Chapter

Emerging Minor Diseases of Rice in India: Losses and Management Strategies

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Abstract

Rice (*Oryza sativa* L) being one of the imperative food crops of the word contributes immensely to the food and nutritional security of India. The cultivation of rice is changed over the decades from a simple cultivation practices to the advanced cultivation to increase yield. Increased in rice yields especially after 1960s is mainly due to the introduction of high yielding semi-dwarf varieties which requires more inputs like chemical fertilizers, water and other resources. As a result, India achieved self sufficiency in rice and currently producing more than 115 MT of rice to meet country's demand. Now India is exporting rice to other nations and earning foreign returns. With the change in rice cultivation practices, problems also aroused side by side. A number of biotic and abiotic stresses emerged as major constraints for rice cultivation in diverse agro-climatic conditions and growing ecologies. Diseases are the major biotic constraints to rice which can reduce the yields by 20–100% based on severity. Major diseases like blast, brown spot, bacterial blight, sheath blight and tungro still causing more damage and new minor diseases like bakanae, false smut, grain discoloration, early seedling blight, narrow brown spot, sheath rot have emerged as major problems. The losses due to these diseases may 1–100% based on the growing conditions, varietal susceptibility etc.., At present no significant source of resistance available for any of the above emerging diseases. But looking into the severity of these diseases, it is very important to address them by following integrated management practices like cultural, mechanical, biological and finally chemical control. But more emphasis has to be given to screen gerrm-plasm against these diseases and identify stable source of resistance. Finally utilizing these sources in resistance breeding program by employing molecular breeding tools like marker assisted selection (MAS), marker assisted back cross breeding (MABB), gene pyramiding and transgenic tools. The present chapter discusses the importance of these emerging minor diseases of rice, the losses and possible management measures including resistance breeding.

Keywords: sheath rot, bakanae, false smut, narrow brown spot, early seedling blight, narrow brown spot, disease management, resistance breeding, molecular tools

1. Introduction

Indian agriculture is considered as "Gambling with monsoon" which means the production and productivity of Indian agriculture is mainly depends on the quantity and distribution of monsoon rains. Among them, South West monsoons are very important which covers major area of the country and directly indicates the country's production. Agriculture sector plays a vital role in country's economy and is the backbone of the country. Country produces almost all the agricultural commodities starting with cereals, pulses, oilseeds, commercial crops, fruits, vegetables and plantation crops [1]. Among the commodities cereals contribute to the major proportion which is the means of daily staple food. Major cereals like Rice, Wheat, Maize and minor cereals like sorghum, bajra, ragi (finger millet), etc.., contribute significantly to the daily calories of the people [2].

Rice (*Oryza sativa* L) is considered as one of the imperative food crops of the globe. Rice is being cultivated since ancient times to feed the population. The crop is the staple food source feeding more than half of the world's ever-growing population [3]. The crop is grown by more than one hundred countries of which more than 70% of the production comes from Asian countries. The crop also cultivated in small to medium scale in Africa, Europe and American countries [4]. India grows rice in 43 M ha with production of 112 million tons (Mt) of milled rice and average productivity of 2.6 t^{-1} ha. The crop is grown in highly diverse conditions ranging from hills to coasts. Primarily a *kharif* crop, it is cultivated round the year in one or the other parts of the country [5]. Rice production in India has made tremendous progress over the years. However, it is facing unprecedented challenges of environmental degradation and climate change in recent years [6–8]. Low and uncertain income, degraded natural resource base, growing labour and energy shortages and threats of climate change are making Indian agriculture highly vulnerable and unsustainable [9–12].

Though green revolution brought tremendous changes in production and productivity of food grains, it also led to some of the related problems. There has been a constant increase in the number of insect pests and diseases, some of the non-insect pests, nematodes over the years [13]. The country witnessed a number of epidemics due to these biotic stresses. The level of incidence, quantum of damage has changed over the years [14]. These pests and diseases showed a concomitant shifts from their minor status to major status/intensity depending on the region, varieties grown, environmental conditions and cultivation practices [15]. Major diseases of rice such as blast, brown spot, sheath blight, bacterial leaf blight and tungro have become more severe over the years, and a number of minor diseases like sheath rot, bakanae, false smut, grain discoloration, early seedling blight and narrow brown spot have emerged as major problems [16]. Similarly, among the insect pests, gall midge, white backed planthopper, gundy bug, leaf folder has emerged as major problems to the rice cultivation [4].

