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Integrated Management of Rice Diseases

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A B S T R A C T

Rice (*Oryza sativa L.*) is a one of the most important staple food crops of the world nearly half of the world population depends on rice. Rice play an important role in global food security, it is prone to attack by many diseases caused by plant pathogens such as, fungi, bacteria viruses and nematodes. Among diseases, rice blast, bacterial leaf blight, brown leaf spot, sheath blight, sheath rot, stem rot, false smut, rice tungro virus and rice root-knot nemato deare economically important and they cause huge economic losses. Recently, due to change in the global temperature and change in climatic situation minor diseases are becoming major (false smut of rice and rice root-knot nematode), The various methods used for managing rice disease includes, use of resistant varieties, cultural practices, biological and chemical control. All these methods have varied degrees of success in managing rice diseases. The most important management tactics used worldwide includes use of resistant varieties and chemical control. Integration of all the management tactics (Integrated Disease Management) could help in effective and successful management of plant disease in rice. In this chapter we are showcasing the important diseases of rice, global distribution, economic importance and management strategies.

Keywords: Rice, Integrated Disease Management, Disease, Viruses

Introduction

Rice (*Oryza sativa*), the most important food crop of the world, it has been grown for more than 6000 years in South Asia. Rice is the staple food for about four billion people i.e., half of the population on the planet earth. It occupies around 160 million hectares in a wide range of climatic conditions. It is cultivated from 6 feet below sea level (Kerala, India) to 2700 feet above sea level in the Himalayas. The crop tenants a significant position in the culture and heritage of many Asian countries. In India, particularly in the eastern states, it is apart of almost every ritual. The crop has been referred in the Vedas, Ramayana, Mahabharata, Buddhist and other ancient literature (Pathak et al., 2018). Rice is currently grown in over 100 countries, and more than 1 billion people depend on it for their livelihood (Anon, 2002). Of the 475 million tonnes of milled rice produced globally, 85 percent is used for human consumption and the remaining 15 percent is used for animal feed or is wasted (FAO, 2012).

Plant diseases are considered as major constraints in achieving the potential yield. It is an important food crop in the world, is attacked by a number of pathogens such as fungi, bacteria, virus and nematodes. Due to change in cultivation practices, reduced varietal diversity resulting in narrow genetic base and apparent climatic changes, the dynamics of rice diseases has changed over time. The major diseases have become more aggressive and spread to new areas. Many diseases which were earlier considered as minor have become economically important in many regions. For example, false smut of rice which was earlier considered as a sign of a bumper harvest has become widespread and a threatening problem in many areas.

Many new disease problems (e.g. red stripe disease of rice, grain discoloration, rice root-knot nematode) have been reported from different rice-growing regions (Laha, et al., 2017). The major rice diseases that often cause great economic losses are rice blast (*Magnaporthe grisea*), Brown leaf spot (*Helminthosporium oryzae*) sheath blight (*Rhizoctonia solani*), Sheath rot (*Sarocladium oryzae*), False smut (Ustilaginoidea virens), Bacterial blight (Xanthomonas oryzae) and Tungro virus disease especially in South and South East Asia and recently rice root-knot nematode (*Meloidogyne graminicola*). All most all stages of rice (from nursery to harvest) are prone to attack by various types of pathogen.

The various methods used for managing rice disease includes, cultural practices, physical practices, use of resistant varieties, biological and chemical control. All these methods have varied degrees of success in managing rice diseases. The most important control tactics used worldwide includes use of resistant varieties and chemical practices. Breeding for disease resistant varieties has been long used for managing the rice diseases and is one of the most economical methods which contributed immensely to world's rice productivity (Mew, 1991; Bonman, et al., 1992). But, breeding of varieties does not give a significant results, most varieties are resistant only to a few major diseases that are the subjects of intensive breeding efforts. The rice production ecosystem, particularly in the tropics, and due to change in cultivation practices and change in global temperature serves as habitats of many rice pathogens causing varying degrees of damage. Even the neglected or minor diseases collectively could pose a significant threat to production (Mew, 1992). Moreover, the pathogen often develops new biotypes resulting in breaking down of resistance in the resistant varieties. Chemical control (fungicides, bactercides, nematicides) provides great opportunity for controlling rice diseases and over last two decades a lot of focus has been shifted towards developing new molecules that can be used for controlling rice diseases but limitations with respect environmental hazardous are more. As the most destructive rice diseases prevalent across the globe are caused by various pathogens viz., fungus, bacteria, virus and nematodes (Ling, 1980; Narasimha murthy, 2017). Hence, Integrated Disease Management (IDM) is an an important tool to control them. This chapter discusses about important diseases of rice, global distribution, economic importance and management strategies.

Important Diseases of Rice

Fungal Diseases

- Blast (*Pyricularia grisea* Cavara)
- Brown Spot (*Helminthosporium oryzae* Hiroë)
- Sheath Blight (Rhizoctonia SolaniJ.G. Kühn)
- Sheath Rot (*Sarocladium* oryzae Sawada, W. Gams & D. Hawksw)
- False Smut (*Ustilaginoidea virens* (Cooke) Takah)
- Stem rot (*Sclerotium oryzae* Catt., R.A. Krause & R.K. Webster)
- Grain discolouration - fungal complex

Bacterial Diseases

- Bacterial Leaf Blight: (*Xanthomonas oryzae* pv.oryzae (Ishiyama Swings et al.)
- Bacterial Leaf streak (*Xanthomonas oryzae* pv. oryzicola)

Viral Disease

- Rice tungro disease: Rice tungro virus (RTSV, RTBV)

Nematode Disease

- Rice-root-knot nematode (*Meloidogyne graminicola* Golden and Birchfield)
- White tip nematode (*Aphelehchoides besseyi* Christie)

Fungal Diseases

Rice is affected by various fungal diseases at different stage of the crop from nursery as well main field, leaf and panicle blast [*Magnaporthe oryzae* (anamorph: *Pyricularia oryzae*)], brown spot [*Cochliobolus miyabeanus* (anamorph: Helminthosporium oryzae)], sheath blight [*Thanatephorus* cucumeris (anamorph: *Rhizoctonia solani*)] and false smut [Villosiclava virens (anamorph: *Ustilaginoidea virens*)], Sheath Rot [*Sarocladium oryzae* (anamorph: *Acrocylindrium oryzae*)] are the most serious diseases. The emerging diseases like foot rot and bakanae [*Gibberella fujikuroi* (anamorph: *Fusarium moniliforme*)], and stem rot [*Magnaporthe salvinii* (anamorph: *Sclerotium oryzae*)] are also causing significant yield losses in some rice-growing regions.

