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Bacterial Leaf Blight of Rice

Dr. Meghaa Sharma[1] and *Amrisha Kaur[2]
[1]Asst. Professor, Faculty of Agriculture, Jagannath University, Chaksu, Jaipur India
[2]Student, B.Sc. (Hons) Agriculture, Jagannath University, Chaksu, Jaipur, India
*Corresponding Author's email: amrishakp@gmail.com

Bacterial Leaf Blight (BLB) is one of the most devastating diseases of cultivated rice (*Oryza sativa* L.) and is prevalent across all major rice-growing regions of the world. The disease is caused by the gram-negative bacterium *Xanthomonas oryzae* pv. *oryzae* (Xoo), and is capable of inflicting yield losses ranging from 20 to 30 per cent under moderate infection to as high as 70 to 80 per cent in susceptible varieties under severe epidemic conditions. The disease was first reported in 1884 from Fukuoka Prefecture, Japan, by Bokura and Ishiyama, who observed widespread wilting and yellowing of rice leaves in the field. Ishiyama formally described the causal bacterium in 1922 and named it Bacterium oryzae. The taxonomy of the organism was subsequently revised several times, and it was finally placed under the genus Xanthomonas by Dowson (1939) and later designated as Xanthomonas oryzae pv. oryzae by Dye et al. (1980). In India, the disease was first recorded in the Godavari delta of Andhra Pradesh during the 1950s and subsequently spread to all rice-growing states. Major epidemics were reported from the Gangetic plains, Coastal Andhra, Tamil Nadu, and Kerala during the Green Revolution period when high-yielding but susceptible varieties were introduced at scale. Today, BLB is recognised as an A-1 priority disease in India's national rice protection programme.

Causal Organism

Taxonomic Classification (Subdivision / Systematic Position)

The causal organism belongs to the following taxonomic hierarchy:
Kingdom: Prokaryotae (Monera)
Division: Gracilicutes
Class: Gammaproteobacteria
Order: Xanthomonadales
Family: Xanthomonadaceae
Genus: Xanthomonas
Species: *Xanthomonas oryzae*
Pathovar: *oryzae (Xoo)*
Note: Two pathovars of *Xanthomonas oryzae* affect rice — *X. oryzae* pv. *oryzae* (Xoo) causes Bacterial Leaf Blight, while *X. oryzae* pv. *oryzicola* (Xoc) causes Bacterial Leaf Streak — a distinct but related disease.

Morphological and Cultural Characters

Xanthomonas oryzae pv. oryzae is a short, rod-shaped (bacillus), gram-negative bacterium measuring approximately 1–2 µm in length and 0.4–0.7 µm in width. Cells are single or paired, non-spore-forming, and motile by means of a single polar flagellum. The bacterium is obligately aerobic and is encased in a characteristic yellow-pigmented slime layer composed of xanthan gum, which gives colonies their typical mucoid appearance. On nutrient agar, colonies appear circular, convex, smooth, and mucoid with entire margins. They are pale yellow to golden yellow in colour due to the production of the carotenoid pigment xanthomonadin. The optimum temperature for growth is 25–30 °C, and growth ceases below

5 °C and above 40 °C. The thermal death point is 53 °C for 10 minutes. The bacterium is slow-growing; colonies become visible after 48–72 hours of incubation.

Biochemical Characteristics

The bacterium is oxidase-negative and catalase-positive. It hydrolyses starch and aesculin. Acid is produced from glucose and several other sugars. Xoo produces several virulence factors including cell-wall degrading enzymes (cellulases, proteases), exopolysaccharides (xanthan gum that helps in colonisation), and type III secretory system (T3SS) effector proteins that suppress host immunity. The bacterium also produces the yellow pigment xanthomonadin which confers protection from photo-oxidative killing by singlet oxygen.

Perfect Stage (Sexual Stage)

Xanthomonas oryzae pv. oryzae is a prokaryote (bacterium) and therefore does not have a true sexual or perfect stage in the mycological sense. Bacteria reproduce asexually by binary fission and do not produce spores with a sexual cycle as fungi do. However, genetic recombination in bacteria occurs through quasi-sexual processes:

- Conjugation — direct cell-to-cell transfer of plasmid DNA through a conjugation pilus, enabling horizontal gene transfer of virulence and resistance determinants.
- Transformation — uptake of free DNA from the environment into competent bacterial cells; demonstrated in Xanthomonas species under certain conditions.
- Transduction — bacteriophage-mediated DNA transfer between bacterial cells.

These mechanisms contribute to the evolution of new pathogenic races (pathotypes) and are of considerable epidemiological significance. Currently, 29 races of Xoo (races 1–29) have been identified globally based on their virulence on a set of near-isogenic differential lines carrying different resistance genes (xa/Xa genes). In India, races 1, 2, 3, 4, 8, and 11 are the most prevalent. In the context of bacteriology, the term 'perfect stage' is not applicable. When the question of a resting stage is considered, the organism survives adverse conditions as epiphytic populations on leaf surfaces, in infected seeds, and in weed hosts — not as dormant spores.