There may be a number of factors responsible for this changed scenario of pest status like intensified rice cultivation of high yielding varieties, cultivation of varieties lacking the resistance to major pests which provide rapid multiplication of pests, imbalanced application of chemical fertilizers, particularly the nitrogenous fertilizers, non-judicious application of chemical pesticides which leads to resistance development and changes in climatic conditions [13, 17]. Present review provides the information on important emerging diseases of rice, nature of damage, yield losses and possible management strategies to mitigate the losses due to these new emerging problems.

2. Important minor diseases, biology and the losses

2.1 Sheath rot

2.1.1 Distribution

Sheath rot has become a common problem in almost all the rice growing ecologies [18]. It is most common almost all the rice varieties with dense planting, nitrogen-responsive semi dwarf and tall varieties growing in India [19]. In eastern Indian states like Odisha, West Bengal, Jharkhand, North Eastern states, the famous varieties become highly susceptible [20]. The disease is emerging as major problem in North and South Indian states also causing both qualitative and quantitative losses. High yield losses due to the disease have been reported from all Asian countries also [21]. Sheath rot was first identified by Sawada in 1922 in Japan where it became a common problem [22]. Later the disease has been reported from low to moderate incidence from South and South East Asia [23], Kenya, Nigeria [24], USA [25] and Brazil [26, 27] Reported that, the disease is a major problem in Upland rice in West Africa where the rice cultivars were introduced from Asia. The yield losses due to the disease may vary from 20 to 85% depending on the growing conditions, cultivars and environmental conditions.

2.1.2 Identification symptoms

The disease is very important emerging problem caused by a number of pathogens. Among them, *Sarocladium oryzae* is the major fungal pathogen. The initial symptoms start as discoloration of the flag leaf. Rotting occurs on the on the leaf sheath which encloses young panicle. Irregular lesions on leaf sheath which are having gray centre with reddish brown margin. The lesions coalesce each other and covers entire sheath. Under severe infestation, the developing grains also infected and turn to dirty discolored having white fungal mass. The grains ultimately rot and gets chaffy. The panicle will not emerge out of sheath. The plants may stunt and dies prematurely [22]. The disease symptoms are provided in **Figures 1–4**.

2.1.3 Pathogen

Rice sheath rot is a complex disease that can be caused by various fungal and bacterial phytopathogens. Major phytopathogens associated with the disease are *Sarocladium oryzae* and *Fusarium fujikuroi* species complex (*Fusarium*

Figure 1.
Infected leaf sheath.

Figure 2.
Severe infection.

Figure 3.
Infected grains.

Figure 4.
The panicle turned chaffy.

fujikuroi, *Fusarium verticilloides* and other *Fusarium* spp.). Bacterial pathogen like *Pseudomonas fuscovaginae* is associated with the disease. Among these pathogens, *Sarocladium oryzae* is the major pathogen which was originally identified as *Acrolyndrium oryzae* when it was first reported from Taiwan in 1922 [28]. Later in 1975, the genus *Sarocladium* was established [29] and the pathogen was renamed as *Sarocladium oryzae*. The genus Sarocladium currently comprises of 16 species including plant pathogens, saprophytic microbes, endophytes, mycoparasites and some of the potential human pathogens [30]. The pathogen grows slowly on Potato Dextrose Agar (PDA) at 2.5 mm per day at 28°C. It produces sparsely branched white mycelium with yellow pigmentation underside. It also produces numerous microsclerotia which are round in shape and orange colored. The pathogen produces simple or branched conidiophores. The conidia are cylindrical, septate./ aseptate and hyaline measuring 4–7 X 1–2 μm in size (**Table 1**).

