STUDY ON INCIDENCE AND SEVERITY OF BLAST, BACTERIAL LEAF BLIGHT AND SHEATH BLIGHT IN SELECTED INDIGENOUS RICE VARIETIES

A THESIS

BY

MAHBUBUL HAQUE

Student No.: 1701218

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IN

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DEPARTMENT OF PLANT PATHOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,

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Approved as to style and content by:

Professor Dr. A.T.M. Shafiqul Islam
Supervisor

Professor Dr. Md. Mamunur Rashid
Co-Supervisor

Professor Dr. Mohidul Hasan
Chairman, Examination Committee
&
Chairman, Department of Plant Pathology

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR-5200

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Dedicated
To My
Beloved Parents

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Abstract

The study was conducted to assess the performance of six indigenous rice varieties (Binni Pakri, Uknimodhu, Sanla, Bolder, Zetha Katari, and Jira Katari) against three major diseases (blast, bacterial leaf blight and sheath blight) during the Aman season of 2023 at the research farm of Hajee Mohammad Danesh Science and Technology University in Bangladesh. The study focused on disease incidence and severity at six different growth stages, as well as the impact of these diseases on yield and related characteristics. During the experiment, Sanla exhibited the highest incidence and severity of leaf blast at 25.68% and 10.32% at 40 DAT, respectively, while Binni Pakri demonstrated the lowest values at 0.32% and 0.05% at 80 DAT. For neck blast, Sanla again recorded the maximum incidence and severity at 29.54% and 13.93% in 90 DAT, with Binni Pakri showing the minimum values at 0.00% in 80 DAT respectively. Regarding bacterial leaf blight (BLB), Binni Pakri had the highest incidence (5.57%) and severity (1.90%) at 80 DAT, while Uknimodhu had the minimum incidence at 0.47% in 40 DAT, and Bolder had the minimum severity at 0.08% in 40 DAT. In the case of sheath blight, Uknimodhu had the maximum incidence and severity at 15.20% and 3.45% in 80 DAT, respectively, while Sanla exhibited the minimum incidence at 0.77% in 40 DAT, and Zetha Katari showed the minimum severity with 0.14% at 50 DAT. The organisms responsible for the three diseases, namely *Pyricularia oryzae*, *Xanthomonas oryzae pv. oryzae* and *Rhizoctonia solani*, were successfully isolated from the leaves that were infected. These organisms were then identified through a detailed examination of their cultural characteristics and the morphology of their conidia. Among the factors influencing yield, Binni Pakri exhibited the greatest panicle length and the highest number of grains per panicle. In terms of overall yield, Binni Pakri stood out with the highest production 3.67 tons per hectare. The superior yield of Binni Pakri can be attributed to its minimum incidence and severity of blast, as it was recorded with the lowest values in this regard.

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AEZ	: Argo Ecological Zone
CV	: Co-efficient of Variation
DAT	: Days After Transplanting
DI	: Disease Incidence
DS	: Disease Severity
LSD	: Least Significance Difference
PDI	: Percent Disease Index
PLP	: Plant Pathology
P. oryzae	: *Pyricularia oryzae*
R. solani	: *Rhizoctonia solani*
RCBD	: Randomized Complete Block Design
SRDI	: Soil Resource Development Institute
Xoo	: *Xanthomonas oryzae pv. oryzae*

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa*) is an edible starchy cereal grain belongings to the family Poaceae mostly cultivated in Bangladesh. Approximately 50% of the global population, encompassing nearly all East and Southeast Asia, is entirely reliant on rice as their main food source; humans consume 95% of the world's rice harvest. Rice can be crushed into flour or cooked by boiling it. In Asian, Middle Eastern, and many other cuisines, it is consumed both on its own and in a wide range of soups, side dishes, and main courses (Britannica, 2023). Rice is the main food crop grown in 113 countries, and it is the primary way that about 100 million households in Asia and Africa make money (FAO, 2004). Main rice production regions in the world are East and South Asia. Asia produces and eats over 90% of the world's rice, and it is home to 60% of the world's population (Kole, 2006). China holds the title of the world's top rice producer, producing over 210 million metric tons, with India, Indonesia, Bangladesh, Vietnam, and rest of the world (FAO, 2017a). Sub-Saharan Africa bought over $3.6 billion worth of rice from Asia in 2008 to make up for the difference between how much rice it produced and how much rice it consumed (Anonymous, 2011a). Rice is the main food crop in 17 Asian countries and provides 20% of the world's dietary energy, more than wheat (19%) and maize (5%) (FAO, 2004). Half of the calories that humans consume come from wheat, rice, and maize (Gnanamanickam, 2009). Rice accounts for about 23% of the calories that people around the world eat (Nagaraj *et al*., 2019). Even though rice is not the most widely planted crop in the world, it is the most important food source for Asian countries, especially in Southeast Asia, where it is a major economic crop for farmers and workers who grow it on millions of hectares of land (Gomez, 2001).

Rice is a major staple food and a dietary mainstay for the poor rural population, ensuring their food security. Bangladesh is the fourth largest rice producer in the world, with a production of 3,265,000 MT. Rice is the staple food of approximately 166.5 million people in Bangladesh. (BBS, 2021**).** Rice is the most important agricultural sector in Bangladesh, contributing half of the country's agricultural GDP and one-sixth of its national income. More than 28 million acres of land in Bangladesh are used to grow rice (BBS, 2017). The average rice yield in Bangladesh is 3.02 t/ha, which is below the world average of 3.84 t/ha (FAO, 2017b). Bangladesh cultivates rice in three distinct seasons: Aus (April to August), Aman (August to December), and Boro (January to June), covering nearly 11.0 million hectares of land (DAE, 2010). Rice is the staple food of over 95% of the population, providing 76% of their daily calories and 66% of their total protein intake (Bhuiyan *et al.*, 2002). Almost all of the 13 million farming households in the country cultivate rice. Over the past three decades, the land area dedicated to rice cultivation has remained relatively stable at 10.5 million hectares. Rice is grown on more than 75% of the total arable land and over 80% of the total irrigated land. Therefore, rice cultivation plays a crucial role in the livelihoods of the people in Bangladesh (BRKB, 2023).

