Sheath Blight of Rice: A Review

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Among the different diseases of rice, sheath rot caused by Sarocladium oryzae (Sawada) W. Gams and D. Hawksw (Acroclindrium oryzae, Sawada) is one of the most important diseases. The disease has been known almost for a century, but was restricted to South East Asia and the Indian Subcontinent. Occurrence of the disease became widespread in mid 1970s. Sheath rot for the first time was recorded in 1978 Kharif in Chhatisgadh (Narain, 1992). Although this disease was first noted at Hyderabad. The disease causes severe yield losses which varies from negligible to 90% depending upon the degree of severity of disease and environmental conditions. Tikoo (1985) observed the reduced number of spikelets/panicle, number of grains/panicle and 1000 grain weight resulting in losses in crop yield due to sheath rot infection.

Distribution
Sheath rot has been reported to occur in Afghanistan, Argentina, Australia, Bangladesh, Brazil, Brunei, Burundi, Cameroon, China, Colombia, Cote d’ Ivoire, Cuba, Darussalam, Gambia, India, Indonesia, Iran, Japan, Kenya, Louisiana, Madagascar, Malaysia, Mexico, Nepal, Nigeria, Pakistan, Philippines, Saudi Arabia, Senegal, Sri Lanka, Taiwan, Tajikistan, Tanzania, Thailand, USA, Uzbekistan, Venezuela, Vietnam. In India the disease has been reported from Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Kerala, Madhya Pradesh, Manipur, Orissa, Punjab, Rajasthan, Tamilnadu, Uttar Pradesh, Uttrakhand and West Bengal.

Symptoms
The symptoms of the disease occur on the uppermost leaf sheaths that enclose the young panicle during the boot stage. Lesions are oblong or irregular oval spot with brown margins and grayish centres, 0.5-1.5 cm long, which later enlarge, coalesce and may cover most of the leaf sheath. In the centre of the lesions white powdery growth of the fungus may be seen on both outside and inside of affected sheaths. The young panicle fails to emerge from sheaths which is known as choking or may partially emerge. The unemerged portion of the panicle rots and florets trun to dark brown. There may be no grain formation in the panicle fail to emerge from sheaths but the spikelets extended outside the rotted sheath normally develop and form grains. Grains from damaged panicles are discolored reddish-brown to dark brown (Ou, 1985).

The Causal Organism
Sheath rot of rice is caused by the fungus Sarocladium oryzae which belongs to kingdom Fungi, phylum Ascomycota, class Ascomycetes, order Hypocreales, Family, Genus Sarocladium species oryzae. Sparsely branched, septate, measures 1.5-2 μm in diameter mycelium is produced by the fungus. Conidiophores branched once or twice, each time with 3-4 branches in a whorl and are slightly thicker than the vegetative hyphae. Conidia are hyaline, smooth, single- celled, cylindrical and 4-9 x 1-2.5 μm which are borne simply on the tip and produced consecutively (Ou, 1985). The optimum temperature for growth and sporulation varied with culture medium. On potato dextrose agar it was 30°C and on the 2 host extract media it was 25°C. Sporulation was enhanced by exposure of colonies to 12 hour light and 12 hour darkness.

Production of Toxins, Enzymes and Phenols
Alagarsamy (1989) reported that there is a
positive correlation between toxin production and disease development. Different toxins viz. cerulenin (Sakthivel and Gnanamanickam 1986) helvolic acid (Tschep et al. 1997), hydrophilic thermostable phytotoxin (Samiyappan et al. 2003) and cerulenin and helvolic acid (Niraikulam et al. 2005) have been reported. Reddy et al. (1985) reported that Acrocyllndrium (Sarocladium) oryzae secret cellulases (Cx and C1) and PME, PG (exo and endo), PMG (exo and endo), PL and PAL. Saswati et al. (1988) observed that peroxidase and polyphenol oxidase activities increased in rice plants inoculated with Acrocyllndrium (Sarocladium) oryzae. Phenylalanine ammonia lyase (PAL) activity decreased gradually up to 7 d in healthy and inoculated plants but levels were higher in inoculated plants. Velazhahan and Ramadran (1992) studied the effect of potassium on the phenolic content of rice infected by S. oryzae was monitored at different stages of pathogenesis. The application of potash increased the phenolic content. Inoculated plants grown at high levels of potassium accumulated higher levels of phenols than those grown at low levels of potassium.

