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BACTERIAL BLIGHT OF RICE (*XANTHOMONAS ORYZEA PV ORYZEA)* DISEASE AND ITS MANAGEMENT OPTIONS: AN OVERVIEW

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Abstract *Bacterial blight is one of the most dangerous diseases of rice. If this disease enters in field it causes higher yield loss. Yield loss due to bacterial blight of rice is 70% when the susceptible varieties are grown and the environment has become favourable to the pathogen of this disease. The pathogen causing this disease is Xanthomonas oryzea Pv oryzea. The symptoms are appear in rice are wilting and leaves becoming yellow, Kresek (Wilting of seedlings). Patches of fields that do not germinate might be used to describe it. Even if the seeds do succeed in sprouting the seedling might not appear or they might appear but biome brown get pinched and eventually die. Additional signs include yellow or stunted development as well as diminished root growth and brown blotches on the roots and coleoptile.*

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Introduction

Xanthomonas oryzae PV. Oryzae (*Xoo*), previously referred to as *Xanthomonas campestris PV. Oryzae* (Health et al., 2018), is the bacterium that causes bacterial scourge disease (BLB) of rice in Asia. Because the 1960s, it is believed to be one of the maximum serious and enormous ailments to have impacted the rice enterprise in Asia (Bray, 2023). Typically starting on the leaf tip, it causes the leaves to end up yellow before the infected leaf tissues die (Figure 1) due to the lower leaf area size, a polluted powerless plant may have a 50% drop in output (Jain et al., 2019). Even though it simply affected a limited area, the illness first surfaced in rice fields in Peninsular Malaysia in the mid-1980s. Anyhow, it has become increasingly more common these days, which changed into frequently attributed to the huge planting of MR 84, a sensitive rice variety, for the majority of a few years in a row. From 1982 to 1994, the sickness is also estimated to have cost the country RM50 million in losses (Bhatti et al., 2023; Javed et al., 2024; Junaid and Gokce, 2024; Lama, 2023). Because there is no appropriate bactericide available to stop the progression of the illness and its effects, controlling the infection by substance means is unreasonable. Reproducing disease-resistant rice varieties becomes the most acceptable way as it is less costly and earth-friendly. Before the 1970s, MARDI's general rice reproduction system had no specific mandate to raise rice varieties resistant to bacterial contamination (Abbas et al., 2024a; Abbas et al., 2024b; Dorairaj and Govender, 2023). It has recently evolved into one of the requirements to be taken into consideration before an assortment is given. The availability of safe hereditary sources and knowledge of the variation within the relevant microbial population are the two key determinants of the efficacy of reproducing for the infection-safe program. It is necessary to realize the mechanism and the host-pathogen dating to increase an extended-time period sickness treatment strategy (Raju, 2024). Due to or as a consequence of their population's variety, plant diseases have been believed with a purpose to swiftly adapt after the creation of any resistance genes. some of Xanthomonas campestris *Pv*. *Oryzae* (*Xoo*) pathotypes have been recognized in distinctive Asian international locations (Sakthivel et al., 2021). Pathotype is the populace level at which selection and edition happened (Hebb et al., 2022). The advent of the newly added resistant gene will be sizable if it stays resistant and powerful against neighborhood X (Kennedy and Read, 2018). *Oryzae* population at the place of introduction. Data on the pathogenicity and diversity of neighborhood X (Sheoran et al., 2021). *Oryzae* populations ought to additionally be collected.

346 distinct *X. oryzae* traces have been accumulated from unique rice-developing regions in Peninsular Malaysia. The virulence and variability of these isolates towards diverse types, their category into specific pathotypes, and the virulence of specific isolates in opposition to precise improved types and breeding strains have been additionally described. *Xanthomonas oryzae* pathovar *oryzae* (often referred to as *Xoo*), previously known as Bacillus oryzae, turned into identified in 1911 as the causative agent of the sickness after it turned into first visible in Kyushu, Japan, in 1884–1885.