Major constraints to the adoption of rice include the high cost of seed, the requirement for more intensive crop care and management, and the high susceptibility of rice to pests and diseases (AAS, 1999). Out of these constraints, disease is the most significant. Rice is susceptible to many pests and diseases, which cause significant losses worldwide each year. The rice crop is vulnerable to 50 diseases, including 6 bacterial, 21 fungal, 4 nematodes, 12 viral, and 7 miscellaneous diseases and disorders. (Hollier *et al.*, 1993; Webster and Gunnell, 1992; Jabeen *et al.,* 2012). The continued use of old cultivars that are susceptible to diseases, insects, and pests has led to a decrease in rice productivity in Bangladesh. One of the primary reasons for this decline is the lack of access to new cultivars, resulting in older cultivars still being widely used in farming (Hossain et al., 2022). Rice in Bangladesh is susceptible to 31 different diseases (Ali, 2002). Ten diseases, namely brown spot, narrow brown spot, blast, sheath blight, sheath rot, bacterial leaf blight, stem rot, bakanae or foot rot, tungro, and ufra, are the main constraints to rice production in Bangladesh, causing an average yield loss of 10-15% (BRRI, 1999).

Rice blast is the most serious and damaging disease of rice, caused by the fungus *Pyricularia oryzae* (Couch and Kohn, 2002). Rice blast outbreaks are a persistent and severe issue in all rice-producing areas worldwide, including Bangladesh. It's estimated that the amount of rice lost to rice blast alone every three years could feed 60 million people (Zeigler *et al*., 1994). All local and enhanced aromatic rice varieties cultivated during the wet season are susceptible to neck blast. This disease is prevalent globally, but the occurrence and intensity of rice blast disease fluctuate based on time, location, and environmental conditions (Bhat *et al*., 2013). Under favorable conditions, the entire rice field can be destroyed within 15 to 20 days, leading to a potential yield loss of up to 100% (Asibi *et al*., 2019). Blast disease outbreaks were recorded in Bangladesh during the boro season in 1980 and 1990 (Rahman and Uddin, 2017). The disease has become more frequent and widespread in recent years, even invading new areas in the north and northwest of the country. Two popular rice varieties in Bangladesh, BRRI Dhan 29 and BRRI Dhan 28, are highly susceptible to blast disease. (Anonymous, 2011b). The blast disease is even adaptable to adverse environmental conditions of widely changing temperatures and relative humidity. It occurs in irrigated low land, rainfed upland, submerged rice as well as in deep water rice (Bag *et al*., 2021). This disease affects a broad range of grasses, including rice, wheat, and barley, but it is especially destructive to upland rice crops that are grown without irrigation. Areas with frequent and prolonged rain, higher levels of nitrogen in the soil, humid regions, and cool daytime temperatures are particularly susceptible (George, 2005). Thirty percent of rice yields loss may occur due to blast disease caused by fungal pathogen *P. oryzae* (Spence *et al*., 2014).

The disease known as sheath blight of rice, caused by *Rhizoctonia solani,* is widespread in virtually all countries where rice is grown. This disease is particularly damaging to rice crops, especially in regions where rice farming is intensive (Bowman *et al*., 1992) . Sheath blight disease poses a threat to both local varieties of rice and those that are high yielding (Naidu, 1992). Sheath blight is most severe during the aus and transplanted aman rice seasons in Bangladesh, particularly in the northern and central regions of the country. In Rangpur district, the average incidence of sheath blight was 24.5% and the average severity was 3.4% during the 2018 T. aman season. In Cumilla district, the average incidence of the disease ranged from 5% to 80%, with the highest incidence (90%) reported in Keshobpur and Jashore districts. During the 2018-19 boro rice season, sheath blight was widespread in Rangpur district, with an average incidence of 32.5% and an average severity of 5.4%. Sheath blight was also more prevalent than brown spot, bacterial blight, and blast disease in Rangpur district during the 2018-19 boro rice season (BRRI, 2019).

One of the most destructive pathogens causing significant yield losses in rice (*Oryza sativa* L.) is *Xanthomonas oryzae* pv. *oryzae*, which causes bacterial leaf blight (BLB) disease (Ooi *et al*., 2022). Rice bacterial leaf blight (BLB), triggered by the pathogen Xanthomonas oryzae pv. oryzae (Xoo), is the most significant disease affecting rice cultivation, with the potential to reduce yields by as much as 80%, as noted by Sudir and Yuliani, 2016; Banerjee et al. 2018). Bacterial blight is found in rice-growing regions of Asia, the western coast of Africa, Australia, Latin America, and the Caribbean. It thrives in warm, humid conditions (Yen, 2020). In Bangladesh, the severity of the disease varies each year (Jalaluddin et al., 2005). The spread of Bacterial Leaf Blight (BLB) in Bangladesh is largely attributed to the introduction of high-yielding varieties (HYV) in the mid-1960s (Adhikari et al., 1994). However, this disease can lead to a yield loss of up to 32% in Bangladesh (Adhikari et al., 1999; Farooq and Ahmad, 2007). Insect-related wounds provide a pathway for the disease to penetrate the plant through wounds. The disease might spread throughout the field by strong winds. Overfertilization with nitrogen may also promote plant infections (Saleem, 2012).

Given the aforementioned information, the current study was carried out to look at the incidence and severity of three major diseases of rice grown in Dinajpur district. We picked six rice indigenous varieties that are grown in Bangladesh during the Aman season to accomplish these goals.