2.1.4 Epidemiology and integrated disease management

The disease is reported from moderate to severe form in almost all the rice growing countries. The disease is very common and severe in Monsoon/rainy season and reported in low to moderate form in summer months [31]. Sharma et al. [32] observed that, the disease incidence in Nepal was found below 1250 M altitude at a temperature of 20-30°C and relative humidity of 65–85%. Similar observation found by [33]. The sheath rot pathogen survives in infected seeds (having seed borne nature), plant residues like straw, stubble, chaffy grains. It can also found in soil, water when environmental conditions become favorable. The pathogen may attack the plants at various growth stages. The fungus enters through stomata, wounds and found to be most destructive during booting and grain developmental stages [34]. The nature of entry and extent of damage also facilitated by insect and mites damage by weakening of the plants [34]. Secondary transmission of the pathogen may be by wind and rain splash.

2.1.5 Integrated management

Though the disease can be managed through number of measures, breeding for resistance is the best option for its management. Breeding for disease resistance is bit difficult and challenging as the disease is caused by a number of pathogens. Many researchers have identified few resistant varieties. Hemalatha et al. [35] developed method of screening for resistance against. *S oryzae* based on a crude toxin preparation. Pathogen variability, its virulence pattern, geographical location and cultivars growing are the points to be considered while breeding for diseases resistance. Select suitable resistant varieties for sowing: Jalmagna, Latisali, Rasi, Pankaj etc., Apart from resistance breeding other management practices should also be followed [36]. Use of healthy seeds, limiting insect pest population, avoiding densely planting, balanced application of chemical fertilizers especially nitrogen and increased application of potassic fertilizers. Similarly adoption of field sanitation, weed control, crop residue management is the some of the recommended cultural practices. Treat the seeds with carbendazim 50% WP @ 2 g/kg or biological control agents like *Trichoderma* or *Pseudomonas* talc based formulations @ 8–10 g/kg of seeds. Soil application of *Pseudomonas fluorescens* @ 2.5 kg/ha after 30 days of transplanting mixing with 50 kg FYM. Removal and destruction of weeds, infected stubbles should be done at critical periods. Application of potash at tillering stage is helpful in disease reduction. At booting stage, spray fungicides like carbendazim 50% WP @ 500 g/ha or mancozeb 75%WP @ 1 kg/ha or Iprobenphos 48EC @ 1 kg/ha or Thiophanate methyl 70%WP @ 500 g/ha or Isoprothiolane 40%EC @ 750 ml/ha. During grain maturity stage, spray systemic fungicides like Ediphenphos @ 500 g/ha or a combination of Tridemorph 80% EC (fungicide) + phosphamidon 40% SL (insecticide) to give better control of sheath rot. Foliar spray of calcium sulphate and zinc sulphate is effective against sheath rot.

Sl. No	Pathogen	Survival	Host range	Most susceptible plant stage	Dissemination	Reproduction	Relevant metabolites
1	*Sarocladium oryzae*	Seeds, plant residues, soil, water	Weeds, bamboo, sedge	After booting stage	Wind, rain, insects, mites	Aseptate conidia	Helvolic acid, cerulenin
2	*Fusarium fujikuroi*	Seeds, plant residues, soil		All stages	Wind, rain	Macro- and microconidia, no chlamydospores	Fumonisins (low levels in some strains), gibberellins, moniliformin
3	*Fusarium proliferatum*	Seeds, plant residues, soil	Wide host range	All stages	Wind, rain	Macro- and microconidia, no chlamydospores	Fumonisins (high levels), moniliformin
4	*Fusarium verticillioides*	Seeds, plant residues, soil	Wide host range	All stages	Wind, rain	Macro- and microconidia, no chlamydospores	Fumonisins (high levels)
5	*Pseudomonas fuscovaginae*	Seeds, epiphytically and endophytically on rice	Wild and cultivated Gramineae	Seedling and booting stages	Wind, rain	Bacterial cells	Fuscopeptin, syringotoxin

Source: Bigirimana et al. [21].

Table 1.
Pathogens associated with rice sheath rot disease and their characteristics.