Rice Blast

Occurrence and Distribution

Rice blast caused by *Pyricularia oryzae* is earliest known plant disease, it is one of the deadest and widely distributed disease of rice all around the world causes significant yield loss (DRR, 2014; Ou 1985). Due to its damaging potential it ranks in number 1 position among top 10 fungal plant pathogens (Dean et al., 2012). It is distributed in all most all countries where ever the rice is major crop (Figure 1). Blast is a dangerous disease in almost all types of rice cultivation system (Low land rice, upland rice and DSR). In temperate and subtropical Asia, it is highly destructive in nature especially in lowland rice, while in tropical Asia, Latin America and Africa, it affects upland rice. In India, the disease attained importance when a severe epidemic occurred in Thanjavur (Tanjore) delta of South India in 1919. This is the first record of blast disease of rice in India. Presently in India, blast is especially problematic in temperate areas, hilly tracts, tropical uplands and in delta regions. It causes an yield (grain yield) loss 70 to 80% (Laha et al., 2017).

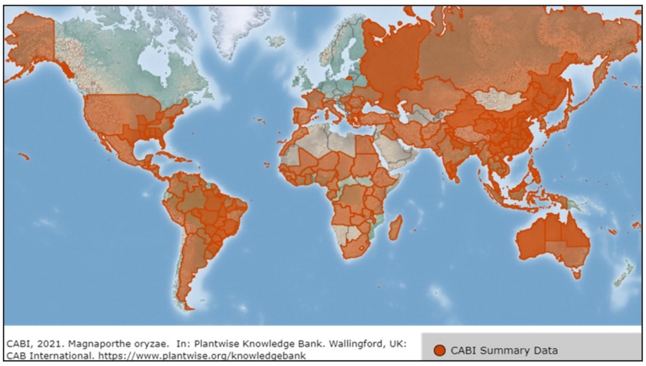

Figure 1.Global Distribution of Rice Blast Disease

Symptoms

The fungus can infect leaves, nodes and various parts of the panicle (Figure 2).

Leaf Blast: Initially, greyish or bluish dots of 1-3 mm diameter appear on the leaf blades. On susceptible cultivars, the spots enlarge quickly under humid conditions and become elliptical or 'eye shaped' with grey or whitish centre and brown or dark brown margin (Figure 2a, b, c).

Nodal Blast: The pathogen also infects the nodes that turn black and get weakened due to tissue disintegration, resulting in breakage of stem at the nodal region followed by death of all the plant parts (Figure 2d).

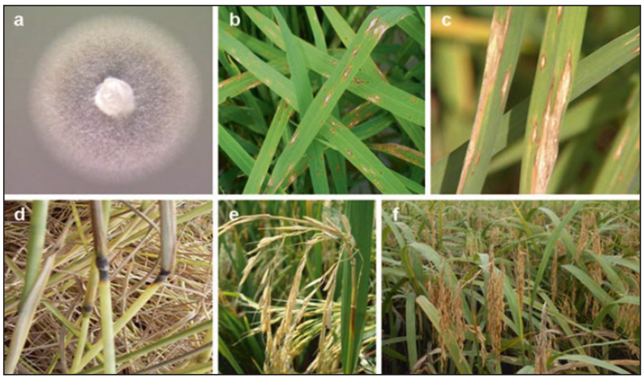

Figure 2.Symptoms and Pathogen of Rice Blast Disease: (a) *Magnaporthe Oryzae*, Pathogen of Rice Blast Disease; (b)Minute Blast Lesions on Leaves; (c) Characteristic Eye-shaped Lesions on Leaves; (d) Node Blast; (e) Typical Panicle Blast; (f) Severe Panicle Blast-infected Rice Field

Neck and Panicle Blast At the time of flowering, area near the panicle base is girdled by a greyish brown lesion, the panicle falls over in the case of severe infection (Figure 2e,f). The neck becomes shrivelled and covered with grey mycelium. If infection appears before the milk stage, the entire panicle may die prematurely. Later, infections may cause incomplete grain filling and poor milling quality. The pathogen also causes brown lesions on panicle branches and on the spikelet pedicels, resulting in panicle blast.

Disease Cycle and Epidemiology

Leaf blast is favoured by the low night temperature (22-28° C), high relative humidity (>95%), dew deposit, leaf wetness for more than 10 hours and high nitrogen. In temperate regions, mycelium and conidia on diseased straw and infected seeds are the principal sources of primary infection. The fungus can attack a number of cereal and grass hosts which could be important source of primary infection. In the tropical climate of South India, where several crops of rice are taken in a year, the pathogen maintains a continuous disease cycle on the rice crop itself. Under favourable conditions, the conidia can produce symptoms within 4-5 days of infection. Conidia are produced on the lesions 6-7 days after infection and disseminated by wind (Laha, et al., 2017).