Survival of the Pathogen

The pathogen of sheath rot of rice has been reported to survive in seed as externally and internally seed borne by Mohan and Subramanian (1981). Singha et al. (1996) observed that pathogen is found on discoloured rice seeds and mainly carried externally. Sachan and Aggarwal (1995) reported pathogen in the seed coat, endosperm and embryo of discolored seeds. Pandey et al. (2000) detected S. oryzae from all parts of the seed i.e. seed coat, endosperm and embryo. Singh and Raju (1981) studied that the pathogen survived for 4 months in seed, 7 months in leaf sheaths under room conditions and 10 months in the field. Although the pathogen survived in the rhizosphere soil for > 6 months after sowing infected seeds. Sachan et al. (1995) reported that the method of spread depicted that the pathogen spread was faster in a vertical manner (movement within the plant) followed by horizontal manner (plant to plant) (Vivekananthan and Rabindran 2008). The disease transmit by insect pests viz., stem borer, leaf hoppers, earhead bug, leaf folder and mite in favoring the sheath rot infection was also proved. Among the insects stem borer paved the maximum way for the sheath rot infection followed by hoppers Vivekananthan and Rabindran (2008).

Survival of Pathogen on Weeds

The pathogen of sheath rot has been reported to survive on different weeds on Echinochloa colona (Rahman et al. 1982), Eleusine indica, Monochoria vaginalis, C. iria and C. tenerifae Balakrishnan and Nair (1981), Orzya rufipogon (Deka and Phookan 1992), Cyperus iria, C. rotundus, C. ditemis, Fimbristylis miliacea, Saccharum spontaneum, Ischaemum rugosum and Echinochloa colona (Yadav and Thrimyuty 2006), sorghum (Sorghum vulgare, Pers.), barnyard grass (Echinochloa crusgalli (L.) Beauv) and maize (Zea maize, Lin.) Cruz et al. (2009).

Factors Affecting Disease Development

Amin et al. (1974) reported that the disease was most severe on densely planted, high yielding and dwarf varieties. He also observed that, those susceptible to stem borer were also severely affected. Srinivasan (1980) observed that incidence of the pathogen increased with reduction in spacing from 40 x 40 to 10 x 10 cm. Narasimhan et. al. (1994) found that spread of the disease is highly dependent on environmental conditions and is severe in densely planted fields and those infested by stem borer. Disease development was maximum when the minimum temperature was 17-20º C and the minimum RH 40-50% at flowering (Singh and Raju, 1981). Soil amended with non edible oil cakes and other organic amendments reduce disease intensity (Rajan 1980). Gill and Bonman (1998) reported that sheath rot of rice incidence was the highest in rice tungro bacilliform badnavirus infected plants. Alagarsamy, (1986) found that foliar sprays of calcium sulfate and zinc sulfate gave the most effective control of the disease. Soil application of calcium sulfate as gypsum in 2 equal splits (500 kg/ha) at different times reduced the incidence of sheath rot. Increasing the potassium level (0-200 kg/ha) reduced disease intensity (Velazhahan and
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Ramabadran 1992). Sekhar and Prasad (1989) studied the effect of K at 0, 50, 100, 150 and 200 kg/ha at each 2 N levels (75 and 125 kg/ha) inoculated with S. oryzae. Disease incidence increased with increase in N level but decreased with increase in K application. Application of N increase the disease also reported by Alagarsamy (1986), Srinivasan (1980), Akanda et al. (1984), Goel et al. (2003) and Vijayabaskar et al. (2004).