Figure 1. Symptoms of BLB in rice

Geographic Distribution of Bacterial Blight of Rice (*Xanthomonas Oryzea Pv Oryzea*)

The species *Oryza meyeriana* (Zoll. & Moritzi) Baill is a wild relative of cultivated rice (Qin et al., 2021). High ranges of immunity or resistance to bacterial blight (BB), a disease because of *Xanthomonas oryzae Pv. oryzae* (*Xoo*), had been said to be *O. meyeriana* (Jiang et al., 2020). To understand the BB resistance of *O. meyeriana* during various problem places in Yunnan, China, 87 accessions of 29 *O. meyeriana* populations were deliberately cut with the *Xoo* virulent strain CX28-3 received from rice in Yunnan. The surroundings and resistance range of every accession have been then analyzed. The results showed that resistance turned into unpredictable. 37.9% of the 87 accessions that were analyzed were touchy to CX28-3 (9 have been very inclined and 24 have been prone), the handiest 20.7% were proof against it (12 have been resistant and 6 have been especially resistant), and the last 41.4% (36 accessions) have been as a substitute resistant. No tested accessions showed immunity to it. There may be more variation in resistance across populations than inside them. The 29 populations of *O. meyeriana* were categorized according to climatic elements, river community, longitude, range, altitude, and managerial quarter. The diversity index and resistance distribution of the 29 *O. meyeriana* populations were calculated. It has shown that there have been outstanding differences in *O. meyeriana* accessions' resistance in most of the 5 administrative regions. Baoshan had the smallest competition, at the same time as Xishuangbanna had the best, accompanied by Purer, Dehong, and Lincang. The cities with the highest variety indices of resistance are Xishuangbanna (0.64), Baoshan (0.69), Lincang (0.67), Dehong (0.95), and Pu'er (1.13) (Qin et al., 2021). Correlation evaluation showed that O. meyeriana's resistance was influenced by nearby and climatic elements. There's a very robust high-quality correlation between range and the sickness index. Moreover, there is a massive high-quality correlation between altitude and the illness index. Those results imply that accessions of *O. meyeriana* located at higher altitudes or latitudes are more at risk of BB. Via batch evaluation of the climatic and geographic features of the *O. meyeriana* allocation websites, the 29 populations have been separated into 5 agencies, each exhibiting various degrees of resistance. Although *O. meyeriana* is believed to be nearly resistant to BB, touchy accessions were in China's Yunnan Province for the first time (Qin et al., 2021).

Importance of Bacterial Blight of Rice (*Xanthomonas Oryzea Pv Oryzea*)

Plants are always under attack from a large range of possible pathogens that lead to a variety of illnesses. 16% of the world's agricultural yields are missing as a result of these illnesses (Nazarov et al., 2020). According to Belete (2018), plants contain sophisticated natural defense mechanisms in each cell that help them repel an attack. Plant immune response involves a two-layered mechanism. Cell exterior-spot pattern recognition receptors (PRRs) control the first layer. They could become aware of pathogen-related molecular styles (PAMPs), which are enormously blanketed molecules important to the pathogen's existence cycle, including fungal chitin or bacterial flagellin. Whilst PAMPs are detected, the immunological reaction is comparatively moderate (PTI). Some of the reactions that comprise PTI are reactive oxygen species (ROS), an increase in intracellular calcium immersion, callose sediment within the mobile wall, antibacterial compounds known as phytoalexins, and the activation of mitogen-prompted protein kinases (MAPKs). The bulk of invasive species are saved through broad competition. To lessen PTI, pathogens advance a mechanism called effector-prompted susceptibility (ETS) that allows them to supply and deliver a huge variety of effectors into host cells.