Disease Management

- Remove collateral weed hosts from bunds and channels
- Use only disease free seedlings
- Avoid excess nitrogen
- In endemic areas, adopt seed treatment with Tricyclazole 75 WP @ 2 g/kg or Carbendazim 50 WP @1 g/kg.
- Apply N in three split doses (50% basal, 25% in tillering phase and 25% N in panicle initiation stage)
- In India, rice genotypes HKR 04-487, HKR 05-436, HKR 05-476, Haryana Mahak 11, PAU 3237-1-B-B-19, PAU 3237-1-B-B-20 and PAU 3237-1-B-B- 22 have been found resistant to both leaf blast and neck blast (Singh et al. 2010).
- Spray Tricyclazole 75 @ 0.6 g/litre or Carpropamid 30 SC @ 1ml/litre. or Isoprothiolane 40 EC @ 1.5 ml/litre or Iprobenphos 48 EC @ 2ml/litre or Propiconazole 25 EC @ 1ml/litre or Kasugamycin-B 3 SL@2.5 ml/litre or Carbendazim 50 WP @ 1 g/litre
- Many combi products like tricyclazole + propiconazole, tricyclazole + mancozeb, trifloxystrobin 25 % + tebuconazole 50 %, fenoxalin + isoprothiolane and epoxiconazole + carbendazim were found to be very effective against blast (DRR, 2014)

Brown Spot

Occurrence and Distribution

Brown spot of rice caused by *Cochliobolus miyabeanus* (anamorph: *Helminthosporium oryzae*) one of the devastating disease in rice it is responsible for famine ie., Bengal famine during 1943. This disease has historic importance as it caused epidemic in Eastern India which is considered to be a major factor for the 'Bengal Famine'. Beside quantitative losses, it is also known to reduce the quality and germin ability of the seed. Brown spot of rice it is known to occur in Japan since 1900. It has been reported from almost all the countries of Asia, Africa, South and North America including the Caribbean region, Australia and several European countries like France, Spain, Portugal, Switzerland, Serbia, Greece and Turkey (Ou, 1985; Khalili et al., 2012). Distributed in all the major rice growing countries (Figure 3). It causes an yield loss up to 90% (Sunder et al., 2014).

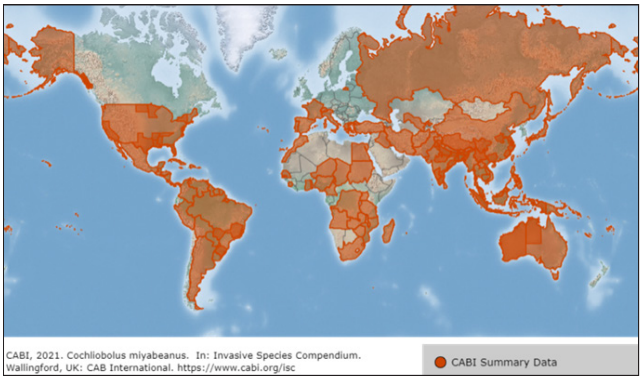

Figure 3.Global Distribution of Brown Leaf Spot Disease of Rice

Symptoms

Brown spot is a very common and destructive disease in lowlands, uplands and hill rice ecosystem, severity is more during kharif season. The disease occur both in nursery as well as main field, Causes blight of seedlings, Leaf spotting, brown, round to oval (resemble sesame seed), Spots measures 0.5 to 2.0mm in breadth - coalesce to form large patches, Seed also infected (black or brown spots on glumes spots are covered by olivaceous velvety growth), Infection also occurs on panicle neck with brown colour appearance, 50% yield reduction in severe cases. (Ou 1985). The pathogen has also been reported to cause brown to dark brown lesions on panicle stalk at the joint of flag leaf to stalk and appearance of greyish mycelial growth (Sunder et al., 2005).

Disease Cycle and Epidemiology

The pathogen survives in soil as well infected plant debris such as stubbles, straw and grains. They serve as primary source of inoculums and cause primary infection. Usually primary infection is initiated by the infected seed as necrotic lesions on coleoptile and sheath of first leaves. Later, lesions developed on leaves arise from secondary infection by airborne spores (Ou 1985). The congenial condition required for the development of disease includes, leaf wetness, more soil pH, delay planting, nutritional imbalances mainly lower levels of Nitrogen, Potash, Manganese, Silicon, low organic matter and other micronutrients. (Ou 1985; Datnoffet al. 1992).

Disease Management

- In endemic area, adopt seed treatment with Carbendazim (12%) + Mancozeb (63%) combination 75 WP @ 2 g/kg or Carbendazim 50 WP @ 2 g/kg or Mancozeb (63%) 75 WP @ 2 g/litre or Mancozeb 75 WP @ 2.5 g/litre
- Growing of resistant/tolerant varieties like Rasi, Jagnanath, IR 36 etc., HRC 726, HRC 7288, NIC 105703, NIC 105784 and NIC 1105815 (Shuklaet al., 1995) and BPT 1788, MTU 1067 and Swarnadhan (Sunder et al., 2005)
- Foliar application of fungicides viz. Mancozeb @2g/l, iprodione @2g/l,,chlorothalonil @1ml/l, propiconazole@1ml/l, hexaconazole2ml/l, tebuconazole @1ml/l, thiophanate-azoxystrobin@1ml/l, trifloxystrobin + propiconazole@1ml/l, difenoconazole + propiconazole @1ml/l and antibiotics like blasticidin SM, aureofungin, mycobacillin and versicolin, is highly effective against brown spot. Among these, propiconazole, hexaconazole and mancozeb are commonly used against both leaf spot disease (Sunder et al., 2014)

Sheath Blight

Occurrence and Distribution

Sheath blight (Rhizoctonia solani) is adevastating fungal disease widley distributed in all rice growing areas of world (Figure 4). The disease was first reported from Japan in 1910 by Miyake (1910) and subsequently from most of the East and Southeast Asian countries. Thereafter, the disease was reported from many African and North and South American countries (Gangopadhyay and Chakrabarti 1982; Dath 1990; Dasgupta 1992; Ou 1985; Sivalingam et al. 2006). In India, sheath blight was first reported from Gurdaspur (Punjab) (Paracer and Chahal, 1963). It is a major production constraint in rice it causes an yield loss upto 50% (Annou et al. 2005).