DISEASE MANAGEMENT

Host Resistance

Manuel et al. (1984) observed that a rice variety Co43 was resistant to sheath rot of rice. Kabir and Miah (1989) reported that BR22 and BR23 were moderately resistant. Ramalingam et al. (1991) observed that MDU4 was resistant to S. oryzae. Lakshmanan and Velusamy (1991) screened 87 lines among these; fifteen lines showed no symptoms under natural infection while only a few exhibited high levels of resistance under artificial methods. Hoang and Tran (1991) reported that VX83 has higher levels of resistance to S oryzae. Rangaswamy et al. (1992) observed that ASD 17 was moderate resistance to sheath rot. Nilakantapillai et al. (1993) reported that TM8602, released as TKM10 was moderately resistant. Disease resistance in ACM16 was reported by Ramalingam et al. (1993). Vandana (RR187-982) a rice cultivar resistant to sheath rot (Sinha et al. 1993). Rajavadlu (RNR99377) and Sagar-Samba (RNR52147) were reported resistant by (Kashikar et al. 1994). Ranjini showed tolerant reaction to the disease (Devika et al. 1997). Shanmugasundaram et al. (1997) observed that ASD20 was resistant. Aggarwal (2000) reported that a rice cultivar BK805-36 has been released as Khushboo was resistant to sheath rot disease. Rice cv. Surabhi developed by (Agrawal and Panwar, 2002), found moderately resistant. Kanak, a rice variety developed by Agrawal and Prakash 2002 was moderately resistant e. Mohanta et al. (2002) screened a total of 28 bred restored lines and 4 standard controls for resistance, 6 were moderately resistant, 26 were moderately susceptible. Malik et al. (2003) reported that Bhudep was moderately resistant against the disease. Bolla et al. (2004) evaluated eighteen rice genotypes for their resistance. Among these genotypes Masuri showed resistant reaction and NTP 98A and NTP 98 B showed moderately resistant. Goel and Lore (2004) screened one hundred elite advanced breeding lines of rice for disease resistances among these 17 lines were resistant to moderately resistant. Dwivedi et al. (2006) reported that Shusk Samrat was found resistant. (Yadav and Thrimurty 2006) evaluated 260 entries, out of these only 2, i.e. VS 99 and Oryza latifolia-100963, were considered as resistant. Dwivedi et al. (2006) observed that NDR2026 is a mid early maturing cultivar was moderately resistant. Narayanasprasad et al. (2011) screened 3000 entries, among these only seven showed resistance.

Cultural Method

The initial step for management of disease is to use healthy seeds. Application of high dose of N₂ fertilizers favour disease development, so recommended dose of nitrogen in disease prone areas should be followed. Hot water treatment of seeds at 52°C for 30 minutes can be used to control the fungus (Singha et al. 1996).

Chemical Control

Many fungicides have been tested by different workers against sheath rot of rice. These fungicides can be use as seed treatment and as foliar spray for managing this disease. Viswanathan and Narayanasamy (1992) reported that Tricyclazole at 1000 to 1500 p.p.m. and Mancozeb at 200 p.p.m. were inhibitory to the fungus. Ekefan et al. (2006) suggested that seed treatment with tolchlofos-methyl (0.5, 1.0, 1.5 and 2.0 g a.i./litre) reduced occurrence of S. oryzae. Kabir et al. (2006) reported reduction in disease when seed were treated with vitavax 200. Kannaian (1979) tested 8 fungicide, Benlate (benomyl) sprays resulted in the least incidence of A. oryzae followed by NF 48 and Dacnil (chlorothalonil). Singh and Raju (1981) conducted the field trails with 10 fungicides and observed that good control can be obtained by 3 sprays of carbendazim, benomyl and Brestanol (fentin chloride). Chinnaswamy et al. (1981) studied the efficacy of six treatments. All six treatments
significantly reduced the incidence of disease; Bavistin (carbendazim) was the most effective, followed by HMP MBC (carbendazim), Aureofungin and Difolatan (captafol). Lakshamanan (1992) observed that tridemorph + phosphamidon protected plants better than the fungicide alone. Viswanathan and Narayanasamy (1993) evaluated mancozeb, edifenphos and tricyclazole against sheath rot of rice. Mancozeb + tricyclazole gave the best control. Dodan et al. (1996) tested the efficacy of carbendazim, propiconazole, mancozeb, edifenphos and tricyclazole and reported that propiconazole and carbendazim significantly reduced disease incidence but propiconazole was the most effective treatment, reducing sheath rot incidence by 46.5%.