2.2 Bakanae/foot rot (foolish seedling disease)

2.2.1 Distribution

Bakanae or foot rot is one of the important emerging diseases of rice, caused by *Fusarium fujikuroi* (Nirenberg) [teleomorph: *Gibberella fujikuroi* (Sawada) Ito]. The disaese has become a major concern in basmati growing tracts of north India during last few years [37, 38]. The northern western states like Punjab, Haryana, eastern UP, Uttarakhand and Delhi are facing serious problem of disease especially in basmati growing regions. But recently the disease is emerging as a major problem in eastern and north eastern states like Odisha, West Bengal and Assam leading to the susceptibility of popular varieties in this region [39]. Bakanae disease induces grain sterility resulting in a considerable loss of grain yield [40]. Reports have shown that the disease can cause even 70% yield loss and quality under field conditions [41]. In eastern and north eastern states of India, popular varieties like Pooja, Swarna and Abhishek became highly susceptible to the disease. Earlier reports indicates that, the disease occurs sporadically in Asia. The term 'Bakanae' is of Japanese origin meaning 'bad', 'naughty' or 'foolish' seedling, indicating the unusual early elongation of seedlings due to the production of gibberellins on infection process. The fungus produces both gibberellins which causes seedling elongation and fusaric acid, attributed to seedling death [42].

2.2.2 Identification symptoms

Initial symptoms appear as pale green and lanky seedling sporadically in the field. The seedling later shows abnormal elongation which is much taller than normal plant. The intermodal length will be more and production of fibrous roots seen from each nodes. White powdery mass of the pathogen produces in each node later covers entire plant. The entire plant gets killed without producing any grains. Death of the plants is called as foot-rot. The pathogen produces two toxins, (1) Gibberellic acid which is a growth hormone leads to elongation symptoms and (2) Fusaric acid which lead to death of the young seedlings.

The symptoms and disease severity is mainly depends on the quantity of these two metabolites produced in response to pathogen infection and environmental conditions. The pathogen is both seed-borne and soil-borne, so the infection may occur either by sowing the infested seeds in non-infested fields or by sowing the healthy seeds in infested fields. The inoculums of the pathogen may build up in soil if a susceptible variety grown in the same field year after year. Seed-borne inoculum plays a major role in secondary transmission of the disease under favorable environmental conditions by producing numerous conidia and infects fresh plant [43]. The pathogen infects rice grains during field and carried to storage, the contaminated seeds after sowing in field will results in disease incidence by the colonization of pathogen in seedlings [44]. *F. fujikuroi*-infected seedlings show morphological and colure abnormalities (**Figures 5**–**8**). The abnormal symptoms include elongation, stunting, large angle between leaf and stem, production of roots from each node and yellowish-green leaves [45]. Because of the different kinds of symptoms, bakanae disease is a complex and contradictory (e.g., elongation and stunting symptoms), and depends on varietal response also.

2.2.3 Epidemiology and Integrated management

Management of the disease is very challenging as the pathogen is seed borne. Once the disease establish in field, it is very difficult to manage. Most commonly

Figure 5.
Death of the seedling after transplanting.

Figure 6.
Abnormal elongation of seedlings.

Figure 7.
Production of fibrous roots from nodes.

used management practice was hot water treatment or fungicide seed treatment [45]. But it was found ineffective as the thermal effect is not efficiently transmitted to the pericarp layer of the seeds. Several fungicides also found in effective as seed treatment chemicals due to development of resistance and as a result fungal spores will not destroy [46]. But several researcher shown that, some of the fungicides as seed treatment and seedling dip treatment found effective [47]. There are also reports of management of the disease with Biocontrol agents such as *Bacillus* spp. (), *Pseudomonas* spp. A combination antagonistic yeasts and thermotherapy was

Figure 8.
White powdery mass of the pathogen at the base of stem.