The second plant defense layer, which primarily capabilities within the cellular, is based totally on highly polymorphic resistance proteins that both directly and in a roundabout way stumble on virulence people launched interior host cells by way of pathogens, activates effector-prompted immunity (ETI) (Javed et al., 2024; Sood et al., 2021). The hypersensitive reaction (HR), now and again referred to as ETI, is a fast and amazing response that normally affects programmed mobile loss of life at infection websites (Saur and Hückelhoven, 2021). other shielding strategies consist of the manufacturing of reactive oxygen species (ROS), the fortification of mobile partitions, the buildup of toxic proteins or metabolites, and the alteration of hormone tiers (Rady et al., 2023). Rice (Oryza sativa L.), a historically domesticated plant, is one of the maximum extensively grown plants in the world and a very crucial bulk meal for humans (Verma and Srivastav, 2020). Even though rice manufacturing has nearly doubled in a long time because of the creation of the semi-dwarf gene sd1, hybrids, and improvements in cultivation control strategies, it still needs to growth considerably to meet the expected call for from the sector's continuously expanding populace (Fahad et al., 2019). However, obstacles to the unfold encompass the supply of farms, water, rich soil, weather alternatives, insects, and illnesses. Rice is at risk of some bacterial, viral, and fungal illnesses (Asibi et al., 2019). Yield losses from BLS might vary from 8% to 32% (Thianthavon et al., 2021). It's miles turning into more vital, specifically in Asia and Africa. China now has BLS quarantine guidelines in region (Bossa-Castro, 2018). In this revised evaluation, we offer an overview of these two diseases and communicate approximately the advancements in the look at of the *Xoo*/*O. sativa* -rice hyperlink.

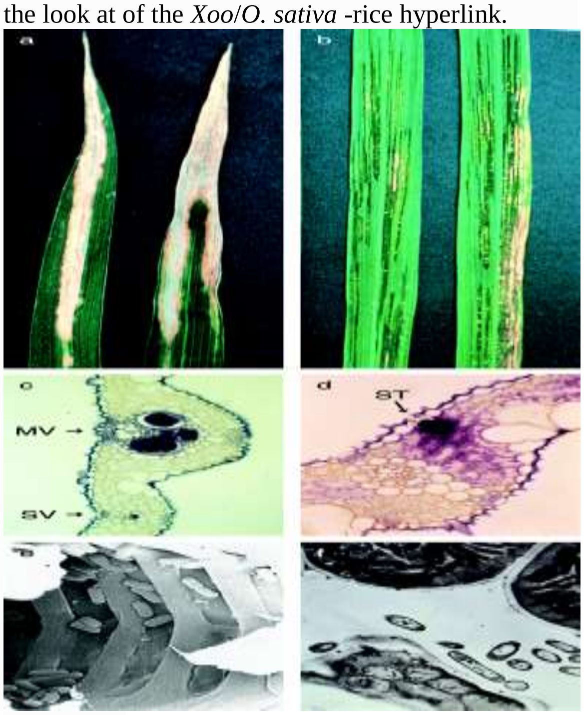

Figure 2. Pathovars of *Xanthomonas oryzae* are specific to their host tissue. (a) while *X. oryzae Pv*. *oryzae* invades the xylem by way of hydathodes, the symptoms of bacterial blight appear on the rice leaves and develop along the veins from the leaf tip and margins. When *X. oryzae Pv. oryzicola* colonizes the interveinal tissue through stomata, the bacterial cells are seen as darkish blue to pink in the midrib's xylem vessels and a peripheral vein inside the spacemen of a rice leaf tormented by *X. oryzae Pv*. Oryzae. (b) Rice leaves with leaf streak symptoms.

Microorganisms invade the sub-stomatal element and mesophyll parenchyma of rice leaves infected with *X. oryzae Pv. oryzicola* in (d), as seen by way of a move-section of the leaf colored as in (c). Stoma, or ST. (e) SEM picture of *X. oryzae Pv*. *Oryzae* cells within the xylem vessel of a rice leaf. (f) An electron micrograph of *X. oryzae Pv. oryzicola* cells in the intercellular areas of the mesophyll parenchyma of a rice leaf. Way to T, pix a and b are to be had. Mew and were taken from the collection of diseases present in rice, 1992, published by the American Phytopathological community in St. Paul, Minnesota.