Symptoms

The disease manifests in three distinct phases depending on the growth stage of the crop and the mode of infection:

Kresek Phase (Seedling Stage): This is the most destructive phase, occurring within 1–3 weeks after transplanting when young seedlings are infected. The entire tiller wilts suddenly, and leaves roll inward, turning from grey-green to straw yellow. Affected tillers eventually dry out completely and collapse. This phase resembles drought stress or stem borer damage and must be distinguished by careful examination. The Kresek phase causes heavy stand loss and can be confused with tungro virus in early stages.

Leaf Blight Phase (Tillering to Heading): This is the most commonly observed phase in adult plants. The disease begins as a water-soaked, translucent stripe along the leaf margin or at the leaf tip, which rapidly enlarges and turns yellow to white. The lesion is separated from the green portion of the leaf by an irregular, wavy margin. Under humid conditions, creamy to milky bacterial exudate oozes out of the lesion surface in the early morning. This ooze dries into yellowish, bead-like droplets — a reliable and characteristic diagnostic feature of BLB.

Pale Yellow Leaf Phase: A third, less common type of symptom is seen in certain moderately resistant varieties. Entire leaves turn uniformly pale yellow without the characteristic water-soaked margins. This phase is non-spreading and causes less crop damage. It is associated with a hypersensitive-like reaction in partially resistant hosts.

Disease Cycle

Primary Inoculum Sources

The pathogen survives between cropping seasons in infected crop stubble and straw left in the field, ratoon rice, infected seed (seed-borne inoculum), weed hosts particularly Leersia hexandra (rice cut-grass), Oryza rufipogon (wild rice), and Cyperus species, as well as in canal and irrigation water contaminated with infected plant debris.

Entry and Infection

At the onset of the cropping season, the bacterium is disseminated from these primary sources to the crop via irrigation and flood water, rain splash, wind-driven rain, and, to a lesser extent, infected transplanting material. The bacterium enters the leaf through natural openings — primarily hydathodes at the leaf tips and margins, stomata along the leaf surface, and wounds caused by mechanical damage, insects, or rain-induced injuries. Hydathode infection is the predominant route and explains why symptoms typically appear first at leaf tips.

Colonisation and Systemic Spread

After entry through hydathodes, the bacterium multiplies in the sub-stomatal cavity and moves into the xylem vessels. Once inside the vascular system, Xoo multiplies extensively in the xylem elements and spreads upward systemically through the plant. The plugging of xylem vessels by bacterial masses and xanthan gum causes the water deficit symptoms characteristic of Kresek. The incubation period is 7–14 days under favourable conditions.

Secondary Spread

The diseased leaves exude massive quantities of bacterial cells in the ooze droplets. These droplets serve as the secondary inoculum. Secondary spread is rapid and occurs through: rain splash and wind-driven water droplets, irrigation and flood water carrying bacteria from plant to plant and field to field, human and animal contact with diseased foliage during crop operations, and leaf-to-leaf contact within the canopy. Secondary cycles repeat multiple times during a single season, leading to progressive disease intensification.

Survival and Perpetuation

At the end of the season, the bacterium persists in crop residues left in the field, in the soil (epiphytically on soil particles), in ratoon rice, in weed hosts, and in infected seed. The bacterium can survive in soil and water for several weeks to months. Infected seed serves as the primary means of long-distance dispersal and introduction of new races into disease-free areas.

Favourable Conditions for Disease Development

- Temperature: Optimum temperature range for infection and disease development is 25–34 °C. Below 20 °C, bacterial growth slows significantly and disease incidence decreases. Temperatures above 35 °C also retard disease development.
- Humidity: Relative humidity above 70% is critical. High humidity prolongs the period of bacterial ooze on leaf surfaces, increasing the availability of secondary inoculum.
- Rainfall and Wind: Heavy rains combined with strong winds create leaf wounds through which the bacterium can enter, and simultaneously splash and disseminate the bacterial ooze to healthy tissue.
- Nitrogen Fertilisation: Excessive application of nitrogenous fertilisers results in lush, succulent, thin-walled tissues with abundant hydathode exudation — ideal conditions for bacterial entry and proliferation.
- Flooding: Deep or continuous flooding favours the disease by providing a medium for dispersal of the bacterium and by creating anaerobic conditions that weaken host defences.
- Crop Density: Dense planting creates a humid microclimate within the canopy that is conducive to infection, reduces air circulation, and facilitates leaf-to-leaf transmission.
- Variety Susceptibility: High-yielding varieties bred purely for yield without BLB resistance are highly predisposed to epidemics under the above conditions.