found to be efficient in managing the disease [48]. Presently the disease is emerging as an alarming state in almost all the rice growing areas of India and worldwide [38]. Looking for alternative management practices other than usage of chemical fungicides is the need of the hour. Alternative management measures such as usage of bio-control agents, chemical elicitor compounds which induce resistance are promising. Along with this, identification of rice bakanae resistant cultivars is more promising and to be taken up in priority [49]. Many researchers have screened numerous accessions against rice bakanae disease to identiofy genes/QTLs responsible for resistance [50, 51]. Select suitable resistant varieties for sowing. Varieties like Chandan, Improved Tapaswini, Sarasa, Kshira, CR Dhan-311, Wifa-10, Improved Lalat, Palguni, Saket-4, Maudamani, Kalinga-II, Naveen, Kalinga-I, CR Dhan-305, Khitish, Satabdi, CR Dhan-310, CR-29-83, IR-29, Udaya, Padma. Treat the seeds with carbendazim 50% WP @ 2 g/kg or biological control agents like *Trichoderma* or *Pseudomonas* talc based formulations @ 8–10 g/kg of seeds. Remove and destroy infected plants from main field. Do not used farmer saved seeds for sowing in the next season. Foliar spray with combination fungicide, Trifloxystrobin 25% + Tebuconazole 50% WG (75%WG) @ 1 g/lit will give the protection to some extent.

2.3 False smut

2.3.1 Distribution

False smut or green smut is a common disease of rice caused by *Ustilaginoidea virens* in rice growing regions of India. Epidemics of false smut disease of rice were reported in Tamil Nadu in India and later in many countries of world [52]. Pannu et al., [53] also reported losses up to 44 per cent in Punjab. In Uttar Pradesh, yield losses up to 44 per cent were observed by Singh and Dube. In some rice growing districts of Bihar, 15–50 percent losses occurs due to false smut of rice when comes as medium to severe form [54]. The fungus overwinters in soil by means of sclerotia and chlamydospores. Sclerotia produces ascospores, which are primary source of infection to rice plants, whereas secondary infection may come from air-borne chlamydospores [55, 56]. Sclerotia can survive in the field for several months. Infection starts in grains of rice before flowering. Infection results in one or more kernels on mature heads of plants being replaced by globose, yellowish-green, velvety smut balls. When smut balls burst open, powdery dark green spores are released [57]. The infection of *U. virens* is favored by high relative humidity (>90%) and temperatures between 25 and 30°C [58]. Rainfall, high humidity, and soils with high nitrogen content during flowering also favors disease development [59]. Reports on the effect of rainfall are conflicting, high disease intensity has been attributed to rainfall at heading, but the opposite (low rainfall favoring the disease) has also been reported [60]. The fungus attacks some of the weed species that commonly occur in rice fields and may also serve as sources of inoculums [57].

The pathogen specifically infects rice flowers and later transforms the grains into smut balls. Initially the balls are slightly flattened, yellow in color covered with a thin membrane. As the smut ball matures, it increases in size converting yellowish-green to green or greenish-black. At final maturity, the entire smut ball looks dark black in color with rough surface. Very few grains in the panicle or all the grains may convert into smut balls (**Figures 9–12**).

2.3.2 Integrated management

Select seeds which are free of smut balls for sowing. Avoid excess nitrogenous fertilizer application. Follow alternate wetting and drying of the field to avoid moisture build-up which helps in disease incidence. Remove and destroy infected panicles, crop debris after harvest. Identification of the stable and durable sources of resistance is always been the better option in disease management [56]. Large number of varieties have been screened and identified for their resistance or tolerance to false smut disease under artificial/natural inoculation conditions [60].

Figure 9.
Yellow ball covered with thin membrane.

Figure 10.
The ball converting to greenish-yellow.

Figure 11.
The ball converted to black sori.

Figure 12.
Heavily infected panicle.

Artificial inoculation is still not dependable which is the major obstacle in screening large number of varieties under artificial conditions [56, 61]. Phenotyping for false smut resistance has been taken by many researchers in India, Philippines, China, Bangladesh, Pakistan and other countries by following standard evaluation system (SES) scale of IRRI (2002). In India, Kaur et al. [62] identified some of the hybrids namely VNR-211, GK-5025, HRI-140, IRH-74, PRSH-9018, KPH-467, RH-10428, 27P64 and KRH-4 showing complete resistance to false smut. Screening and identification of genotypes and QTL mapping is been carried out by pioneer rice research institutes in India such as National Rice Research Institute, Cuttack (Odisha), Indian Institute of Rice Research (IIRR), Hyderabad (Telangana), Punjab Agricultural Universty (PAU), Ludhiana (Punjab) and Indian Agricultural Research Institute (IARI), New Delhi. Identification of quantitative trait loci (QTL) and utilization in resistance breeding program is atmost priority in management of this disease [63]. Other management options like Seed treatment should be followed strictly: use carbendazim 50% WP @ 2 g/kg or biological control agents like *Trichoderma* or *Pseudomonas* talc based formulations @ 8–10 g/kg of seeds. Fungicidal spray with Propiconazole 25EC @ 500 ml/ha or copper hydroxide 77%WP @ 1.25 kg/ha at boot leaf initiation stage. Repeat the above spray at 50% flowering stage. Biological control of false smut disease has been successful with the strains of *Bacillus subtilis* in solution of Validamycine [64, 65].