Objectives:

The exact goals of the current study were to:

1. To screen best indigenous rice cultivars against blast, bacterial leaf blight and sheath blight.
2. To determine the incidence and severity of three major rice diseases blast, bacterial leaf blight and sheath blight.
3. To ascertain the effect of diseases on the yield of rice and yield-contributing characters.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Diseases

Pelczar *et al.* (2023) reported that plant diseases are known from the times preceding the earliest writings. Fossil evidence indicates that plants were affected by disease 250 million years ago. The Bible and other early writings mention diseases, such as rusts, mildews, and blights, that have caused famine and other drastic changes in the economy of nations since the dawn of recorded history. Other plant disease outbreaks with similar far-reaching effects in more recent times include late blight of potato in Ireland (1845–60); powdery and downy mildews of grape in France (1851 and 1878); coffee rust in Ceylon (now Sri Lanka; starting in the 1870s); Fusarium wilts of cotton and flax; southern bacterial wilt of tobacco (early 1900s); Sigatoka leaf spot and Panama disease of banana in Central America (1900–65); black stem rust of wheat (1916, 1935, 1953–54); southern corn leaf blight (1970) in the United States; Panama disease of banana in Asia, Australia, and Africa (1990 to present); and coffee rust in Central and South America (1960, 2012 to present). Such losses from plant diseases can have a significant economic impact, causing a reduction in income for crop producers and distributors and higher prices for consumers.

According to Baranwal *et al.* (2013), the disease is more common in environments with limited water supplies and nutritional imbalances, specifically a shortage of nitrogen.

Khalili *et al.* (2012) stated that all the nations that grow rice, including Japan, China, Burma, Sri Lanka, Bangladesh, Iran, Africa, South America, Russia, North America, Philippines, Saudi Arabia, Australia, Malaya, and Thailand, have been discovered to be affected by the disease.

Dallagnol *et al.* (2011) noted that environmental factors play a crucial role in determining the survival of fungi in both seeds and soil. The temperature and relative humidity conditions during seed storage are significant factors affecting pathogen variability.

According to the findings of Akhtar *et al.* (2011), the disease leads to varying reductions in grain yield, with the extent of the reduction depending on the crop stage, the susceptibility of the cultivar, and the environmental conditions in which it occurs.

In their study, Kamal and Mia (2009) estimated a reduction in yield ranging from 18.75% to 22.50%. Additionally, it has been reported that the glume blotch phase of the disease, as indicated by Kulkarni *et al.* (1986) and causes more significant damage and diminishes seed germination.

Strange *et al.* (2005) reported that plant pathogen populations differ widely in terms of genotype, time, and geography, they make it difficult to control. The most insidious thing about them is that they evolve, frequently conquering the resistance that would have been the plant breeder's hard-earned success.

Pannu *et al.* (2005) discovered that during a five-year span from 2000 to 2004, two rainy season crops (specifically in 2001 and 2003) in India resulted in terminal severities of 9.2% and 8.8%, respectively, corresponding to accumulated rainfalls of 410.5 mm and 502.0 mm. However, in 2002, lower rainfall was associated with increased severity.

According to Jha's (2004) findings, plants exhibit greater susceptibility during the dough and mature stages. In their study, Jha *et al.* (2004) noted a greater disease severity in directly sown plants compared to transplanted crops. Holanda and co-authors (2002) reported that this disease tends to be more prevalent in soils characterized by high pH, low organic matter, reduced levels of nitrogen (N), potassium (K), manganese (Mn), silicon (Si), and free iron (Fe), as well as a low cation exchange capacity (CEC).

Minnatullah and Sattar (2002) found that temperature and humidity, particularly in the form of leaf wetness, exhibit a synergistic effect on infection efficiency. This interaction could account for the observation that a decrease in daily minimum temperatures, from 9.3 to 7.5°C, results in more severe epidemics.

As reported by Veena *et al.* (2000), in India, the disease can result in yield losses of up to 81.3%.

2.2 Blast of rice

Ryan (2016) noted that rice blast disease stands out as one of the most devastating agricultural ailments, exhibiting a broad distribution and inflicting substantial damage with significant losses.

Couch and Kohn (2002) concluded that rice blast, caused by the fungus *Pyricularia oryzae* B. C. Couch, is recognized as one of the most significant diseases affecting rice crops.
Jia *et al.* (2000) stated that the most destructive disease impacting rice is the blast disease, which is caused by *Pyricularia oryzae*.

2.2.1 Geographical distribution of blast

Turaidar *et al*. (2018) documented that 23 states in India that grow rice have endemic rice blast districts; as a result, rice production is subject to varying degrees of losses because of blast incidence.

Khaing *et al.* (2018) cases of leaf blast and neck blast in Aungban, Pindaya, Taunggyi, Kyaukme, Yezin, Lapputa, and Bago during the 2015–2018 rice growing season and annual leaf blast disease incidence in Aungban research farm.

Rahman and Jashim (2017) conducted a study revealing that rice blast disease is caused by the fungus *Pyricularia grisea* (renamed as *Pyricularia oryzae*). This disease was first documented in China in 1637 and subsequently in Japan in 1704. In Italy, the USA, and India, the disease was also identified in 1828, 1876, and 1913, respectively. In Bangladesh, blast disease was not considered a significant issue in the late sixties and early seventies. However, outbreaks of blast disease were recorded in the boro season in Bangladesh in 1980 and 1990.

Aye *et al*. (2015) stated that blast disease cases in 2013 early summer and 2014 rainy season in Nay Pyi Taw Union Territory.

Suprapta and Khalimi (2012) documented that from several reports blast disease leads to varying degrees of yield losses in different regions, ranging from 1% to 100% in Japan (Kato, 2001), 70% in China, 21% to 37% in Bali, Indonesia 30% to 100% in Bangladesh, and 30% to 50% in South America and Southeast Asia.

Kohli *et al.* (2011) highlighted that rice blast had been identified as a destructive disease in various regions, including West Africa, Iran, Malaysia, and the Savannas of South America. Climatic changes associated with global warming may potentially facilitate its spread to other parts of the world.

