Section 2. Bacterial diseases

Chapter 3. Leaf sheath diseases

Introduction

Sheath browning and grain discoloration can be caused by both fungi and pathogenic bacteria (Ou 1985; Cottyn et al 1996a,b). Sheath browning is a common syndrome on rice crops grown during rainy season in tropical environments. Various degrees of browning, from light brown to dark brown, may be observed on the leaf sheath at the booting stage. Some of the leaf sheath browning may be similar to that of bacterial sheath brown rot while others to sheath rot.

Similar situations are also observed in grain discoloration. Isolation from infected tissues of the causative pathogen yields different, and often more than one, bacteria mentioned in this chapter, yet the symptoms are not distinguishable from those caused by an individual bacterium reported in the literature. One may assume that the distribution of these bacteria is commonly associated with the cultivation of the semidwarf modern rice varieties in the rainy season.

Rice plants under stress are predisposed to invasion by pathogenic bacteria. Although there are reports of an antagonistic effect of some of the bacterial pathogens isolated from seed or the leaf sheath, there is little information on interaction among these bacteria in actual disease development *in situ* synergistically or antagonistically. However, research in disease development and design of disease management requires considering all pathogens together rather than as an individual bacterium.

Pseudomonas fuscovaginae, *P. syringae* pv. *syringae*, *B. glumae*, *A. avenae* subsp. *avenae,* and many others that infect the flag leaf sheath and rice grain are distributed worldwide. *P. fuscovaginae*, which supposedly causes sheath brown rot at lower temperatures, is also often isolated together with *P. syringae* pv. *syringae* and other bacteria from leaf sheath showing sheath rot and discolored grains. Together, these bacteria may be involved in spikelet sterility and leaf sheath browning. *B. glumae, B.* gladioli, and *A. avenae* subsp. *avenae* are also associated with spikelet sterility and grain discoloration. Independently, *A. avenae* subsp. *avenae* supposedly causes brown stripe on leaf sheath while *B. glumae* causes seedling rot on seedlings raised in nursery box. The symptoms produced on rice grains by this group of bacteria are difficult to distinguish at late stage of symptom development.

Other bacterial pathogens that are isolated from tissues of rice showing leaf sheath browning and grain discoloration, and shown to cause the said symptoms, are *P. syringae* pv. *aptata* (Brown & Jamieson) Young et al, *Erwinia amylovora* (Burrell) Winslow et al, *E. carotovora* (Jones) Bergey et al; *Xanthomonas cinnamona* (Miyake & Tsunoda) Muko; and *X. atroviridigerum* (Miyake & Tsunoda) Tagami & Mizukami. We know little of these bacteria that may be involved in grain discoloration even though they have been frequently isolated from rice seeds (Cottyn et al 2009).

In contrast, diseases with defined symptoms, proven pathogenicity, and known causative agents, described in the following sections, have been substantially reported and cause distinctive symptoms.

References

Cottyn, B., Cerez, M. T., Van Outryve, M. F., Barroga, J., Swings, J., Mew, T. W. 1996a. Bacterial diseases of rice. I. Pathogenic bacteria associated with sheath rot complex and grain discoloration of rice in the Philippines. Plant Dis.80:429-437.

Cottyn, B., Van Outryve, M. F., Cerez, M. T., DeCleene, M., Swings, J., Mew, T. W. 1996b. Bacterial diseases of rice. II. Characterization of pathogenic bacteria associated with sheath rot complex and grain discoloration of rice in the Philippines. Plant Dis. 80:438-445.

Cottyn, B., Debode, J., Regalado, E., Mew, T. W., Swings, J. 2009. Phenotypic and genetic diversity of rice seed-associated bacteria and their role in pathogenicity and biological control. J. Appl. Microbiol. ISSN 1364-5072:1-13.

Ou, S. H. 1985. Rice Diseases. CABI, Surrey, England. 368 p.

1. Bacterial sheath rot

Sheath rot, caused by *Pseudomonas syringae* pv. *syringae* van Hall (syn. *P. oryzicola* Klement), is almost identical in appearance to the symptoms of bacterial sheath brown rot caused by *P. fuscovaginae*. It is the only reported bacterial sheath rot pathogen of rice in Chile and has also been reported in Asian countries, Australia, and Hungary (Ou 1985). The symptoms on leaves start initially as indistinctive dark grayish green spot, which turns dark brown to reddish brown in the later stage. Eventually, the lesion becomes black and the infected tissues die. The causal bacterium also infects the stem, producing symptoms similar to those shown on leaves.

Zeigler and Alvarez (1990) made an extensive study with a large number of seed-borne Pseudomonads originating from 22 different countries comparing them with reference strains. Among the strains handled by them, nearly 25% of the strains were serologically differentiated *as P. syringae* and *P. fuscovaginae*. This study concluded that the bacterial species involved in grain or sheath rot of rice is caused by four groups: (i) *P. fuscovaginae*, (ii) *P. syringae* pv**.** *syringae*, (iii) *P. avenae*, and (iv) *P. glumae*. The *P. fuscovaginae* and *P. avenae* groups are the most common.