2.4 Grain discoloration/dirty panicle disease

Pathogen: *Drechslera Oryzae, Sarocladium oryzae, Alternaria padwickii, Curvularia spp., Epicoccum sp., Fusarium moniliforme, Aspergillus spp.*

2.4.1 Identification symptoms

Seed discoloration has time and again proved to be a major recurring issue in the Indian coastal regions haltering the levels of desired grain production. Discoloration, though a minor disease in nature, has assumed a greater importance in agriculture owing to effect of global warming in production due to unpredictable hailstorms, delayed or low levels of rainfall, higher temperature and humidity levels after fowering stage. This has further led to relaxation in the procurement norms by the agencies. Grain discoloration serves as a visible indicator of seeds having lower quality in association with [66] microorganisms. This malady has been a prime retardant in the post-harvesting of paddy grains. The minimum threshold for the procurement of discolored kernels of paddy crop is kept at 3%, and all the samples above that are rejected. Several biotic and abiotic factors are responsible for discoloration of rice seeds. Glume discoloration is term for the alteration in color of mature seed from its original color, and seed possesses series of problems in seed certification programme. This disease though minor in nature reduces the vigor and yield of the crop and causes grain discoloration at maturity, thus reducing the economical and marketable value of the crop. The prevalence of monoculture and year around growth of only economical crops like paddy and wheat have led to seed discoloration gradually turning out to be a major problem [67]. This is also due to the many pests and pathogen that are common to both the crops. Since rice is a crop of immense importance, there is an increased need for research and development on various fungal fora that can afect the vigor, yield, morphology and constitution of the newly introduced higher yielding and aromatic rice cultivars. The reason for such discoloration whether pathological and/or non-pathological is not always clearly understood. In most of the cases, discolored rice seeds are frequently associated with micro-organisms, mainly fungi, though sometimes it also occurs due to insect bite and physiological or genetic reasons. Attempts have been made in the past to identify causal agents causing seed discoloration and also to control them by the use of chemicals. Grain discoloration is the early indication of poor yield and quality which leads to reduced market value. The discolored grain suffers more infection during storage also due to the development and infection of many storage fungi [68, 69]. Storage fungi such as *Aspergillus* spp. and *Fusarium* spp. produce deadly micotoxins which are detrimental to the human and animal health. Fungal pathogens such as *Alternaria alternata* (cause ashy gray discoloration) and *Helminthosporium oryzae* (cause black dicolration with dark brown spots on seeds) found mostly on the seed coat and endosperm region of the seeds. *Curvularia geniculata* which caused eye shaped spots, *Fusarium* spp. (*Fusarium oxysporum, F. moniliformae*) are responsible for pink discoloration and *Sarocladium oryzae* causes light brown discoloration. All these fungi found in embryo, seed coat and endosperm of the seeds [70]. Maximum colonization of seed borne fungi was observed in seed coat (0–3.30%) and endosperm (0.1–1.65%) as reported by Halgekar and Giri [71]. The losses due to grain discoloration were estimated approximately about 20–25 percent [72]. In our previous studies we reported that, the grain discoloration incidence ranged from 25 to 92% in different rice genotypes [73]. There may be a number of factors responsible for the disease starting from the varietal susceptibility, changed climatic conditions and agronomic managements which ultimately leads to the increased incidence of the disease with more damage.