Huang (2011) stated that rice varieties that initially exhibit resistance to blast often lose their resistance within a few years due to shifts in strains within the fungal population.

Sundaram *et al*. (2011) reported that in India, blast epidemics were observed in various regions, including the sub-Himalayan areas of Jammu and Kashmir, Andhra Pradesh, Tamil Nadu, the Coorg region of Karnataka, and the northeastern region, which comprises the states of Arunachal Pradesh, Manipur, Mizoram, Meghalaya, and Assam.

Ali *et al*. (2009) observed that over the last two decades, rice blast has been predominantly common in six districts of Pakistan, including Faisalabad, Toba Tek Singh, Vehari, and locations such as Gaggoo Mandi.

Naing (2008) observed that leaf blast epidemic and neck blast around Yezin area on the variety IR50 in the cold and dry seasons.

Nutsugah *et al*. (2008) found that lowland rice cultivated in temperate and subtropical climates in Asia is particularly susceptible to this pathogen. However, in tropical upland regions, susceptibility is primarily observed under irrigation conditions.
Arshad *et al*. (2008) documented that in Pakistan over the past two decades, rice blast disease was predominantly observed in districts including Faisalabad, Toba Tek Singh, Vehari, and locations such as Gaggoo Mandi.

Gilbert *et al*. (2004) documented that rice blast, caused by the fungal pathogen *P. oryzae*, is documented as a highly destructive factor impacting rice production and is prevalent in over 85 rice-growing countries worldwide.

Leong (2004) described from his experiments that rice blast disease is a major concern in the Penna River belts and Godavari regions of Andhra Pradesh. The blast fungus has the ability to infect over fifty other grass species and is known to cause diseases in rice plants at both the seedling and adult stages, affecting the leaves, nodes, and panicles. It can occur in irrigated lowland or rainfed upland rice, as well as in submerged or deep-water rice cultivation. Rice blast stands as the most severe disease affecting extensive rice-growing regions in Latin America, Africa, and Southeast Asia, posing a global challenge to rice production. This disease represents a significant barrier to global food security and agricultural trade.

Jia *et al*. (2000) noted that blast disease, caused by *Pyricularia oryzae* Cavara (formerly known as *Pyricularia grisea* Sacc., the anamorph of *Pyricularia grisea* (T.T Hebert) Yaegashi and Udagawa), significantly disrupts rice production in Pakistan.

Feakin (1974) noted that it was first reported in Africa in 1930.

2.2.2 Significance of blast

Mahmud *et al.* (2023) disclosed that significant yield losses were experienced, with the most severe impact seen among 11% of farmers who faced a disease severity scale of 9 in BRRI dhan28, leading to a yield loss of 3.92 t/ha. In a similar vein, a blast severity scale of 9 resulted in yield losses of 2.0 t/ha in BRRI dhan29, impacting 7% of farmers of Kusthia district in Bangladesh.

Shahriar *et al.* (2020) conducted a study highlighting the significant economic implications of rice blast disease, given that 60 percent of the global population relies on rice as a primary source of calories. While the disease can have destructive effects, it has also evolved into a valuable model for studying host-pathogen interactions. The outbreak of the disease is strongly influenced by local weather and climatic conditions, resulting in varying occurrences and symptoms from one region to another. Susceptible cultivars can lead to substantial yield losses in rice production. The primary factor contributing to the breakdown of resistance against rice blast disease in rice crops is the pathogenic variability. Pathogenic changes that can be observed during sexual hybridization may provide insights into pathogenic variation present in the asexual stage of the fungus. Virulent pathotypes are responsible for causing severe disease incidence. Identifying these pathotypes typically requires pathogenicity research involving a diverse collection of rice varieties, each carrying various resistance genes.

Pyricularia grisea (*Anamorph Pyricularia grisea Sacc. synonym Pyricularia oryzae Cav*.) causes rice blast disease in rice cultivation areas worldwide (BBS, 2017; Chiba *et al*., 1996; Kato, 2001).

Based on Olufolaji’s (2014) findings, it’s been observed that the agro-ecological region of Nigeria experiences a substantial decrease in rice yield, ranging from 30–50%. This considerable decline has created significant difficulties for both the researchers studying rice and the farmers cultivating it in the region.

Suprapta (2012) documented that rice blast in Bali, Indonesia, resulted in yield losses ranging from 21% to 37%.

Suprapta and Khalimi (2012) and Kato (2001) documented that the Blast disease causes yield losses from between 1- 100% in Japan 70% in China, 21-37% in Bali Indonesia 30-100% in Bangladesh and 30-50% in South America and Southeast Asia.

Koutroubas *et al.* (2009) highlighted that blast disease results in a yield reduction of 10-20 percent. However, in severe instances, the yield loss can escalate to as much as 80 percent.

According to Chandrasekhara *et al.* (2008) one of the deadliest rice diseases, rice blast (*Pyricularia oryzae*), can result in yield losses of up to 65% in susceptible rice cultivars.

Nutsugah *et al*., (2008) observed that in West Africa, the largest region for African rice production, this pathogen stands as the primary obstacle to production, resulting in yield losses spanning from 4% to 77%. The fungus has the capability to infect plants at all stages of growth and development, irrespective of whether they are grown in upland or lowland rice production systems.

Agrios (2005) pointed out that multiple rice blast epidemics have occurred in various regions across the world, resulting in production losses ranging from 50% to 90% of the expected crop yield.

Oerke and Dehne (2004) found that rice blast disease, which is spread by the fungus *Pyricularia oryzae*, is one of the primary productivity constraints. 35% of the global rice output was estimated to have been lost annually due to this fungus during the 1990s.