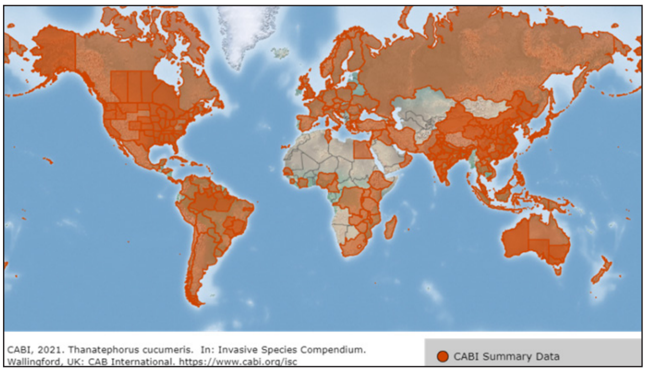

Figure 4.Global Distribution of Sheath Blight Disease of Rice

Symptoms

Most panicles sterile or partially filled grains, Typical sheath blight symptoms appear as greyish, water-soaked lesions on leaf sheaths at or above the water line. The lesions soon enlarge, with irregular dark brown margins, while the centre is bleached to greyish white. Appearance of many such lesions on the leaf sheath gives the look of snake skin. The infection spreads rapidly to upper leaf sheaths and leaf blades of the same or adjacent tillers from the water level to flag leaf, ultimately causing death of whole leaf, tiller and the plant. Infected plants are usually found in a circular pattern, locally referred to as 'bird's nest' bearing few grains only (Hollier et al. 2009; Figure 5).

Figure 5.Symptoms and Causal Organism of Sheath Blight Disease of Rice: (a)Rhizoctonia Solani, (b) Symptom on Sheath; (c)Symptom of Sheath Blight Extending up to Flag Leaf along with Fungal Sclerotia; (d)Rice Nursery Bed Showing Severe Sheath Blight Infection; (e)Severely Sheath Blight-Infected Rice Field Resembling Bird's Nest Structure

Disease Cycle and Epidemiology

Sheath blight is a serious problem in coastal and high rainfall areas. The disease is mostly prevalent in areas where the relative humidity is very high (above 95%), the temperature is moderate (28-32^0 C) and N application is high. Although basidiospores produced by T. cucumeris on the host plant can initiate infection, it is generally considered unimportant in the epidemiology of rice sheath blight. Sclerotia produced by the fungus and to a lesser extent the fungal mycelium surviving in the plant debris serve as a major source of primary infection, particularly in humid tropics. Sclerotia can also survive for a long period in the temperate rice production areas. Different agricultural operations such as ploughing, levelling, transplanting and weeding help the surviving sclerotia to come up at the plant water surface and make initial contacts with the host (Singh et al., 2012c).

Disease Management

- Wider spacing (to reduce high humidity in the plant ecosystem and to reduce plant-to-plant contact)
- Destruction of stubbles and weeds in and around rice fields
- Adoption of green manuring, avoidance of fieldto field irrigation, planting of rice seedlings a little distance away from the bundsand keeping the bunds and field free from alternate and collateral weed hosts can significantly reduce sheath blight disease severity (Rodrigues et al., 2003)
- Reduce or delay the top-dressing or nitrogen fertilizer and apply in 2-3 splits
- Cultivation of traditional rice varieties viz., Swarnadhan, Radha, Pankaj, Vikramarya, Tetep, Jasmine 85, Tequing, Bhasamanik, Lalsatkara (Singh et al., 2010b; Srinivasacharyet al., 2011)
- Spraying of Validamycin 3 L 2.5 ml/ litre or Thifluzamide 24 SC @ 0.75 g/ litre or Hexaconazole 5 EC @ 2 ml/ litre or Propiconazole 25 EC @ 1ml/ litre or Carbendazim 50 WP @ 1g/ litre reduced the disease incidence

Sheath Rot (Sarocladiumoryzae)

Occurrence and Distribution

Recently, sheath rot is emerging as a serious menace in rice cultivation system, prevalent in most of the rice-growing countries worldwide, particularly in rain-fed rice ecosystems, is more prevalent during wet than dry seasons. The disease has widely distributed in almost all the country where rice is a major crop it includes, both Asian and African countries such as Sri Lanka, Pakistan, China, India, Nepal, Bangladesh, Japan, Korea, Malaysia, Indonesia, Philippines, Taiwan, Thailand, Vietnam, Brunei, Kenya, Nigeria, Gambia, Cameroon, Cote d'Ivoire, Niger, Burundi, Tanzania, Madagascar, United States, Mexico, Cuba, Colombia, Venezuela, Peru, Brazil, Argentina and Australia (Suparyono 1990; Webster and Gunnell 1992; Gill et al. 1993; Figure 6). Sheath rot is considered to be potential threat to rice cultivation in both temperate and tropical regions due to severe damage cause yield losses up to 90% in India (Srinivasan 1980; Manibhushan Rao 1996).