The disease is an important emerging problem in all the rice growing seasons. The type of infection may be external contamination by saprophytic pathogens or internally seed born where pathogens infects endosperm. There are different kinds of like ashy gray discoloration, black discoloration, pink discoloration and light brown discoloration based on the pathogens involved (**Figures 13**–**16**). The infected grains convert into dirty discolored grains which have numerous spots and lesions on them. Infection in field may transfer to storage where the pathogens multiply and produces some of the harmful toxins. The early infection in field leads to complete yield losses due chaffiness of the grains. The severe infection leads to rotting of the panicles leads to qualitative and quantitative losses.

2.4.2 Integrated management

Use disease free seeds. The seeds should also be free from damage, chaffiness and other deformities. Treat the seeds with carbendazim 50% WP @ 2 g/kg or biological control agents like *Trichoderma* or *Pseudomonas* talc based formulations @ 8–10 g/kg of seeds. At tillering and pre-flowering stage, spraying of carbendazim 50% WP @500 g/ha or copper oxychloride 50% WP @ 1 kg/ha will control the disease effectively. At boot leaf initiation stage, spray with Mancozeb 75% WP @ 1 kg/ha or Iprobenphos 48% EC @ 500 ml/ha or Carbendazim 50% WP @250 g/

Figure 13.
Infected panicle.

Figure 14.
Discolored grains.

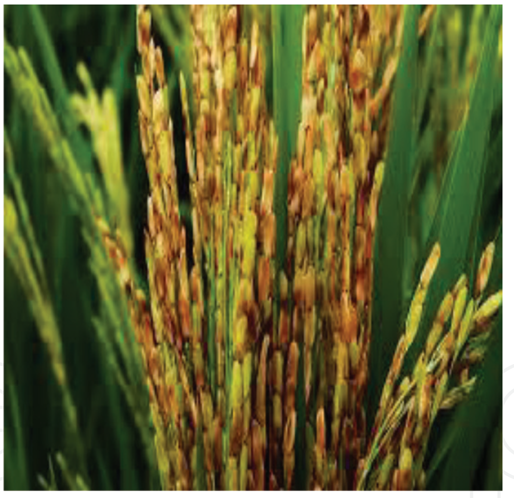

Figure 15.
Severe infection of the grains.

Figure 16.
Chaffy grains.

hac. During grain maturity stage, spray with Mancozeb 75% WP @ 1 kg/ha or Iprobenphos 48% EC @ 500 ml/ha. Biological control agents like *Trichoderma atroviride* or *Bacillus amyloliquefaceance* talc based formulations @10 g/lit of water at grain maturity stage.

2.5 Early seedling blight

Pathogen: *Sclerotium oryzae, Sclerotium rolfsii*.

2.5.1 Identification symptoms

The disease is one of the important emerging disease generally appears in nursery beds during cold season (winter months). Initial symptoms starts as wilting or drooping of the seedling in the nursery bed. Later, white mycelia mat of fungus developes on soil surface covering the seedlings (**Figures 17** and **18**). The fungal mat covers almost both root and shoots. As the disease progresses, development of white mustard shaped sclerotial bodies seen which later turn to dark brown hard structures. The disease may appear sporadically in nursery or covers entire nursery. Severe infection leads to death of the seedlings.

Figure 17.
Development of white sclerotial bodies of the fungus.

Figure 18.
Drying and death of the seedlings in nursery.

2.5.2 Integrated management

The disease is seasonal and do not have any resistant varieties. Follow clean cultivation: do not allow the nursery to in wet condition, always allow stand in water. Remove and destroy the infected seedlings. Drench with Carbendazim 50% WP @ 3 g/lit or Carbendazim (12%) + Mancozeb (63%) WP@ 2 g/lit of water.

