discoloration (Datnof *et al*., 1991). After a long drought, followed by rain and storm, glume discoloration can develop during the panicle-emergence stage. The disease was shown to be highly widespread in rainfed wetland areas than in dry ones. In almost all the rice cultivars, unbalanced NPK fertilizer application enhanced disease incidence. Liming or adding straw ash, Si, or Mg to the mix (in addition to NPK) lowered disease incidence (Yamauchi and Winslow 1989). Grain discoloration slows down germination and causes coleoptiles/radicle to decay, leading in unfilled grains and low yields (Misra and Vir 1991). An incidence or intensity of seed discoloration and its effect on test weight are directly proportional to each other (Zulkifi *et al*., 1991). Grain weight was reported to be reduced as the prevalence and incidence of grain discoloration, having high level of discoloration from 1 to 50%, the test weight (thousand grain weights) decreased from 20.0 to 16.4 gram (Saifulla *et al*., 1998). A reduction in discolored grain from 3.8 to 28.8% test weight (thousand grain weight) compared to healthy grains, indicating grain deterioration owing to discoloration (Bag, 2010).

Symptoms of Seed Discoloration. Based on the microorganism and the severity of infection, several sorts of symptoms appear. Rice seed discoloration symptoms include prominent stripes or spots on grains ranging from brown to black depending on the intensity and type of fungus, infested panicle become hollow with empty grains. Grain discoloration has a direct impact on grain morphology in terms of shape, size and color. In some circumstances, black blotches are caused by wind pressure during pollination, food shortage, low plant population, improper pollination/fertilization, immature grain filling and rainfall at maturity stage. Grain discoloration is also developed due to swelling of the grain coat's sub epidermal layer, which led to epidermis breaking (Jorgensen, 1976). Swelling occur in humid conditions and happened in a matter of minutes. It's possible that seed discoloration is caused solely by excessive humidity. Hafiz *et al*. (2009) demonstrated the pathogenic ability of numerous fungus isolation that cause seed discoloration. The spore suspension technique was used to inoculate three different grain discoloring fungus into the panicles of rice produced under field conditions. The inoculations were carried out at three different stages of growth: blossoming, milking and soft dough. The most discoloration happened during the blossoming stage, followed by the milking stage and finally the soft dough stage.

Seed discoloration is mainly the result of various fungal mycoflora such as *Helminthosporium* spp. *Curvularia* spp., *Fusarium* spp., *Trichoconiella* spp., *Gerlachia* spp., *Cercospora* spp., *Phoma* spp. and *Pseudomonas* spp. (Tariq *et al*., 2012). It may occur or seen on both kernels and glume. One of the parameters controlling this disease was discovered to be the overall opening period of an individual flower during blossoming. The proportion of grain discoloration was found to be highest in the variety with the longest flower opening period (Tariq *et al*., 2012).

Pathogens associated with seed discoloration. Rice seeds infected from a total number of 59 genera of fungus and 99 species. These fungi are divided into two types:

1. Storage fungus: These are saprophytes that develop after harvest, and

2. Field fungi: A parasitic fungi and contaminate the grains prior to harvest.

Fungus associated with the different types of seed discoloration is elaborated in Table 1.

Table 1: Fungal pathogen associated with different types of seed discoloration.

Sr. No.	Seed discoloration	Pathogens attributed to discoloration	References
1.	Tip spot discoloration	*Fusarium moniliforme*	Pratap *et al*. (2020)
2.	Base discoloration	*Curvularia lunata*	Pratap *et al*. (2020)
3.	Grey spot discoloration	*Alternaria alternate*	Chandramani and Awadhiya (2014)
4.	Black spot discoloration	*Cochilobolus miyabeanus*	Chandramani and Awadhiya (2014)
5.	Ash gray spot discoloration	*Alternaria alternata*	Sachan and Agarwal (1995)
6.	Seed coat, endosperm, and embryo of discolored seed have a light brown color	*Sarocladium oryzae*	Sachan and Agarwal (1995)
7.	Eye shaped spots discoloration	*Cochliobolus geniculatus*	Sachan and Agarwal (1995)
8.	Dark brown, Black, dark purple, colour spots and light to dark brown dot like spots on the seed coat and endosperm	*Bipolaris oryzae*	Sachan and Agarwal (1995)
9.	Light pink spot discoloration	*Fusarium graminearum, Fusarium equiseti and F. moniliforme*	Sachan and Agarwal (1995)
10.	Brown or black spots or blotches on grain	*Trichoconiella [Alternaria] padwickii and Drechslera oryzae*	Ranganathaiah (1985)