Manandhar *et al*. (1998) reported that *Pyricularia oryzae* is one of the most significant fungal pathogens affecting rice due to its wide distribution and destructive characteristics. This fungus can infect any above-ground part of the rice plant, including the seeds. They also proposed the possibility of systemic transmission of the fungus from seeds to seedlings.

Chiba *et al*. (1996) reported that rice blast disease is widespread and can be found in approximately 85 countries across all continents where rice cultivation takes place, encompassing both paddy and upland conditions. The presence of rice blast is closely tied to regions where rice is grown, but the disease's occurrence varies significantly depending on climate and the specific cropping system in place. Environments characterized by frequent and prolonged periods of dew, along with cooler daytime temperatures, are more conducive to the development of rice blast.

As per the findings of Manandhar *et al.* (1996), in Nepal, the disease caused a reduction in yield ranging from 10% to 20% in susceptible rice varieties. However, in severe cases, the yield reduction had increased significantly, reaching up to 80%.

2.2.3 Symptoms of blast

Jackson (2015) stated that blast disease symptoms manifest on various parts of the rice plant above the ground, including the coleoptiles, leaf sheaths, leaf blades, neck of panicles, stem nodes, and spikelets. These symptoms typically appear as oval or diamond-shaped spots measuring between 5-15 mm in length and 3-5 mm in width, featuring distinct dark borders. Often, these spots are accompanied by yellow haloes.

Shafaullah *et al.* (2011) noted that blast disease was recognized for its ability to affect virtually all above-ground plant parts and can strike during any growth stage. Recent findings have indicated that the fungus is also capable of infecting plant roots.

Sreenivasa *et al*. (2011) highlighted that neck blast infection affects the panicle, leading to unfilled seeds or causing the entire panicle to topple over due to rot. This type of infection can be highly damaging and directly diminishes the economic worth of the crop. The lesions typically manifest as a greyish-brown discoloration on the panicle branches, which may eventually break at the lesion site over time. Among the three symptoms, neck blast is identified as the most destructive.

Ribot *et al.* (2008) observed that a strong transcriptional reprogramming is applied to infected rice cells, which is probably influenced by hormone responses to auxins, abscissic acid, and jasmonates. Many of the rice genes expressed during infection encode plasma membrane proteins, which is consistent with the significant plant–fungal interactions that occur during the biotrophic phase.

Zhu *et al.*, (2005) stated that this form of the disease infects the panicle, leading to the failure of seeds to fill or causing the entire panicle to rot and collapse. Neck blast infections can be highly detrimental, directly reducing the economic value of the crop. These lesions often manifest as a greyish-brown discoloration of the panicle's branches, and over time, the branches may break at the lesion site.

Seebold *et al*. (2004) reported that the fungus *Pyricularia oryzae* can attack rice crops at all stages of their growth, and it typically symptoms on both the leaves and nodes of the plants.

Sesma *et al.* (2004) revealed a novel aspect of the life cycle of M. grisea: this fungus was capable of a distinct, yet unidentified set of programmable developmental events that were characteristic of pathogens that infect roots.

Bastiaans (1991) documented that leaf blast lesions have a substantial impact on the net photosynthetic rate of individual leaves, extending beyond the visible portion of the diseased leaf. Neck blast, often considered the most destructive phase of the disease, can occur without being preceded by severe leaf blast.

According to Bonman *et al*. (1989), neck blast was characterized by infection at the panicle base and rotting symptoms, which are more severe in this type of scenario.
Harmer *et al.* (1989) reported that the infection of rice blast takes place when fungal spores land and attach themselves to leaves, facilitated by a special adhesive released from the tip of each spore.

Hamer *et al*., (1989) concluded that the germinating spore forms an aspersorium, which is a specialized infection structure that generates significant turgor pressure, sometimes reaching up to 8 megapascals (MPa). This pressure causes the rupture of the leaf cuticle, enabling the invasion of the underlying leaf tissue.

2.2.4 Disease development of blast

Miah *et al*. (2017) concluded that numerous environmental factors play a crucial role in influencing the rate of infection and the spread of blast disease. These factors include temperature, nitrogen levels, intermittent rain showers or drizzle, air movement, high relative humidity, and drought conditions. It's worth noting that susceptibility to blast is inversely related to soil moisture levels. Specifically, plants grown in upland conditions tend to be more susceptible, while those in lowland conditions exhibit greater resistance.

Jackson (2015) stated that water used for irrigation can spread. Spores disperse over short and large distances due to wind and air currents. Straw and stubble, seeds, volunteer rice plants, and alternate hosts, primarily grass species, are the places where crops can survive in between crops. When the temperature is between 24 and 28 degrees Celsius and there are frequent, persistent showers, the disease is more severe.

According to Ram *et al.* (2007), the leaf blast fungus can attack the rice plant at any stage of its growth, leading to significant leaf necrosis and hindering the process of grain filling. This, in turn, results in a reduction in both the number and weight of the grains produced.

Koga and Nakayachi (2004) established that the infection is caused by a spore (conidium) that lands on the surface of a rice organ. Until it may germinate, conidium remains attached to the host plant.

Howard and Valent (1996) concluded that in cases of compatible interactions, the appressorium undergoes a differentiation process, forming a penetration peg that enables the pathogen to enter and establish itself within the host's tissues.

Based on a 13-year dataset, Padmanabhan (1963) concluded that whenever the minimum temperature falls to 24°C or below in combination with relative humidity levels of 90% or higher, these conditions are conducive to blast infection.

2.2.5 Blast incidence and severity

Shivakumar and Patil (2023) observed that the Mandya district in Karnataka, India, had the highest average leaf blast disease incidence at 37.20 percent.

Mandal *et al.* (2023) noted that the 26 predictive models were successful in estimating the severity of rice blast, with values ranging from 0.48 to 0.85.

Rajeswari *et al*. (2022) observed that among the various experimental cultivars, HMT Sona had the highest incidence rate of 71.33 percent, while the cultivar Tellahamsa had a lower incidence rate of 49.16 percent. The pathogen if. oryzae was most frequently isolated in Siddipet, with a rate of 75 percent, followed by Mahabubnagar at 50 percent.