References

Ou, S. H. 1985. Rice Diseases. 2nd ed. Commonwealth Mycological Institute, CABI, Kew, England. 380 p.

Zeigler, R. S., Alvarez, E. 1990. Characteristics of *Pseudomonas* sp. causing grain discoloration and sheath rot of rice and associated pseudomonads epiphytes. Plant Dis. 74:917-922.

2. Sheath Brown Rot (SbR)

SbR caused by ***Pseudomonas fuscovaginae*** Tanii, Miyajima & Akita occurs in Asia, South America, and Central and East Africa, including Madagascar (Zeigler and Alvarez 1987, Duveiller et al 1990). The disease is manifested as a sheath and grain (dry) rot of mature plants as well as seedling (soft) rot and has caused substantial yield losses in South America (Zeigler and Alvarez 1987). The symptomatology of SbR reported in Japan by Funayama and Hirano (1963) and the bacterial bruzone disease reported earlier in Hungary (Klement 1955) are identical. The disease is now known by the latter name, sheath brown rot. *P. fcuscovaginae* also causes bacterial sheath brown spot on other cereals such as maize and sorghum (***Sorghum bicolor***; Duveiller et al 1989) and wheat (*Triticum aestivum*; Duveiller 1990). The first report of the disease in northern Japan seemed to indicate that it occurred on rice plants that experiences low temperature stress (Tanii et al 1976).

2.1. Symptoms

SbR Fig. 1. Symptoms of sheath brown rot on rice. Symptoms typically occur on the flag leaf sheath at the booting stage and on the panicle.

On seedlings, a systemic discoloration of the leaf sheath occurs, which may spread to the midrib or veins of the leaves. On mature plants, symptoms typically occur on the flag leaf sheath at the booting stage and on the panicle (**SbR Figure 1**). On the leaf sheath, oblong to irregular dark green, water-soaked lesions occur, which become gray-brown or brown and may be surrounded by an effuse dark brown margin. The sheath may also exhibit general water-soaking and necrosis without definable margins. With severe infections, the entire leaf sheath may become necrotic and dry out and the panicle withers. Glumes of panicles emerging from infected plants exhibit water-soaked lesions that turn light brown. Grains of infected panicles are discolored, deformed, or empty (Tanii et al 1976). These symptoms are similar to those described for bacterial brusone (Klement 1955). The disease can be confused in diagnosis with other sheath diseases such as dirty panicle and sheath rot of fungi causing somewhat similar symptoms (Zeigler and Alvarez 1987)

2.2. Causal organism

Both Klement (1955) and Funayama (1963) identified the causal organism as *Pseudomonas oryzicola* Klement. However, the Japanese isolates causing this disease were found to be *P. marginalis* (Brown) Stevens based on similarities in the bacteriological and pathogenicity details of *P. oryzicola* and *P. marginalis* (Goto 1965). The pathogen was later renamed as *P. fuscovaginae* Tanii, Miyajima & Akita, a new species. This name was omitted from the Approved Lists of Bacterial Names (Skerman et al 1980). However, the name *P. fuscovaginae* has subsequently been revived (Miyajima et al 1983).

P. fuscovaginae is a gram-negative, nonsporeforming rod, measuring 0.5-0.8 x 2.0-3.5 µm, with one to four polar flagella. After 4-5 days at 28^{o}C, colonies on nutrient agar are white to cream-colored, smooth, convex, translucent, butyrous, and 3-5 mm in diameter. The bacterium produces a fluorescent pigment on King's medium B and is positive for oxidase and arginine dihydrolase.

The biochemical characters that distinguish the different fluorescent pseudomonads associated with sheath rot are presented in **SbR Table 1** (Jaunet et al 1995). Two groups of researchers have independently sequenced the genome of *P. fuscovaginae* (Patel et al 2012, Xie et al 2012). This might greatly help in advancing the knowledge on epidemiological aspects and host-pathogen relationships of the disease.

2.3. Host range

Besides rice, pathogenicity has been demonstrated on *Hordeum vulgare, Triticum aestivum, Avena sativa, Zea mays, Lolium perenne, Bromus marginatus, Phleum pratense,* and *Phalaris*

SbR Table 1. Biochemical patterns of reference rRNA group I pseudomonads and rice sheath rot isolates. Source: Jaunet et al (1995).

Characteristics	Biochemical pattern[y]																						
	G1[z]	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23
Kovac's oxidase	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	-	-	+	+	+	+	+
Levan production	-	-	-	-	+	+	+	-	-	-	-	+	+	-	+	-	-	+	-	-	-	-	-
2-ketogluconate production	-	-	+	-	+	+	+	-	+	-	-	-	+	+	-	+	+	-	+	-	-	-	+
Arginine dihydrolase	+	+	+	-	+	+	+	+	+	-	-	-	+	+	+	+	-	-	+	+	-	-	+
Acid production from:																							
Sucrose	-	+	-	-	+	+	+	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-
Sorbitol	-	+	+	-	+	-	+	-	+	-	-	-	+	-	+	-	+	+	-	-	-	+	-
Trehalose	+	+	+	-	+	+	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-
Inositol	-	+	+	-	-	+	+	+	-	-	-	-	+	+	+	-	+	+	-	-	+	+	-

[y] + = positive reaction; - = negative reaction
[z] Biochemical pattern of *Pseudomonas fuscovaginae.*

arundinacea by artificial inoculation (Tani et al 1976, Miyajima et al 1993). Natural occurrence of this disease on maize and sorghum (Duveiller et al 1989) and on wheat (Duveiller 1990) has also been recorded.