The prevailing fungi in the embryo section were *Dreschelera oryzae, Sarocladium oryzae* and *Curvularia lunata*, which were isolated from the husk, pericarp, endosperm and embryo. In comparison to other components, the husk part was more prone to fungal disease (Rao *et al*., 2018). In the field, six fungal species have been observed connected with discolored panicles of various varieties: *Curvularia oryzae, Alternaria alternata, Fusarium moniliforme, Dreschelera oryzae, Cercospora oryzae* and *Helminthosporium oryzae*. *Alternaria alternate* and *Helminthosporium oryzae* were the predominant species on all the varieties (Azher and Muhammmad 2017). Fungi isolated from rice discolored seeds were *Sarocladium oryzae, Bipolaris oryzae*, *Curvularia lunata, Fusarium moniliforme, Aspergillus flavus* and *Penicillium* spp. (Said *et al*., 2015). *Cochliobolus geniculate* was identified to be the cause of eye-shaped markings.

Pink colour on the seed coat, endosperm, and embryo of discolored seeds was also found to be caused by *Fusarium equiseti, Fusarium oxysporum* (*Gibberella* *zeae*), and *Fusarium moniliforme* (*Gibberella fujikuroi*), while light brown discoloration on the seed coat, endosperm, and embryo was caused by *Sarocladium oryzae* (Sachan and Agrawal 1994). Grain discoloration, caused by a complex of fungal species such as *Bipolaris oryzae, Sarocladium oryzae*, (*Cochliobolus miyabeanus*), *Curvularia lunata, Pyricularia grisea* (*Magnaporthe grisea*), *Microdochium* spp. and *Phoma* spp. *Fusarium* spp. and *Nigrospora* spp. are a major constraint for lowland and upland rice production, and is becoming more serious problem (Balgude *et al*., 2016). The pathogen was discussed morphologically, based on the color, shape, and size of the colony (Agarwal *et al*., 1989). On the basis of mycelial growth, spore shape and size stated in the technical bulletin on seed-borne illnesses and seed health testing of rice, microscopic examinations were done to confirm the pathogen. They divided seeds into two groups, one of which was surface sterilized for 2 minutes with a 2 percent sodium hypochlorite solution (Hafiz *et al*., 2009). The fungal pathogens isolated from discolored rice by the various researchers are listed in Table 2.

Table 2: Fungal pathogens isolated from discolored grain of rice.