Mandal *et al.* (2022) estimated that Rice severity was 0.00929 and 0.002301, respectively, under upland conditions. Meanwhile, the amplitude of scores for 0 and 9 was 0.010421 and 0.00193, respectively, for upland rice cultivation.

Mostaque *et al.* (2021) documented that Dinajpur experienced the greatest incidence of leaf and neck blast, with rates of 28% and 11% respectively. Conversely, Rajbari and Jashore had the least occurrence. The intensity of leaf blast fluctuated, with Dinajpur at the peak with 28% and Rajbari and Jashore at the trough with 2%. Dinajpur also recorded the highest severity of neck blast, while the lowest was seen in Rajbari and Jashore.

Zhang *et al.* (2020) found that Mongolian rice is susceptible to blast with a disease incidence of 83.33%, 97.06% and 83.87%, respectively.

Phaneendra *et al.* (2018) found that the highest average incidence of blast disease, at 38.99%, was observed in the Kovvur mandal of the Nellore district, while the lowest incidence, at 15.41%, was found in the Madugula mandal of the Visakhapattanam district of Andra Pradesh in India.

Sarada *et al.* (2018) estimated that the highest average blast incidence, 38.99%, was observed in the Kovvur mandal of the Nellore district, while the lowest incidence, 15.41%, was found in the Madugula mandal of the Visakhapattanam district. The incidence of blast varied greatly among different cultivars in these locations.

Hossain *et al.* (2017) conducted a study to record the incidence and severity of rice blast disease in eleven agro-ecological zones (AEZs) in Bangladesh during the Boro (irrigated ecosystem) and Transplanted Aman (rain-fed ecosystem) seasons. They found that in terms of disease incidence and severity, the irrigated ecosystem during the Boro season exhibited a higher rate at 21.19%, outperforming the rain-fed ecosystem during the Transplanted Aman season, which had an incidence rate of 11.98% across the AEZs.

Rameshbabu (2015) noted that rice blast symptoms can appear at all stages of plant growth. On leaves, these symptoms often manifest as spindle-shaped lesions with a broad center and pointed ends. Larger lesions typically take on a diamond shape, featuring a grayish center and a brown rim.

Asfaha *et al.* (2015) conducted an experiment in south west Ethiopia and estimated that the blast incidence was highest 85.69% and lowest 42.01%.

Olufolaji (2014) reported that the incidence of blast on farmland was between 35–65%. The severity of this incidence varied from a low of 3.2 to a high of 5.4.

Dar *et al*. (2010) conducted a study documenting the frequency and distribution of rice blast in Kupwara district, Jammu and Kashmir. They reported a 25% disease incidence and 15% severity, with the incidence increasing from the transplanting stage to the panicle commencement stage.

Ali *et al*. (2009) conducted a survey in the temperate areas of Kashmir, measuring leaf blast severity that ranged from 3.7% to 41.3%. In this survey, specific zones in the Anantang district, namely Klugam (7.3%), Khudwani (5.4%), and Lamoo (3.8%), showed the highest node blast severity. Every district in the survey exhibited the most severe form of neck blast, with an average range of 0.3% to 4.9%..

Castilla *et al.* (2009) carried extensive research on rice blast over an extended period and found that the pathogen can infect various parts of the rice plant at different growth stages. This includes the leaf, collar, nodes, internodes, base or neck, as well as other parts such as the panicle and leaf sheath. They described a typical blast lesion on a rice leaf as having a gray center with a black border and a spindle-shaped appearance.

Hossain and Kulakarmi (2001) accompanied a survey of rice blast in various villages across Dharwad, Belgaum, and Uttar Kannada districts during the Kharif season of 1999. Their findings indicated that the disease was most prevalent in the Haliyal taluka, with an incidence rate of 61.66%, and in the Mundagod taluka, with an incidence rate of 54.00%, both of which are in North Karnataka.

Zhu *et al.* (2000) conducted an experiment and found that when disease-susceptible rice varieties were cultivated alongside resistant varieties in mixed plantings, the yield increased by 89%, and the severity of blast disease was reduced by 94% compared to when the susceptible varieties were grown in monoculture.

2.3 Bacterial leaf blight of rice

According to Fatimah *et al.* (2014), *Xanthomonas oryzae pv. oryzae* (Xoo) ranks fourth among the top 10 bacterial plant pathogens, following *Pseudomonas syringae*, *Ralstonia solanacearum*, and *Agrobacterium tumefaciens*.

Dai *et al.* (2007) highlighted that Bacterial Leaf Blight Disease (BLB), a significant affliction for rice, is known to reach epidemic levels in various regions globally. They pointed out that this disease could potentially cut rice production by over half.

Swings *et al.* (1990) stated that bacterial leaf blight of rice (BLB), caused by *Xanthomonas oryzae pv. oryzae*, is a significant disease that affects rice crops.

2.3.1 Geographical distribution bacterial leaf blight

Nino *et al.* (2020) established that bacterial blight is a commonly occurring disease in the rice-producing regions of the Korean peninsula.

Chen *et al*. (2016) found that bacterial leaf blight (BLB), which is caused by *Xanthomonas oryzae pv. oryzae*, is among the most prevalent and destructive diseases affecting rice (Oryza sativa) across Asia.

Basso *et al.* (2011) reported that there have been recent instances of bacterial leaf blight (BLB) causing significant damage to crops in West African nations such as Burkina Faso, Niger, and Mali.

Kadai (2010) observed that bacterial leaf blight was prevalent in most rice-growing regions of Togo, with high incidence and severity. Furthermore, the virulence of the pathogen was also determined.

Waheed *et al.* (2009) noted that bacterial leaf blight has the potential to become a devastating bacterial disease for rice in Pakistan. This is primarily due to a lack of information about the pathogen and effective control measures, which can lead to significant losses.