2.6 Narrow brown leaf spot

Pathogen: *Cercospora janseana.*

2.6.1 Identification symptoms

Narrow brown leaf spot symptoms and disease cycle Cercospora janseana causes narrow brown leaf spot of rice [74]. Symptoms of narrow brown leaf spot (NBLS) disease include long cylindrical dark brown spots with dark margins and grayish centers with or without chlorosis. Lesions range from 1 to 10 mm x 1–1.5 mm on leaves and 15–45 x 1–2 mm on mid-ribs and leaf sheaths [74]. Morphology of symptoms varies with the susceptibility of the cultivar. On resistant cultivars, symptoms are long, narrow lesions that sometimes do not develop fully. In susceptible cultivars, spots are broad and necrotic. Initially, dark spots develop on the leaf lamina and later on the leaf mid-vein, leaf sheath, panicle, seed coat and glumes. Symptoms appear late in the season on all leaves regardless of age. NBLS causes a premature ripening of the grains, reduces yield quantity, and grain milling quality [75]. The disease cycle begins when *C. janseana* enters the plant tissues through stomata, establishes beneath the stomata in the parenchyma cells, and spreads longitudinally in intercellular. Upon development, conidiophores emerge through the stomata. Preliminary studies have shown that 30 or more days are required to develop symptoms after inoculation [76]. This long latent period may be the probable reason of late appearance of symptoms during the season even though infection occurs at early plant developmental stages. The initial source of inoculum appears to be from *C. janseana* that has survived on residues of previous rice crops, infected seeds, and seasonal weeds [77].

The disease is emerging as a major problem in wet periods. The disease causes severe necrosis of the leaf tissue and drying and death of the leaves. Initially, short, linear, brown lesions appears on leaf blades later extends to leaf sheath, pedicels and glumes. The lesions are 2–10 mm long and 1 mm wide in size (**Figures 19** and **20**). The size of the lesions depends on varietal susceptibility. The resistant cultivars have narrower and darker lesions whereas; the susceptible cultivars have wider and light brown. The lesions coalesce each other giving dried and burning appearance to field [78].

2.6.2 Integrated management

Use of resistant varieties should be the top priority in managing this disease. Mechanical control measures like removal and destruction of weeds, balanced nutrients especially Potasium is important. Foliar spray of Carbendazim 50% WP @ 500 g or Mancozeb 75% WP @ 2 kg or Hexaconazole 5% SC @ 500 ml/ha.

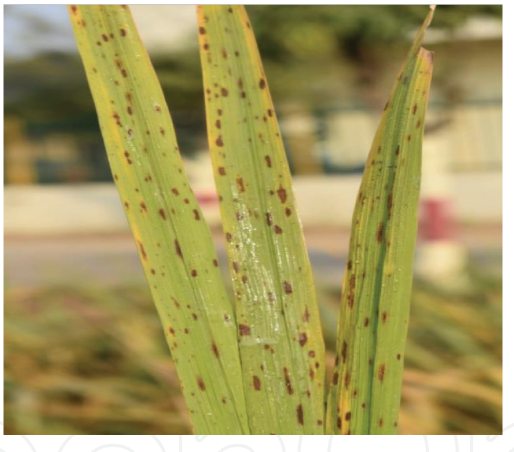

Figure 19.
Elongated, broad and light brown lesions on susceptible variety.

Figure 20.
Severely infected field.

3. Conclusion

Rice cultivation is subject to various constraints including environmental conditions, socio-economic status of the farmers, adequate resources availability. Change in cultivation practices like practicing intensive agricultural practices to enhance yield, the crop is suffering from a number of biotic constraints such as pest and diseases. In order to feed the ever-growing global population, it is necessary to manage the diseases to avoid losses. Over the decades, disease and pest management in rice relied primarily and most importantly on resistant varieties and chemical pesticides. But continuous cultivation of a single variety resulted in the familiar "Bom and Burst" cycle where most popular and high yielding variety will become highly susceptible to certain pest and diseases. This is mainly due to the shift in pathogen/pest dynamics, virulence level and population build-up. In several cases continuous use of chemical pesticides had lead to development of resistance, pest resurgence etc..,. on the other hand, a number of minor diseases have emerged as major problems which have created new challenges to rice cultivation. So, it is most important to address these emerging issues urgently by integrated management practices. Proper agronomic management measures, nutrient management is most essential. Developing resistance should be prioritized in tackling these emerging problems. Use of molecular tools like MAS, gene pyramiding, RNAi, Gene silencing, QTL mapping and CRISPR Cas9 technologies should be widely adopted. Used of biological control agents and their products is ecofriedly approach. At last, chemical pesticides should be an option not priority.

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