Sr. No.	Fungal pathogen associated with seeds	References
1.	*Curvularia pallescens and Curvularia lunata*	Nasla *et al*. (2019)
2.	*Drchslera oryzae, Sarocladium oryzae,* and *Curvularia lunata*	Rao *et al*. (2018)
3.	*Curvularia oryzae, Alternaria alternata, Dreschelera oryzae, Fusarium moniliforme, Helminthosporium oryzae* and *Cercospora oryzae*	Azher and Muhammmad (2017)
4.	*Alternaria padwickii, Bipolaris oryzae, Curvularia lunata, Fusarium moniliforme, Aspergillus* spp. and *Fusarium oxysporum.*	Naher *et al*., (2016)
5.	*Bipolaris oryzae*, *Sarocladium oryzae*, *Pyricularia grisea*, *Curvularia lunata*, *Fusarium* spp., *Phoma* spp., *Nigrospora* spp., and *Microdochium* spp.	Balgude *et al*. (2016)
6.	*Bipolaris oryzae, Sarocladium oryzae, Fusarium moniliforme, Curvularia lunata, Aspergillus flavus* and *Penicillium* spp.	Said *et al*. (2015)
7.	*Curvularia* spp., *Fusarium* spp., *Cercospora* spp., *Gerlachia* spp., *Trichoconiella* spp., *Phoma* spp. and *Pseudomonas* spp.	Tariq *et al*., (2012)
8.	*Alternaria padwickii, Bipolaris oryzae, Sarocladium oryzae, Fusarium moniliforme, Fusarium pallidoroseum, Microdochium oryzae, Burkholderia glumae* and *Acidovoraxavenae* sp. *avenae*	Hajano *et al*. (2012)
9.	*Drchslera oryzae, Pyricularia grisea, Sclerotium, Alternaria alternata, Fusarium solani, Alternaria padwickii, Alternaria longissima, Aspergillus niger, Curvularia lunata, Curvularia oryzae, Fusarium moniliforme, Fusarium semitectum, Fusarium oxysporum* and species of *Phoma, Cercospora, Chaetomium, Colletotrichum* spp. and *Penicillium, Myrothecium*	Habib *et al*. (2012); Khan *et al*. (1990)
10.	*Curvularia* spp., *Alternaria* spp., *Helminthosporium* spp. and *Fusarium moniliforme*	Butt *et al*. (2011)
11.	*Fusarium moniliforme, Curvularia lunata, Bipolaris oryzae, Rhizopus stolonifer, Aspergillus* spp., *Phoma* spp., *Penicillium* spp., *Alternaria tenuissima, Nigrospora oryzae, Chaetomium globosum,Tilletiabarclyana* and *Xanthomonas oryzae*	Ora *et al*. (2011)
12.	*Bipolaris oryzae, Alternaria padwickii, Alternaria alternata, Dreschelera oryzae, Fusarium moniliforme, Curvularia oryzae* and *Nigrospora oryzae.*	Hafiz *et al*. (2009)
13.	*Alternaria padwickii, Bipolaris oryzae, Pyricularia oryzae, Phomasorghina, Fusarium moniliforme, Fusarium grminearum, Curvularia* spp. *and Nigrospora oryzae.*	Arshad *et al*. (2009); Ou, (1985)
14.	*Alternaria alternata, Pyricularia oryzae, A. padwickii, Curvularia oryzae, A. longissima, Drechslera oryzae, Curvularia lunata, Fusarium moniliforme, Fusarium semitectum, Aspergillus niger, Fusarium oxysporum, Fusarium solani* and species of *Phoma, Cercospora, Chaetomium, Sclerotium, Colletotrichum* and *Penicillium, Myrothecium*	Nguefack *et al*. (2007); Javed *et al*. (2002)

Rice seed discoloration epidemiology. In past, several researchers have reported that incidence of rice seed discoloration on the samples collected from Indian states such as Uttarakhand, Punjab, Haryana, Maharashtra, Uttar Pradesh, Kerala and Karnataka. It has also been reported in Uttar Pradesh's Terai region (Agarwal and Singh 1974). It was also reported in September, 1979 in Haryana where unexpected rainfall and storm occur after an extended period of drought that led to a severe occurrence of grain discoloration (Ahuja *et al*., 1980).

The rice grain discoloration also posed a major problem in Bhubaneswar, during June-July when rice was grown under semi-deep water. According to researcher, the rice malady had different effects in samples taken from all around Punjab, with Ludhiana having the highest prevalence of paddy discolouration at 4.42 percent, and Moga having the lowest frequency of rice seed discoloration (2.10 percent) (Jain *et al*., 2014).

Seed discoloration was particularly prevalent in Karnataka's coastal districts, posing a major threat to paddy cultivation (Saifulla *et al*., 1998). It is reported that a significant increase in occurrences of rice seed discoloration in the common of rice-growing areas in Assam results in lower utilization and poor market value (Bora and Gogoi 1993). Under natural conditions, 28 to 46 percent seed discoloration found in rice varieties in Tamil Nadu (Uma and Wesely 2013). Glume discoloration is an ongoing issue for major rice-producing countries, as it is typically caused by fungus and other associated bacteria (Sumangala *et al*., 2010). This disease degrades the nutritional content of seed and poses a threat to consumers, maybe due to the incidence of numerous contaminants.

MANAGEMENT

Management of this disease can be done by various methods which are reported by earlier workers.

Currently, there is no effective control strategies or rice types that are completely resistant to the disease (Schaad, 2008).