Symptoms

Xoo generally penetrates the leaf of rice by water pores at the leaf border and tip (Schmidt et al., 2021). When guttation fluid *ooze*s at night and is withdrawn in the morning, cells on the surface of the leaf may get hanged in fluid and enter the plant passively or actively (Singh, 2020). Bacteria grow in underlying episteme's intercellular gaps before entering and dispersing throughout the plant into and out of the xylem (Figure 2). Injuries or gaps created by developing roots at the site of the leaf of leaf sheath may also provide *Xoo* access to the xylem (De La Fuente et al., 2022). According to An et al. (2020), *Xoo* likely interacts with xylem parenchyma cells within the xylem. Primary veins in the leaf allow the pathogen to go vertically through it, but commissural veins also allow it to travel laterally across the leaf. A typical symptom of illness and an origin of peripheral inoculum, pellet or strands of exudate on the surface of leaf are formed inside some days when cells of bacteria and bacterial EPS load the xylem arteries and *ooze* out from water pods (Harun-Ur-Rashid et al., 2023). Contrarily, *O. sativa* enters the leaf primarily by stomata, grows in the sub-stomatal chamber, and eventually establishes a colony parenchyma's intercellular spaces (Wahab et al., 2022).

In the same way, as *Xoo* can enter via wounds, *O. sativa* can only enter the apoplast of mesophyll tissue; it cannot enter the xylem (Wahab et al., 2022). *O. sativa* can also flow out of the leaf's natural holes in a pattern or, in damp environments, as tiny pellets. Yellow *ooze* at the leaf surface is a clear signal of BLS; like *XOO*, it can fall into floodwater or be carried by using the air, rain, bugs, or different methods, which aids within the sickness's unfold (Cowan and Morell, 2021).

Early on in the course of the illness, it is simple to distinguish between BB and BLS symptoms, which correspond to the various ways that each pathogen causes infection (Elbehiry et al., 2023). Small, green drenched patches present on the leaves and edges of fully formed leaves are the typical foliar signs of BB that first appear at the tillering stage. The spots usually grow from the leaf's sharp end through the veins and margins, merging, becoming chlorotic, and finally necrotic, leaving opaque, white to grey-colored lesions. In contrast, BLS symptoms start as tiny, wet sores all over the leaf in the middle of the layer. Layer serve as a fence when diseased regions grow and consolidate lengthwise, causing the disease's signature symptom (Ongaro, 2019).

Translucent streaks are usually golden in color. Infected leaves eventually become greyish-white and die (Osdaghi et al., 2023). When an infection spreads through leaf splits, as could happen when there is strong air, signs might spread over smash and lengthwise, destroying most or all of the leaf. The symptoms of both disorders converge as they advance. Leaf blades that have dried out and died may wilt and roll (Erbs and Newman, 2024). In addition to becoming white or grey from the development of expedient or saprophytic fungi, BLS leaves can also look like BB. BB and BLS may be mistaken for one another or other physiological problems of the plant, depending on the growing circumstances or level of resistance of the cultivars. Individual leaves may have signs of both *Xoo* and *O. sativa*, which frequently coexist in rice fields (Timilsina et al., 2024). (R. Sonti, independent source) Kresek and pale-yellow leaf are two disease syndromes caused by *Xoo* in torrid, specifically on cultivars of *O. sativa* ssp. Indica that are susceptible. These symptoms are different from those of conventional bacterial blight. A seedling blight called Kresek appears soon after seedlings are transferred from nurseries to the field. Cutting off leaf tips before transplanting is a typical procedure that significantly contributes to the syndrome's development. The pathogen uses cut leaves as a breeding ground for infection, and after a few days, water-soaked areas appear immediately below the cut tips. In addition, germs prevalent in flood-irrigated fields enter through damaged roots caused by pushing seedlings away from the seedbed. Infected leaves at the base of other leaves were infected by bacteria, which then killed the entire plant in two to three weeks. The tiller growth of plants that survive kresek is halted, they seem stunted, and their overall color is yellowish green (ALEENA, 2021; Sah and Joshi, 2020). Older plants often have pale-yellow leaves, which are sometimes thought to be a side consequence of seedling leaf blight and wilt. Fresh leaves are consistently light yellow or yellowish and farmers do not grow fully, but older leaves look healthy and green (Feng et al., 2024; Isaac et al., 2018; Reed, 2019).