M a ncozeb was the least effective. Among six fungicides (edifenphos, thiophanate methyl, carbendazim, Kitazin (iprobenfos), validamycin and mancozeb) were evaluated for the control of sheath rot of rice, two sprays of thiophanate methyl or carbendazim at 0.1% were highly effective in controlling the disease. Thiophanate methyl recorded the lowest incidence of the disease (3.5%) and provided maximum protection of 75.8%. Carbendazim protected the crop from the disease to the extent of 73.1% (Das and Nayak 1997). Thapak et al. (2003) tested (edifenphos), Antracol (propineb), Baynate (thiophanate-methyl), Octave (prochloraz), Tilt 25 E (propiconazole), Bavistin (carbendazim), Neem gold, Neem azal and Raze (Lantana camara). All formulations tested showed efficacy against the disease. The most effective were Tilt, Bavistin and Antracol. Venkateswarlu and Venkateswarlu (2004) conducted the field trails to test the efficacy of 8 fungicides, mancozeb at 0.2% or carbendazim at 0.1% or propiconazole at 0.1% were found more effective than the other fungicides (edifenphos at 0.1%, hexaconazole at 0.2%, ziram at 0.2%, kasugamin at 0.05% and chlorothalonil at 0.2%). Narayanaprasad et al. (2008) reported that three sprays starting from panicle initiation can effectively manage the sheath rot of rice. He observed that carbendazim is effective in controlling the disease.

Several bio-control agents have been used for managing sheath rot of rice. The workers have reported that bio-agents manage the disease. The bio-agents have been applied as seed treatment and foliar application. Panneerselvam and Saravanamuthu (1996) studied the antagonistic interaction of the soil fungi, Aspergillus candidus, A. flavus, A. fumigatus, A. nidulans, A. niger, A. sulphureus, A. terreus, A. varicicolor, Gliocladium sp. Penicillium citrinum, P. fumiculosum and Trichoderma viride against the S. oryzae in vitro. The maximum % inhibition of growth was observed with T. viride followed by Gliocladium sp. (Viswanathan and Narayanasamy (1990) reported that an isolate of Bipolaris zeicola (Cochliobolus carbonum) from the phylloplane of cv. IR20 at tillering inhibited growth of S. oryzae in culture. Sakhivel et al. (1986) reported effective biological control of sheath rot of rice with bacterization with Pseudomonas fluorescens. Sarala et. al. (2004) studied the effect of Bacillus subtilis, Pseudomonas fluorescens, Trichoderma viride, T. harzianum, T. reesei (T. longibrachiatus), T. longibrachiatum, Gliocladium virens and Saccharomyces cerevisiae on discoloration of rice caused by pathogen S. oryzae. B. subtilis and P. fluorescens were effective (85.62 and 84.37%, respectively) in inhibiting the growth of S. oryzae. Srinivas and Ramakrishnan (2005) observed that S. oryzae seed infection was completely reduced by A. fumigatus, Asp, P. oxalicum, SL8 and T. viride. (Gopalakrishnan and Valluvaparidasan 2006) suggested that seed borne S. oryzae in rice could be successfully managed by seed treatment (at 10 g/kg), followed by foliar application (at 1%) at boot leaf stage with B. subtilis or P. fluorescens. Duraisamy et al. (2009) observed that combination of Pseudomonas strains PfI, TDK1 and PY15 was more effective in reducing sheath rot disease in rice compared to individual strains under glasshouse and field conditions. Chaliganjewar et al. (2010) given the spray of P. fluorescens, B. subtilis, T. viride and T. harzianum at booting stage of rice cv. Mahamaya, 48 hour prior to inoculation of tillers with half cooked rice grains coated with spores and mycelia of S. oryzae at 6 x 10⁴. The fungal BCAs were tested at 4 x 10⁴ and the bacterial BCAs at 9 x 10⁴ cfu/ml. All the treatments showed significantly lower disease intensity compared to the control.