Cultural Practices. The use of clean seeds minimizes the spread of rice seed-borne infections resulting increasing output. It reduces unfilled grains by 5.83-8.73% in the dry season and discolored seeds by 8.32-8.65 % in the rainy season. Seed quality is improved by using a simple hand seed cleaning approach (Mathur *et al*., 2001). Low moisture level and high physical purity promote germination and high vigor index along with minimal microbial invasion (Khamari *et al*., 2018). The temperature ranged from 25 to 37 °C, moderate rainfall, high relative humidity (70-76 %) and high wind speed played a critical role in the disease outbreak in NRRI, Cuttack in 2019 (Baite *et al*., 2010). Seed treatment (ST) with benomyl (0.3%), later *P. fluorescens* (0.5%) + soil application of rice husk ash at sowing on raised beds (1 kg m^{-2}) and soil application of rice straw @ 2 tones ha-1 at transplanting with highest per cent disease reduction and increase grain yield (Balgude and Gaikwad 2016). reported that seed treatment with *P. fluorescens* @10g/kg performed better with lowest per cent incidence of sheath rot and grain discoloration (Jayasekhar and Kavitha 2020). Farmers generally dry and winnow seeds before sowing, but they were unconcerned with seed treatment before sowing. As a result, seed therapies should be considered in the disease's remedy.

Biological Management. The application of fungicides on a regular basis causes ecological and health problems coupled with the development of resistance (Jayawardana and Weerahewa 2016). Many biopesticides, such as neem, nishinda, garlic, and alamanda, plus biological control agents, such as *Trichoderma*, can be utilized as seed treatment agents, resulting in increased germination, plant stand, disease incidence, and yield of crops. Over the beneficial effects of nano encapsulation of neem oil, some issues need to be resolved so that the synergistic effect of nanoparticles associated with this botanical insecticide can significantly contribute to the control of disease and insect pests (Ahmad *et al*., 2015). It is reported that plant extracts are being used to combat a specific pathogen in order to control plant disease (Naher *et al*., 2016). Seed treatment with plant extracts is an environmentally acceptable method of preventing seed-borne diseases, yet it is recognized to put consumers at risk. Because it lowers or removes seed-borne diseases and enhances seed germination, it might be considered a rapid approach.

Ahmad *et al*. (2016) tested leaf extracts from five plants, including *Azadirachta indica, Acalypha indica, Calotropis procera, Datura stramonium* and *Eucalyptus globulus* against *Alternaria alternata*. The workers found that all extracts were effective of suppressing fungus mycelial proliferation. Leaf extract of *Eucalyptus globulus* at 20% concentration caused the highest inhibition followed by *Azadirachta indica, Datura stramonium* and *Calotropis procera*. The lowest inhibition was recorded with *Azadirachta indica* in comparison to control. In Bangladesh, a study is conducted on three different plant spp. such as neem, chirata and garlic were investigated for their efficiency against various seed-borne fungi responsible for seed discoloration in rice (Ahmed *et al*., 2013). *Curvularia* spp., *Bipolaris* spp., *Alternaria* spp. and *Fusarium* spp. were all efficiently reduced by seed treatment with garlic extract at a 1:1 dilution. Neem extract (1:1) and chirata (1:1) extracts were also found to be efficient against seed-borne fungus.

In-vivo and In-vitro tests has done to assess the efficiency of pungam oil and neem -based emulsions against *Helminthosporium oryzae* and *Pyricularia oryzae* (Rajappan *et al*., 2001). Both pathogens were inhibited by neem cake extracts and neem oil, which resulted in a decrease in disease severity and enhances grain yield. The formulations were shown to outperform commercially available fungicides in terms of efficacy. In addition to being environmentally safe and sustainable in use, they are also easily biodegradable, which contributes to their overall effectiveness (Narasimhan *et al*., 1998). Therefore, seed should be treated before sowing.