Ghasemie *et al.* (2008) noted in their study that bacterial leaf blight (BLB) disease has been observed in several major rice-growing states in India, including Andhra Pradesh, Bihar, Haryana, Kerala, Orissa, Punjab, and Uttar Pradesh.

Ezuka and Kaku (2000) concluded that Bacterial Leaf Blight (BLB) has been observed in several countries around the world. These include Australia, Bangladesh, Cambodia, Indonesia, India, Korea, Mainland China, Malaysia, Sri Lanka, Thailand, the Philippines, the USA, West Africa, and Vietnam.

Mew *et al.* (1993) estimated that bacterial leaf blight is a highly prevalent and damaging disease affecting rice crops in numerous countries located in tropical rice-growing regions, including Asia, Australia, the United States, Latin America, and Africa.

According to Mew (1987), bacterial leaf blight (BLB) can lead to a reduction in yield between 20% and 30%, and in severe cases, the loss can escalate to as much as 50%.
Yamanuki *et al.* (1962) reported that BLB disease is prevalent in regions such as Asia, Australia, Latin America, and the United States. Interestingly, the disease was first documented in Kyushu, Japan, during the years 1884-85.

2.3.2 Significance of bacterial leaf blight

Kim and Reinke (2019) and Fiyaz *et al*. (2022) documented that in rice crops, plants that are defenseless and directly infected by Xoo can experience substantial yield reductions of up to 50% in tropical Asia.

Safrizal *et al*. (2020) showed that the yield loss due to bacterial leaf blight (BLB) disease varies by country. In Indonesia, the yield loss can reach 70-80%, while in India, the loss ranges from 6-60%. In Japan, the yield loss due to BLB disease is around 20-50%.

Shaheen *et al.* (2019) highlighted that bacterial blight, caused by *Xanthomonas oryzae pv. oryzae* (Xoo), is a significant bacterial disease in rice that results in substantial yield and economic losses.

Shaheen *et al.* (2019) indicated that the bacterial leaf blight disease resulted in the highest weight loss of 17.84% in Sialkot and the lowest weight loss of 11.17% in Narowal.

Yasmin and Hafeez's (2017) research found that infections occurring at the maximum tillering stage can lead to a decrease in crop yield by 20-40%. However, if the infection occurs early, the yield losses can be approximately 50%.

According to Sudir and Yuliani's (2016) study, the yield losses due to disease can range from 15% to 80%, depending on the stage of harvest at which the disease strikes.

Singh *et al.* (2015) documented that *Xoo*, which is the organism that causes Bacterial Leaf Blight (BLB), results in a substantial decrease in rice yield. This disease is prevalent and impacts a wide range of rice genotypes around the world.

Khan *et al.* (2012) stated that Bacterial Leaf Blight (BLB) can lead to yield losses due to a reduction in the plant's photosynthetic activities. These losses can range from 30-50% and can even reach 100% if the bacterial infection occurs at the tillering stage of the crop.

Akhtar *et al.* (2011) observed that the impact of the disease on grain yield varies. It depends on factors such as the stage of the crop, the susceptibility of the cultivar, and the conduciveness of the environment in which it occurs.

Shivalingaiah and Umesha (2011) stated that the disease is most severe during the tillering stage, potentially leading to a yield loss of up to 75%. However, the disease can also affect the host during the seedling, vegetative, and reproductive stages.

Sere *et al.* (2005) reported that the yield losses due to Bacterial Leaf Blight (BLB) can range from 50% to as high as 90%. This highlights the significant impact this disease can have on rice production.

According to a study by Veena *et al.* (2000), the disease can lead to a substantial reduction in rice yield in India, with losses reaching up to 81.3%.

Ou (1985) documented that in 1985, it was reported that Bacterial Leaf Blight (BLB) caused a reduction in rice yield ranging from 25-35% in Japan.

Reddy and Shukla (1978) estimated that when Koruna and Sona were infected with bacterial leaf blight (BLB) at the panicle initiation stage, there was a yield loss of 72.7% and 43%, respectively. They also discovered that inoculating the flag leaf with two strains of *Xanthomonas oryzae pv.oryzae* led to a 38%-40% decrease in yield.

2.3.3 Symptoms of bacterial leaf blight

Barakat *et al.* (2021) bacterial leaf blight (BLB), a vascular disease, results in a discoloration that can be white-yellow or tannish grey in rice crops. This discoloration is visible along the veins, leaf margins, and leaf blades, and can even extend to the sheath.

Park *et al.* (2020) indicated that when *Xanthomonas oryzae pv. oryzae* (Xoo) infects rice, the disease symptoms may be noticeable at the tillering stage. However, the disease's severity can continue to escalate as the plant develops.

Sopialena *et al*. (2019) described in their study that bacterial leaf blight manifests as leaves appearing curled and folded, with a color change from gray to yellow. In severe conditions, all the leaves may wither and die.

Suparyono *et al.* (2004) documented that the symptoms appearing in rice plants during the vegetative phase are referred to as 'kresek', while those occurring in the generative phase are called 'blight'. Infections by Xanthomonas oryzae can diminish the photosynthetic capability of the plants and interfere with the grain filling process.

Goto (1992) observed that the initial symptoms of Bacterial Leaf Blight manifest on the leaf blades during the tillering stage, beginning from the lower parts of the plant and gradually extending to the upper parts.

Ou (1985) noted that in the most severe cases of Bacterial Leaf Blight, stripes that are yellow to white in color can be observed just inside the margins of the leaf blades. These stripes eventually turn yellow and ultimately lead to the death of the leaf tissues.

2.3.4 Disease development of bacterial leaf blight

Lestari *et al.* (2023) suggested that abiotic factors are believed to have an impact on the intensity of bacterial leaf blight disease in Babaksari village. The study's objective is to ascertain the extent of the influence exerted by each abiotic factor, such as air humidity, soil pH, and air temperature, on the intensity of the bacterial leaf blight disease, and to understand its correlation with other factors.