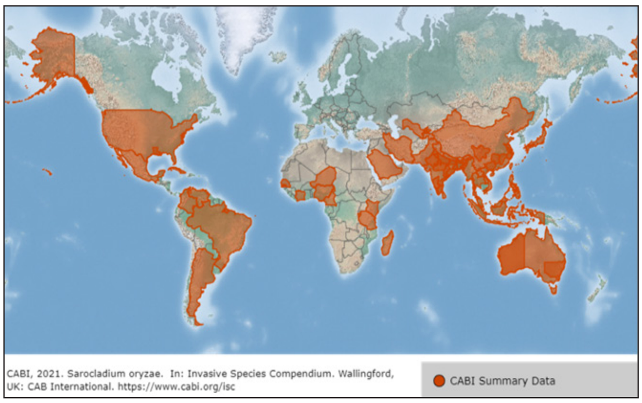

Figure 6.Global Distribution of Sheath Rot Disease of rice

Symptoms

Symptoms of sheath rot disease it affects sheath and grains (Figure 7). Initially disease start with irregular spots or lesions, with dark reddish brown margins and gray center on sheath. Later, coalescing of lesion leads to covering the entire leaf sheath. Severe infection causes un emergence of panicles and florets turn red-brown to dark brown color. Under severe infection whitish powdery growth inside the affected sheaths and young panicles can be noticed. Later stage, infected panicles become sterile, shriveled.

Figure 7.Symptoms of Sheath Rot Disease of Rice

Disease Cycle and Epidemiology

Pathogen survives as mycelium in the infected plant debris and on seeds (Singh and Raju 1981; Singh and Mathur 1993). It also infects several weeds and cultivated hosts, viz. *Eleusine indica, Monochoria vaginalis, Cyperus teneriffae, C. iria, C. difformis, Echinochloa crus-galli, E. colona, Oryza rufipogon, Bambusa balcooa, B. vulgaris, Hymenachne spp., Leersia hexandra* and *Panicum walense* (Singh and Dodan 1995). Generally, the disease severity is more in late and densely planted fields. The conditions like moderate temperature (20-30 °C), high humidity, cloudy days during booting stage and occasional rainfall favoured the buildup of the disease.

Disease Management

- The disease can be managed effectively through integrated programme of seed treatment, selection of resistant cultivars and foliar application of fungicides
- Foliar application of *Pseudomonas fluorescens, Azospirillum lipoferum* and *T. harzianum* either singly or as consortium (Sundaramoorthy et al., 2013)
- Spraying of effective fungicides such as Propiconazole 25 EC @ 1 ml/litre or Hexaconazole 5 EC @ 2 ml/litre or or Thiophanate methyl 70 WP @ 1 g/litre

False Smut (*Ustilaginoidea Virens*)

Occurrence and Distribution

False smut caused by *Ustilaginoideavirens was* first reported in India by Cooke in 1878, subsequently, the disease was reported from more than 60 countries including China, the Philippines, Indonesia, Vietnam, Thailand, Bangladesh, Burma, Brazil, Fiji, Japan, Pakistan, Egypt, Nepal, Nigeria, the United States and France (Brooks et al. 2010; Figure 7). Earliear this disease was considered as a minor disease, but now a days it is emerging as serious problem causes yield loss upto 49% (Dodan and Singh 1996). In addition to direct loss to the crop, the fungus also produces a toxin known as 'Ustiloxin' (Koiso et al., 1994) which can inhibit seed germination and is also poisonous to domestic animals and humans (Koiso et al., 1998).

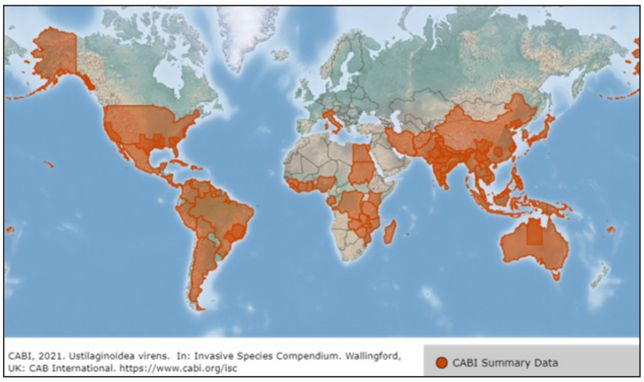

Figure 8.Global Distribution of False Smut Disease of Rice

Symptoms

Initially, pathogen infect young ovary of spikelets and later transforms them into yellow, olive green to blackish smut balls known as pseudomorph (Figure 9). Firstly, the fungal growth is confined between glumes which later get enlarged enclosing the floral parts. Young smut balls are white in colour enclosed in a whitish membrane. Subsequently, the membrane bursts, releasing orange spore masses which later turn into olive green to black.

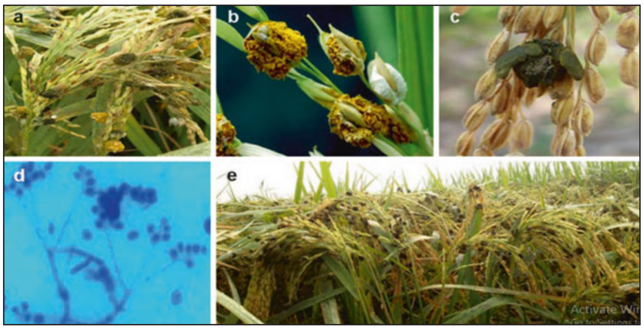

Figure 9.Symptoms of False Smut Disease of Rice: (a)Yellow to Olive Green Smut Balls; (b)Young Smut Ball Covered with Whitish Membrane; (c)Sclerotia of *U. Virens*; (d)Ovoid Minute Conidia of *U. virens*; (e) Severe False Smut Infection under Field Condition

Disease Cycle and Epidemiology

Sclerotia act as a major source of primary inoculum and chlamydospores play an important role in the secondary infection. Release of ascospores from sclerotia coincides with the anthesis of rice crop and initiates infection on the floral parts producing chlamydospores. These airborne chlamydospores may cause infection again. The congenial condition for the development of disease includes low temperature, high humidity with moderate rainfall (Laha et al., 2017).