The Pathogen

The rod-like morphology and round ends are characteristics of the Gram-terrible species X. oryzae. Character cells vary in the period from around 0.7 mm to 2.0 mm and in width from 0.4 mm to 0.7 mm. Cells may additionally pass by using the usage of a single polar flagellum (Figure 3). Colonies on solid medium containing glucose are round, convex, mucoid, and yellow in coloration because of the synthesis of the precise pigment *xanthomonad* (Mahmood et al., 2020). The cells of *X. oryzae* generate a whole lot of extracellular polysaccharide (EPS). This EPS is critical for the formation of bacterial exudate droplets or strands on diseased leaves, presenting safety against desiccation and assisting in the transmission of the ailment by using wind and rain (Bourouiba, 2021; Mahmood et al., 2020).

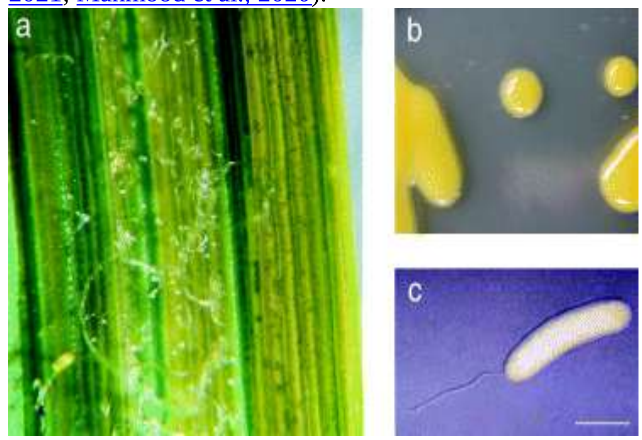

Figure 3. Morphology of *Xanthomonas oryzae*. (a) Strands and condensed droplets of *ooze* composed of *X. oryzae Pv, oryzicola* cells covered with extracellular polysaccharide extruded from the surface of an infected rice leaf. (b) *X. oryzae* colonies on agar supplemented with yeast extract and glucose. (c) Tsuchiya provided the SEM picture of a single *X. oryzae Pv* and *oryzae* cellular; bar, 1.0 m. *X. oryzae* is a vital cardio organism that does not form spores. 25 to 30 °C is the finest boom temperature. The other species, *X. oryzae* is catalase-fantastic, has a restrained capacity to produce acids from carbohydrates, and is not able to lessen nitrate. The capacity to grow on 0.3% vitamin-unfastened casamino acids, create acetoin, develop with L-alanine as the only carbon source, and tolerate publicity to 0.001% $Cu (NO_3)$ in line with, there are strategies to differentiate Pathovars *oryzae* from *Oryzicola*.

Disease Cycle

- **Inoculum**

Both weed hosts and rice stubble may contain inoculum. Although the pathogen may briefly be present on infected seeds and in soil, they are not thought to constitute significant inoculum sources (Nallathambi et al., 2020). Transmission methods include plant-to-plant contact, irrigation water, rain, and instruments used for transplanting seedlings. Typhoons are linked to the illness spreading quickly.

- **Infection**

Through natural openings like hydathodes and stomata on leaf blades, growth fissures brought on by the formation of new roots at the base of the leaf sheath, and wounds on leaves and roots, the bacteria accesses leaf tissues. When the number of bacteria increases enough, some of them can penetrate the circulatory system and even seep out of hydathodes (Ray, 2024).