2.4. Disease cycle

P. fuscovaginae survives on rice seed at low levels, as an epiphyte on growing rice plants, and on gramineous weeds in the vicinity of rice fields. The bacterium is seedborne and seed-transmitted with the seedlings emerging from the infected seeds showing symptoms on the sheath and leaves (Zeigler and Alvarez 1987). Natural infection of other economically important cereals such as maize, sorghum, and wheat demonstrates the pathogen's broad host range, which might serve as a potential source of inoculum in a rice-based cropping system when these crops are cultivated in rotation.

The bacterium can be recovered from healthy rice leaf blades and sheaths in the field. Epiphytic populations of the bacterium peak at the booting stage (Zeigler and Alvarez 1987). Disease development on mature plants is favored by cool daytime temperatures (17-23^{o}C) under which panicle emergence is delayed and predisposed for attack (Tanii et al 1976).

2.5. Control measures

Because being seedborne is an important component of the life cycle, the use of clean seed is an important practice to avoid disease outbreaks (Mew et al 2004). Treating the seeds at 65^{o}C for 6 days eliminates the seedborne pathogen (Zeigler and Alvarez 1987). However, although it is possible to use heat therapy in research institutions' germplasm exchange programs, it is probably technically difficult for farmers to use. Although the use of streptomycin alone or in combination with oxytetracycline may also control the disease when applied a few days before panicle emergence, the use of these chemicals must be observed with caution and proper guidance.

References

Duveilller, E.1990. Bacterial sheath rot of wheat caused by ***Pseudomonas fuscovaginae*** in the highlands of Mexico. Plant Dis. 74:932-935.

Duveiller, E., Notteghem, J. L., Rott, P., Snacken, F., Maraite, H. 1990. Bacterial sheath brown rot of rice caused by *Pseudomonas fuscovaginae* in Malagasy. Trop. Pest Manage. 36:151-153.

Duveiller, E., Snacken, F., Maraite, H. 1989. First detection of *Pseudomonas fuscovaginae* on maize and sorghum in Burundi. Plant Dis. 73:514-517.

Funayama, H., Hirano, T. 1963. A sheath brown rot of rice caused by *Pseudomonas.* Ann. Phytopathol. Soc. Japan. 28: 67-68.

Goto, M. 1965. A comparative study of the sheath rot bacteria of rice. Ann. Phytopathol. Soc. Japan, 30:42-45.

Jaunet, T., Laguerre, G., Lemamceau, P., Frutos, R., Notteghem, J. L. 1995. Diversity of *Pseudomonas fuscovaginae* and other fluorescent pseudomonads isolated from diseased rice. Phytopathology 85:1534-1541.

Klement, Z. 1955. A new bacterial disease of rice caused by *Pseudomonas oryzicola* n.sp. Acta Microbiological Acad. Sci. Hungaricae 2:265-274.

Mew, T. W., Leung, H., Savary, S., Vera Cruz, C. M., Leach, J. 2004. Looking ahead in rice disease research and management. Crit. Rev. Plant Sci. 23:103-127.

Miyajima K., Tanii A., Akita T. 1983. *Pseudomonas fuscovaginae* sp.nov., nom. Rev. Int. J. Syst. Bacteriol. 33:656-657.

Patel, H. K., da Silva, D. P., Devescovi, G., Miraite, H., Paszkiewicz, K., Studholme, D., J., Venturi, V. 2012. Draft genome sequence of *Pseudomonas fusco-vaginae*, a broad host range pathogen of plants. J. Bacteriol. 194:2765-2766.

Skerman, V. B. D., McGowan, V., Sneath, P. H. A., eds. 1980. Approved lists of bacterial names. Int. J. Syst. Bacteriol. 30:225-420.

Tanii, A., Miyajima, K., Akita, T. 1976. The sheath brown rot disease of rice plant and its causal bacterium, *Pseudomonas fuscovaginae,* A. Tanii, K. Miyajima et T. Akita sp. nov. Ann. Phytopathol. Soc., Jpn. 42:540-548.

Xie, G., Cui, Z., Tao, Z., Qiu, H., Liu, H., Ibrahim, M., Zhu, B., Jim, G., Sun, G., Almoneafy, A., Li, B. 2012. Genome sequence of the rice pathogen *Pseudomonas fuscovaginae* CB98818. J. Bacteriol. 194:5479-5480.

Zeigler, R. S., Alvarez, E. 1987. Bacterial brown rot of rice caused by *Pseudomonas fuscovaginae* in Latin America. Plant Dis. 71:592-597.