Disease Management

- Use of disease free seeds, cleaning of bunds, adjustment of sowing dates to avoid coincidence of booting stage with rainy period and application of balanced fertilizer can substantially reduce disease incidence in the fields
- Furrow-irrigated rice cultivation system has been reported to have less disease severity compared to flooded fields (Ladhalakshmi et al. 2012b)
- Several rice cultivars were reported to be resistant or tolerant to false smut under natural conditions, viz. Anupama, Cauvery, China 988, Govind, HKRH 21, MTU 1067, Sakha 102, VL 501, HKR 47, HKR 127, Jhelum and Shalimar Rice-1, HKR 95-222, HKR 98-418, HKR 08-12, HKR 08-17, HKR 08-71, HKR 08-110, IR 50, Paicos-1, PR 113 and PR 114 (Singh et al. 2010b; Sanghera et al. 2012, Singh and Sunder 2015)
- Spraying chlorothalonil 75 WP at 2 ml/l or copper oxy-chloride 50 WP at 4 g/l or epoxiconazole 12.5 EC at 2 ml/l or propiconazole 25 EC at 1 ml/l at the time of flowering found to be effective in reducing the disease or application of trifloxystrobin 25 % + tebuconazole 50 % (Nativo 75WG) at booting or 50 % panicle emergence stage (Singh and Sunder 2015)

Stem Rot (*Sclerotium Oryzae*)

Occurrence and Distribution

Of late, this disease has becoming a serious menace to rice causes significant yield loss. The disease was first reported by Cattaneo in 1876 from Italy (Ou 1985). It is widely occur and distributed in several countries asian and european countries. Asia includes (Japan, India, Sri Lanka, Myanmar, Bangladesh, Burma, China, Indonesia, Vietnam, Iran, Iraq, Pakistan, Taiwan, Thailand and the Philippines), Europe (Bulgaria, France, Portugal, Turkey and Spain), Africa (Madagascar, Mozambique, Egypt, Somalia and Kenya), Americas (the United States, Venezuela, Brazil, Costa Rica, Colombia, Guyana, Panama, Suriname, Trinidad and Tobago and Argentina) and Australia (Figure 10). Since the disease is soil borne in nature it cause an yield loss up to 60%.

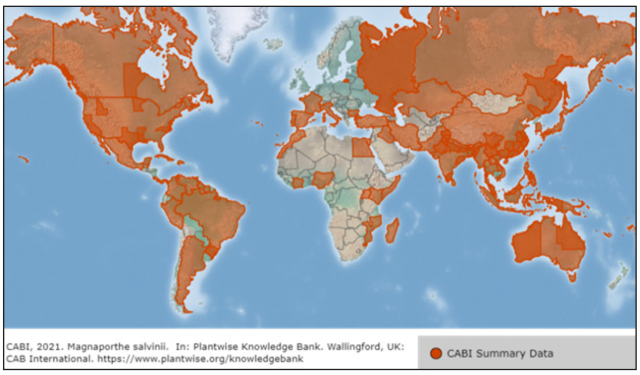

Figure 10.Global Distribution of Stem Rot Disease of Rice

Symptoms

Initially, small irregular black lesions or spots appear on the outer leaf sheath. As the disease progresses, the lesions enlarge and producing lesions on the inner leaf sheaths. Subsequently, the fungus infects the culms, resulting in partial or complete rotting of the infected plant (Figure 11) and premature lodging of the crop. Severely infected plants bear partially filled or unfilled grains. if pull the infected plants it may easily come out from the soil due to rotting of crown. As disease progresses, dark greyish mycelium may be found on the sheath stem region, later it converted into numerous small, round and black sclerotial bodies.

Figure 11.Characteristic Symptoms of Stem Rot Disease of Rice

Disease Cycle and Epidemiology

The vulnerable condition for the development of disease includes high Nitrogen, high temperature, high relative humidity and water logging conditions. Disease incidence is more in early planted crop because of high temperature and relative humidity.

Disease Management

- Application of recommended dose of fertilizer and *Potashic fertilizers*
- Application of additional organic manure reduces the disease
- Burning of rice stubbles after harvest may reduce incidence and disease development
- Spraying of fungicides such as Carbendazim 50 WP @ 1 g/litre or Iprobenphos 48 EC @ 2 g/litre or Thiophanate methyl 70 WP 1 g/litre or Isoprothiolane 40 EC @ 1.5 ml/litre
- Growing of resistant varieties like Jalmagna, Latisali, Pankaj, Rasi, etc found to be effective for management of disease

Grain Discolouration Fungal Complex

It is a new emerging problem in rice it is believed to be a fungal complex disease due to several pathogens viz., Alternaria sp.,*Curvularia sp., Cladosporium spp., Bipolaris* spp results in discolouration in rice. Of late, it is emerging as a serious problem in most of the rice growing regions.

Symptoms

It affects both quality and quantity of grains. The infection may be external or internal causing discoloration of the glumes or kernels or both. Initially, small dark brown or black spots appear on the grains. Later infected grains turn to red, yellow, orange, pink or black, depending upon the organism involved and the degree of infection. This disease affect both quantity and quality of the grains (Figure 12).

Figure 12.Symptoms Grain Discoloration

Mode of Spread and Survival: Primary spread of the disease takes place through air-borne conidia and the fungus survives as parasite and saprophyte in the infected grains, plant debris and also on crop debris.

Preventive Methods

- Use of disease-free seeds or healthy seeds for sowing
- Seed treatment with carbendazim 2.0g/kg of seeds
- Removal and proper disposal of infected plant debris

Bacterial Diseases

Bacterial Blight

Occurrence and Distribution

Bacterial Blight (BB) of rice (Xanthomonas oryzae pv. oryzae (Ishiyama)) is one of the devastating disease is widely distributed throughout the globe (Figure 13). The disease was first reported from Fukuoka Prefecture, Japan in 1884. However, the causal bacterium was described in 1922. In India, the disease was first reported from Maharashtra (Srinivasan et al., 1959),All though the disease is reported worldwide, it has economic importance mainly in Asia and in some parts of Western Africa, especially in irrigated and rain-fed lowland ecosystems. Epidemics in Northwestern India during 1979 and 1980 and in South India during 1998, 2010 and 2013 (Laha et al., 2009; Yugander et al., 2014) are some of the examples of its destructive nature in the tropics.