- **Symptoms and signs**

The two primary disease signs are leaf wilt and leaf blight, the latter of which is also known as rasp (Kiran et al., 2021). The most prevalent symptom, leaf blight, often appears after the maximum tillering stage. The first signs are water-soaked stripes and lesions on the leaf blades. On immature lesions, bacterial *ooze* drops may be seen. The stripes become longer and wider, turn yellow, and then turn white with wavy edges. They might combine to completely cover the leaf blade. In difference to the lighter brown lesions brought on *Xanthomonas oryzae Pv. oryzicola*, lesions on older infected leaves frequently appear grey to white. The same plant may contract both diseases. On highly infected glumes, small, circular lesions with water-soaked edges can also occur. Less and lighter grains of lower quality are produced by infected plants. "Yellow leaf" or "pale yellow" is the name of a third, less frequent bacterial blight symptom (Kiran et al., 2021). The plant's youngest leaf develops a wide chlorotic stripe or turns a consistently light-yellow color. The bacteria that cause yellow leaf can be identified in the infected stems' internodes and crowns but not in the leaf itself. The most harmful symptom of the illness is the wilt or kretek symptom. From the seedling until the early phases of tillering, it occurs in the tropics. Infected plant leaves wilt, fold up, and become grayish-green. Then, the plant as a whole usually perishes as the leaves turn yellow to straw-colored and wither. Yellowish and stunted plants are those that do survive. With kresek, complete crop failure is not unusual (Gangwar et al., 2021).

- **Survival**

The virus is kept alive by rice stubble, ratoons shoot, and weeds that emerge from the roots of infected plants. The bacteria lives on *Oryza rufipogon* and *Oryza australiensis*, two wild Oryza species, in Australia (Abdelghany et al., 2021). Although the virus may persist for a brief period in soil and on infected seeds, it has not been displayed that these are significant sources of inoculum.

CONTROL

Preventive method

• Seed treatment with zinc sulfate (2%) and bleaching powder (100g/l) reduces bacterial blight.

• Seed treatment: wettable ceresan (0.05%) and Agrimycin (0.025%) soaked in hot water for 30 minutes at 52–54°C.

• ceresan (0.1%) soaked in hot water for 8 hours

• treatment with streptocyclin (3g in 1 liter);

• Spray NSKE 5% or 3% neem oil. To combat bacterial blight, mist fresh cowdung extract on the affected area. Stir 20 g of cowdung into 1 liter of water, let it settle, and then sift. Utilize liquid supernatant. (Beginning with the disease's first symptoms and continuing every two weeks).

Cultural methods

- Plant the tolerable IR 20, IR 72, PONMANI, and TKM 6 types.
- Grow nurseries, ideally in secluded highland areas, with disease-free seeds.
- Refrain from trimming seedlings when transplanting.
- Balanced fertilization; avoid applying too much nitrogen.
- Skip the N appeal during kick if the illness is mild.
- Evacuate the field (unless when the crop is in the blossoming stage).
- Elimination of weeds and incidental hosts.
- Prevent water from damaged fields from flowing.
- Uphold ideal plant spacing.

Chemical methods

- Seed treatment with zinc sulfate (2%) and bleaching powder (100g/l) reduces bacterial blight.
- For seed treatment, seeds should be soaked for 8 hours in wettable ceresan (0.05%) and Agrimycin (0.025%) before being treated in warm water for 30 minutes at 52–54°C.
- Drenched seeds in ceresin (0.1%) for eight hours and treated with strepto-cyclin (3g per liter);
- Apply a spray mixture of 300 g of streptomycin sulphate, 1.25 kg of copper oxychloride, and tetracycline. Repeat if required 15 days later.
- In the kretek stage, it is advised to apply bleaching powder to the irrigation water at a rate of 5 kg/ha.
- To prevent secondary spread, treat the leaves with copper fungicides or Strepto-cyclin (250 ppm).

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Declarations

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All authors contributed equally.

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Regarding conflicts of interest, the authors state that their review was carried out independently without any affiliations or financial ties that could raise concerns about biases.