Biological Control
The disease intensity with *B. subtilis* (60.0%) followed by *T. harzianum* and *T. viride* (65.0%). All the treatments showed significant difference over the control for discolored and chaffy spikelets. The healthy grains were found highest in *B. subtilis* (60.1%), followed by *T. harzianum* (57.1%) and *T. viride* (50.3%).

**Botanical Control**

Many researchers have tested many botanical *in vivo* and *in vitro* for managing the sheath rot fungus. Jeeva and Ramabadran (1992 and 1995) reported that water extracts of *Caesalpinia pulcherima* and *Ipomoea crasicaulis* at 10 and 5% sprayed (1) before inoculation (2) before and after inoculation (3) after disease development reduced the sheath rot disease incidence in pot culture experiments. The 10% spray was more effective than the 5% and the extracts sprayed both before and after inoculation showed the lowest disease incidence, increased percentage seed germination. Extract of weeds Bracken fern (*Diplazium esculentum*), followed by sickle pod senna (*Cassia tora*) at 20% concentration were effective in inhibiting the mycelial growth of *S. oryzae in vitro* (Ranjana and Phookan 1999). Ten plant extracts tested for efficacy against *S. oryzae* inhibited mycelial growth *in vitro*. An aqueous extract of *Ocimum sanctum* was the most effective followed by *Eucalyptus citriodora* and *Azadirachta indica* (Pramanick and Phookan 1998). Yadav and Thrimurty (2006) studied the effect of leaf extracts of 34 medicinal plants on the growth of *S. oryzae in vitro*. All the leaf extracts, except *Gmelina arborea*, *Ocimum basilicum* and *Argyrea speciosa*, were found to be effective in reducing the radial growth of the pathogen compared with the untreated control. *Mentha viridis* (*M. spicata*) leaf extract was the most effective and completely inhibited the growth of the fungus until the observation period of 30 days. Chaliganjewar et al. (2010) tested the efficacy of leaf extracts of *Azadirachta indica* (Ai), *Datura stramonium* (Ds), *Jatropha curcas* (Jc), *Mucuna prurita* (*M. pruriens*) (Mp), *Allium cepa* (Ac), *Kalanchoe pinnata* (Kp), *Curcuma amada* (Ca), *Ocimum basilicum* (Ob), *Cymbopogon flexuosus* (Cf), *Andrographis paniculata* (Ap) and *Pogostemon patchouli* (*P. cablin*) (Pp) against sheath rot fungus *in vitro* by poisoned food technique and under field conditions. All the medicinal plant extracts showed significant reduction in mycelial growth over the control. Thakur et al. (2010) tested the efficacy of leaf extracts (2, 5 and 10%) of neem (*Azadirachta indica*), Dhatura (*Datura stramonium*), Ashoka (*Polyalthia longifolia*), Tulsi (*Ocimum basilicum*) and Vinca (*Vinca rosea* (*Catharanthus roseus*)) in field trials. Neem, Vinca and Dhatura leaf extracts were the most effective in controlling the radial growth (>60%) of *S. oryzae* at 10%. Tulsi leaf extract was the least effective. Meera and Balabaskar (2012) tested forty plant extracts against *S. oryzae*. Among these, *Spharanthus indicus*, *Lawsonia inermis*, *Brassica campestris*, *Jatropha curcas*, *Ricinus communis* and *Cymbopogon citrates* did not showed any effect. Among all the plant extracts *Eugenia caryophyllata* and *Eucalyptus globules* exhibited strong fungitoxicity at 50% concentration followed by, *Acorus calamus* and *Cinnamon zylanicum*. *Pavonia zylanica* exhibited least inhibition of pathogens.

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