Symptoms

Bacterial leaf blight disease mainly produces three distinct phases of symptoms. Such as, Leaf Blight Phase, Kresek or Wilt Phase and Pale Yellow Leaf Phase.

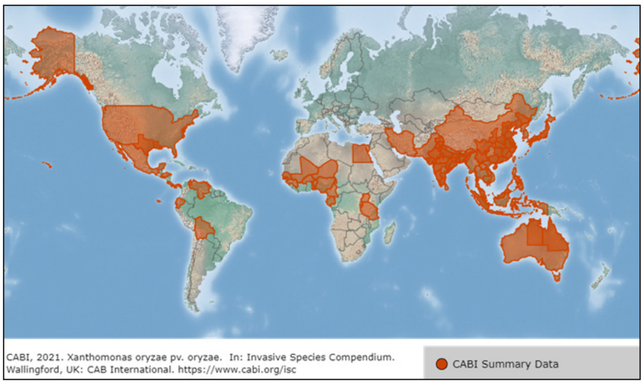

Figure 13.Global Distribution of Bacterial Leaf Blight Disease of Rice

Leaf Blight Phase: It is very common phase of this disease, in which water-soaked lesions appear on the tip of the leaves and increase longitudinally downwards or Water-soaked to yellowish stripes on leaf blades or starting at leaf tips then later increase in length and width with a wavy margin.

Kresek or Wilt Phase: It is the most destructive phase of the disease in the tropics, which results from early systemic infection in the nursery or from seed infection.

Pale Yellow Leaf Phase: This phase of the disease has been reported from the Philippines only. Some of the youngest leaves in a clump may become pale yellow or whitish. The diseased leaves later wither, turn yellowish brown and dry up.

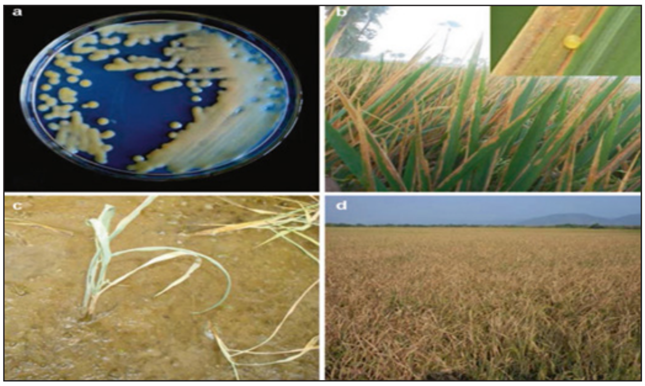

Figure 14.Symptoms of Bacterial Blight of Rice: (a) Colonies of *Xanthomonas Oryzae* Pv. Oryzae; (b) Typical Leaf Blight Phase (Inset Bacterial Ooze on Infected Leaf); (c)Kresek Phase of the Disease; (d) Rice Field Severely Infected with Bacterial Blight

Disease Cycle and Epidemiology

The ratoons and self-grown plants serve as primary source of inoculum. The pathogen also survive on some grasses like *Leersia hexandra*, *Cyperus rotundus* and *Panicum repens* and irrigation water contaminated with bacteria flowing through the fields also act as a source of primary inoculum. Disease favours Cloudy weather along with rainy or drizzling condition, floods, cyclone or strong winds besides excess and late application of nitrogenous fertilizer and moderate temperature of 28-30°C favour the build up and spread of the disease (Ezuka and Kaku 2000).

Disease Management

- Apply recommended dose of Nitrogenous fertilizers with more potash
- Apply N in 3-4 splits
- Avoid flood irrigation from infected to healthy field
- Avoid insect damage to the crop
- Destroy weed hosts and infected stubbles
- Growing of resistant varieties such as Ajaya, IR 64, Radha, Pantdhan 6, Pantdhan 10 found to be effective
- Seeds treatment with Agrimycin 100 (an antibiotic containing 15 % streptomycin and 1.5 % terramycin) plus 0.05 % for 12 h in 0.025 %. Overnight soaking of infected seeds in 100 ppm Streptocycline (streptomycin 12 % + chlorotetracycline hydrochloride 1.5 %) solution can also effectively eradicate the seed infection
- Two sprays of Agrimycin 100 (250 ppm) can effectively reduce the disease intensity and have been advocated for checking secondary spread of the disease
- Five sprays (at 12-day interval) of Agrimycin 100 and Fytolan (copper oxychloride) (50:500) or 665 ppm of Agrimycin 500 (streptomycin sulphate 1.75 % + terramycin 0.17 % + tribasic copper sulphate 42.4 %) can also satisfactorily reduce the disease (Singh et al. 1980)

Viral Disease

Rice Tungro Disease

Occurrence and Distribution

Rice Tungro Disease caused by rice tungro baciliform and spherical viruses, it is highly devastating disease. Tungro', means degenerated growth in Filipino language, was first recognized to be caused by a leafhopper-transmitted virus in 1963 (Rivera and Ou 1965). The disease is widely distributed in South and Southeast Asiaian countries (Figure 15). In India Muralidharan et al. (2003b) has been reported epidemics from 1984 to 1994, especially during 1981 in many parts of West Bengal (India) (Krishnaveni et al. 2009). During 1998, in Gurdaspur and Amritsar districts of Punjab (India) (Varma et al. 1999). Dai and Beachy (2009) reported 5-10 % reduction in rice yields in South and Southeast Asia due to Rice Tungro Disease.