Control Measures

Cultural Control

Cultural practices form the backbone of sustainable BLB management:

- Resistant Varieties: Cultivation of BLB-resistant or tolerant varieties is the most economical and effective means of control. Recommended varieties include IR-20, IR-64, Pusa Basmati-1, CO-51, ADT-43, Jaya, and Swarna Sub-1 (which also carries submergence tolerance). Several varieties carry resistance genes such as Xa4, xa5, xa13, and Xa21.
- Certified Seed: Use of disease-free, certified seed eliminates seed-borne inoculum and prevents the introduction of the pathogen into new areas.
- Balanced Fertilisation: Avoiding excessive nitrogen application; splitting nitrogen doses into two to three applications; ensuring adequate phosphorus and potassium to strengthen cell walls and improve host resistance.
- Water Management: Periodic drainage of fields (alternate wetting and drying) reduces the dispersal of bacteria through flood water and improves crop health.
- Destruction of Crop Residue: Ploughing under or burning infected crop stubble, ratoon rice, and weed hosts after harvest eliminates primary inoculum sources.
- Optimum Plant Spacing: Adequate spacing between hills (20 × 15 cm) reduces canopy humidity and limits leaf-to-leaf contact.

Mechanical Control

- Roguing: Removal and destruction of Kresek-affected tillers and symptomatic plants in nursery beds and in the early stages of main field infection prevents primary foci from expanding.
- Avoidance of Leaf Wounding: Care should be taken during inter-culture operations (weeding, earthing-up) to avoid injuring leaves, as wounds serve as important infection courts for the bacterium.
- Field Sanitation: Removal and proper disposal of heavily infected plant material from the field to reduce the inoculum load.

Biological Control

Biological control using naturally occurring antagonistic microorganisms has shown considerable promise and is now recommended as a standard component of integrated disease management (IDM) packages in India:

- Pseudomonas fluorescens (Pf-1): This fluorescent pseudomonad is the most widely recommended and commercially available bioagent for BLB in India. Seed treatment with talc-based Pf-1 formulation at 10 g per kg of seed, followed by two foliar sprays of 0.2% suspension (2 g/L water) at tillering and panicle initiation stages, has been shown to reduce BLB incidence by 40–60%. The mechanism involves production of antifungal and antibacterial metabolites (2,4-diacetylphloroglucinol, pyocyanin), siderophores (pseudobactin) that compete for iron, and induction of systemic resistance (ISR) in the host.
- Trichoderma harzianum / T. viride: Soil application of Trichoderma-enriched farmyard manure (2.5 kg/ha mixed with 100 kg FYM) at the time of last ploughing improves soil microbial balance and induces systemic resistance in rice plants against bacterial pathogens.
- Bacillus subtilis: Strains of B. subtilis produce iturin and bacillomycin compounds that exhibit antagonism against Xoo in vitro and have shown moderate efficacy in field conditions. Seed treatment at 10 g/kg with talc-based formulation is recommended.

Chemical Control

Chemical control is recommended when cultural and biological measures are insufficient or when the disease pressure is high. It serves as a corrective measure and should be integrated with other management strategies to delay the development of resistance in the pathogen.

- Seed Treatment: Soak seeds in 100 ppm Streptomycin sulphate solution (Agrimycin) for 12–16 hours before nursery sowing. This eliminates seed-borne inoculum effectively.
- Copper Oxychloride 50 WP (Blitox): Spray at 3 g per litre of water at the first appearance of symptoms. Repeat at 10–15 day intervals for 2–3 sprays. Copper-based bactericides act as protectants by denaturing bacterial proteins.

- Streptomycin Sulphate + Copper Oxychloride (Tank Mix): The most widely recommended chemical combination in India. Streptocycline (Streptomycin sulphate + Tetracycline, 90:10) at 200 ppm (0.2 g/L) is mixed with Copper oxychloride at 3 g/L and sprayed as a foliar application. The antibiotic component provides curative action while the copper provides protectant activity.
- Validamycin 3 L: 2 mL per litre as foliar spray and soil drench. While primarily registered for sheath blight, it offers additional suppression of BLB and is useful where both diseases co-occur — an advantage in integrated scheduling of sprays.
- Propiconazole 25 EC: 1 mL per litre as an adjuvant spray to reduce secondary infection spread; also manages fungal co-infections such as sheath blight and brown spot simultaneously.

Note: Antibiotics such as Streptomycin should be used judiciously and strictly as per label recommendations. Repeated use of the same antibiotic increases the risk of resistance development in Xoo populations. Rotate between chemical groups and integrate with biological and cultural measures for sustainable disease management.

Conclusion

Bacterial Leaf Blight remains one of the most significant constraints to rice production in tropical and subtropical regions of the world. The disease is caused by Xanthomonas oryzae pv. oryzae, a gram-negative, yellow-pigmented bacterium belonging to the family Xanthomonadaceae under the class Gammaproteobacteria. As a prokaryote, it does not possess a perfect (sexual) stage in the traditional sense; however, genetic recombination through conjugation, transformation, and transduction drives the evolution of new virulent races. Effective management of BLB requires an integrated approach combining the use of resistant varieties, balanced crop nutrition, field sanitation, biological agents such as Pseudomonas fluorescens, and judicious use of bactericides when necessary. A thorough understanding of the disease cycle, epidemiology, and the host-pathogen interaction is essential for developing region-specific and season-specific control strategies that are economically viable and environmentally sustainable.