Seed treatment with *Trichoderma viride* inhibited *Curvularia lunata* associated with seed discoloration and enhance seed germination upto 90.05 with vigor index of 1170.00. *Bacillus subtilis* increase 87.99% seed germination and 989.11 vigor index (Koulagi, 2011). It also reduces number of infected seeds and *Pyricularia oryzae* of rice. Hot water treatment (50°C for 15 min) and seeds treatment with microbial agents (*Trichoderma asperellum* and *Bacillus subtilis*) reduces the percentage of blast (*Pyricularia oryzae*) disease infected paddy seeds by 4.3 to 52.7 % comparative to non-treated seeds. *Trichoderma harzianum* and *Trichoderma viridae* recorded maximum mycelial of *Fusarium moniliforme* and *Curvularia lunata* accountable for seed discoloration in vitro (Pratap *et al*., 2020).

Chemical Management. Management of seed discoloration disease by application of different chemicals at different stages of flowering had been reported by different workers. Research was conducted among the twelve rice varieties, Nativo and Kumulus outperformed all compounds in reducing discolored panicle by 49.59 percent and 51.34 percent, respectively, compared to 67.40 percent for control. As a result of which the paddy yield may be improved significantly (Arunyanant *et al*., 1981). It is found suggested that kumulus was the most effective therapy for lowering grain contamination (Azhar *et al*., 2017). Habib *et al*. (2010) investigated various fungicides, including Copperoxycholoride, Dithane M45, Thiophanate Methyl, Alert Plus and Trimaltox forte to control seed-borne fungus of various rice varieties. Tebuconazole, Propineb and Mancozeb were proven effective against grain discoloration in the field trial and enhanced paddy output. A combination of fungicides (Carbendazim + Mancozeb) decreased panicle infection and improved paddy yield (Adhikari and Bhowmic 2010).

Silicon foliar spray controlled the disease to the same extent as a fungicide, allowing for a reduction in the amount of fungicide required. As a result, suggested that it could be a feasible alternative to synthetic fungicide application (Nasla *et al*., 2019). Different researchers found similar results in an experiment using Dithane M 45 and Ceresan to inhibit various rice seed-borne fungus. To control grain discoloration, apply anvil at a rate of 1-1.5 litre per acre 5-10 days after flowering (Hai, 1996). Integrated disease management of seed discoloration, three years pooled results reported that the lowest seed discolouration (22.11 %) with highest per cent disease reduction (58.02) and highest grain yield (31.14 q/ ha) with 126.66 per cent increase over control was recorded in the treatment combination of seed treatment (ST) with benomyl (0.3%) followed by *Pseudomonas fluorescens* (0.5%) + soil application of rice husk ash at sowing on raised beds (1 kg m^{-2}) and soil application of rice straw @ 2 tones ha^{-1} at transplanting with three sprays of propiconazole (0.10%) starting first spray at disease appearance, second at panicle emergence and third at grain filling stages (Balgude *et al*., 2016). ST + cultural practices with sprays of carbendazim (0.10 percent), bitertanol (0.25 percent) and tricyclazole (0.10 percent) reduced grain discoloration by 49.16, 55.49, and 47.89 percent, respectively and increased grain yield by 113.32, 99.47 and 88.12 percent (Balgude *et al*., 2016). Different rice-based fungicides *viz*; Trifloxystrobin (25%) + Tebuconazole (50%) WG, Tebuconazole (25.9%) EC, Carbendazim (50%) WG, Propiconazole (25%) EC, Hexaconazole (5%) EC and Mancozeb (63 %) WP against the mycelial growth of rice seed discoloration causing pathogen *Curvularia lunata*. Among all the fungicides tested, Trifloxystrobin (25%) + Tebuconazole (50%) WG and Tebuconazole proved to be completely effective in inhibiting the growth of the pathogen at low concentrations i.e., 750 and 500 respectively compared with other fungicides and control (Rao *et al*., 2018). These losses can be minimized through single spray of Propiconazole @ 0.10 % milking to dough stage which also improved certain yield contributory characters like grain and weight (Said *et al*., 2015).

CONCLUSIONS

Looking at the losses caused by seed discoloration in rice and the pathogens associated with them, the management strategies should be designed by improving the cropping practices at the farmer's level. Utilization of the genetic resources of rice (such as resistant varieties) and management of the pathogens using integrated and advanced approach like bio-intensive practices, bio fungicides and new generation formulations should be adopted which will minimize the losses caused by seed discoloration.

Conflict of Interest. None.

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