Symptoms

- Plants affected by tungro exhibit stunting and reduced tillering
- Later, leaves become yellow or yellow to orange
- Initially, discoloration start from leaf tip and extends down to the blade or the lower leaf portion
- Later infected plants fail to produce flowers or delayed flowering. Even though if plants produce flowers the panicles become sterile and seeds become chaffy

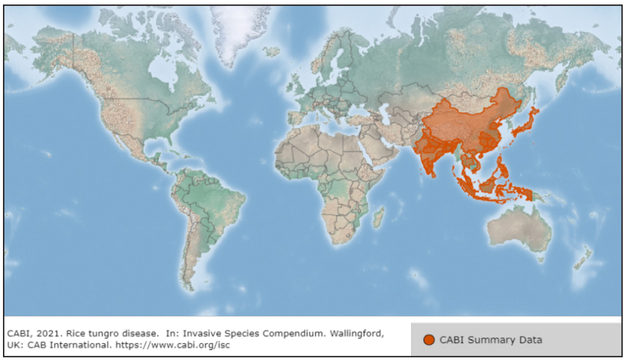

Figure 15.Global Distribution of Rice Tungro Disease of Rice

Figure 16.Symptoms of Rice Tungro Disease

Disease Management

- **Field Sanitation:** Removal and destruction of infected plants and plant debris
- Application of Carbofuran 3 G @ 12-15 kg/ha or Fipronil 0.4 G @ 25 kg/ha for nursery in top 2-5 cm layer of the soil before sowing of sprouted seeds
- In the main field, spray Carbaryl 50 WP @ 0.65 litre/ha or Fipronil 5 EC @ 1 litre/ha
- Foliar application of imidacloprid 200 SL at 125 ml/ ha or etofenprox 10 EC at 750 ml/ha or thiamethoxam 25 WG at 100 g/ha or acephate 50 WP at 1200 g/ha or monocrotophos 36 EC at 1500 ml/ha has been recommended for the protection of transplanted crop from RTD
- Growing of resistant/tolerant varieties viz., Nidhi, Vikramarya, Radha, Annapurna, Triveni etc found to be good

Rice Root-Knot Nematode (*Meloidogyne Graminicola*)

Meloidogyne graminicola, has becoming a serious problem in rice in almost all the rice growing countries especially throughout the world and it has occupied a place of 'National Pest' owing to its severity (Narasimha murthy et al., 2017). This is a major constraint in successful rice cultivation leading to significant loss to the rice grower. *M. graminicola* was found infecting weed hosts especially grasses like, *Echinochlo acolonum*, *Poaannua, Alopecurus carolinianus, Eleusine indica* and oats in USA during 1965 (Golden and Birchfield, 1965). Later, this nematode was described as *Meloidogynegraminicola* (Golden and Birchfield, 1968). The rice crop yield losses caused by *M. graminicola* have been reported to be between 20-80 percent, varying with growing conditions, soils and cultivation pattern (Bridge and Page 1982; Arayarungasarit, 1987; Netscher and Erlan, 1993; Padgham et al., 2004). *M. graminicola* has very wide distribution particularly in the rice growing areas of the world (Figure 17).

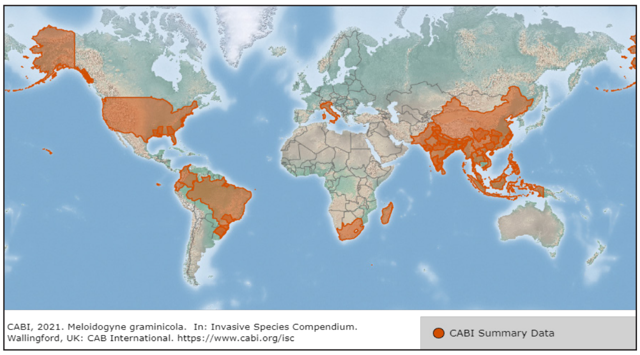

Figure 17.Global Distribution of Rice Root-Knot Nematode (*Meloidogyne graminicola*)

Symptoms

Infected plants become stunting/ dwarfing and chlorosis leading to reduced tillers and yield, infected seedlings exhibit characteristic hook-like galls on roots, Reduction in tillers numbers, heavily infected plants fail to produce flowers and mature early. Under severe infestation size of the ear head is reduced with reduction in number of grains.

Figure 18.Symptoms of Rice Root-Knot Nematode (*Meloidogyne Graminicola*)

Disease Management

- Crop rotation with resistant or non-host plants
- Use of nematode-free planting materials, including resistant varieties (African rice species, *Oryza glaberrima* and *O. longistaminata*, as well as in a few Asian rice cultivars)
- Increasing soil fertility can compensate for some damage by *M. graminicola*
- *M. graminicola* will survive normal flooding but damage to the crop can be avoided by raising rice seedlings in flooded soils thus preventing root invasion by the nematodes. Integrated Nematode Management Technology resulted in reducing the nematode population application of cabrofuran (0.3 g a.i/m^2), Pseudomonas fluorescence at 20 g/m2, *Trichoderma viride* 20 g/m^2 (Somasekhara et al., 2012)
- The combined treatment of carbofuran + *P. fluorescens* as root dip and single soil application (15 DAP) of carbosulfan or carbofuran @ 10g /m^2

Rice is prone attack by a number of diseases from nurseries to harvesting stage. If the variety selected for sowing is not resistant to these, they need to be controlled by cultural, chemical and biological control options. But no single option for a given disease may be adequate for maximizing the economic returns and to minimizing the disease incidence. Moreover, the existing control measures are neither economical nor environmental friendly; therefore an economic and eco-friendly way to manage the disease effectively is required. Hence, an integrated approach to the management of diseases is highly required for the successful and effective management of the diseases in rice.

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