Septiyanto's (2018) research indicated that the occurrence of bacterial leaf blight disease can be influenced by several factors. These include acidic soil pH, wind, infection through seeds or host plant residues, injuries due to mechanical activity, high humidity, and warm temperatures. The spread of *X. oryzae pv.oryzae* bacteria in rice fields can occur through irrigation water, friction between leaves, and the bottom few seeds.

Li *et al.* (2014) observed that rice plants that are less than 21 days old are more prone to the disease. Additionally, the bacteria seem to prefer temperatures between 28–34°C for their growth.

Akhtar *et al.* (2011) found that the impact of the disease on grain yield varies. It depends on factors such as the stage of the crop, the susceptibility of the cultivar, and the conduciveness of the environment in which it occurs.

McGee (1995) noted that Seed-borne bacteria serve as a primary source of inoculum, potentially leading to epidemic conditions in the field. Infection of the seed typically happens during three key phases: seed production, seed development, and seed maturation.

Exconde (1973) highlighted that Significant yield losses ranging from 24-50% due to Bacterial Leaf Blight (BLB) disease have been reported in the Philippines.

Mizukami and Wakimoto's (1969) research concluded that the bacterium responsible for the disease resides in the roots of the weed "Leersia haxandra". During the rice growing season, the bacterium moves from the weed to the rice nursery beds and spreads through the irrigation water applied to the young plants. In addition, the pathogen can also be introduced into the rice nursery through infected straw present in the field or infected seeds.

2.3.5 Bacterial leaf blight incidence and severity

Ahsan *et al*. (2021) estimated that the incidence of BLB disease varied across different regions. In Gujranwala, Sialkot, and Narowal, the disease incidence was recorded at 35%, 50%, and 21% respectively, with severity ranging from 0-80%, 0-70%, and 0-70% respectively. In the Khyber Pakhtunkhwa (KP) region, three rice-growing areas were surveyed. Mansehra had a lower disease incidence (37%) and severity (0-70%) compared to Swat and Lower Dir.

Arshad *et al.* (2021) documented that both the incidence and severity of the disease were higher in 2010, 2012, and 2013 in areas where basmati rice was predominantly grown. In contrast, the ten districts that primarily grew non-basmati rice varieties exhibited less incidence and severity of BLB. The highest average incidence of 20-25% was noted in Faisalabad, Chiniot, and Sahiwal during at least one year of the rice season.

Shaheen *et al.* (2019) found that the incidence of BLB disease in different districts of Pakistan varied between 49.23% and 70.12%.

Rafi *et al.* (2013) involved a survey of all the rice cultivation areas in Pakistan. They found that the region with the highest incidence of disease was Khayber Pakhtoon Khaw, with a rate of 36-80.2%. This was followed by Punjab with a rate of 37.6-74.6%, Sindh with 12.67-46.68%, and Balouchistan with 13.21%. These findings were based on data collected during the crop seasons from 2005 to 2007.

Chaudhary *et al.* (2009) noted that varying doses of Nitrogen (N) resulted in a BLB incidence ranging from 06.67% to 55.11% at the Agricultural Research Farm (ARF), and from 7.12% to 62.00% in farmer's fields.

Sere *et al.* (2005) observed that Bacterial Leaf Blight (BLB) was found to occur in fields with a high incidence rate of 70 to 80% in several West African countries.

Khan *et al.* (2000) reported that BLB was observed in patches in the districts of Sheikhupura, Gujranwala, and Hafizabad, with disease incidence rates of 5-10%. However, in some nearby village fields, the infection rate was significantly higher, ranging from 70-80% and even reaching 90-95%, indicating a severe epidemic.

2.4 Sheath blight of rice

Noman *et al.* (2022) stated that sheath blight disease in rice (*Oryza sativa*), which was caused by *Rhizoctonia solani* Kuhn, was considered a significant biotic factor that restricts crop production in rice-growing regions globally.

As stated by Singh *et al.* (2019), *Rhizoctonia solani* Kühn, the pathogen responsible for rice sheath blight disease (ShB), significantly influences both the yield and quality of the rice crop. Lee (1983) noted that Sheath blight, caused by the fungus *Rhizoctonia Solani*, is a severe rice disease that leads to significant losses in both quality and production of rice globally.

2.4.1 Geographical distribution of sheath blight

Sudarsanam (2017) highlighted that Rice Sheath blight is a major issue affecting production in various parts of India, including Punjab, Haryana, eastern Uttar Pradesh, Bihar, West Bengal, Orissa, Assam, Tripura, Coastal Andhra Pradesh, coastal Tamil Nadu, Kerala, select regions of Karnataka, and Chhattisgarh.

As pointed out by Singh *et al.* (2016), the pathogen responsible for this disease, initially discovered in Japan in 1910, has expanded to almost all rice-growing regions globally. The disease poses a significant challenge in the top ten rice-producing countries, which include China, India, Indonesia, Bangladesh, Vietnam, Thailand, Burma, the Philippines, Pakistan, and Brazil.

Sivalingam *et al.* (2006) *Rhizoctonia solani* is a fungus that has made its way to various countries around the world that cultivate rice in both temperate and tropical climates. These countries include Bangladesh, Brazil, Burma, China, Taiwan, Thailand, Nigeria, India, Iran, the United Kingdom, the United States, and Vietnam. This widespread distribution of the fungus poses a significant challenge to rice cultivation globally.

Miah (1973) verified its presence and stated that Bangladesh was seeing an increase in the disease's incidence. It has now developed into a significant rice disease in the nation due to the development of rice agriculture.

Talukder (1968) initially documented the presence of rice sheath blight in Bangladesh in 1968. The disease is attributed to the fungus *Thanatephorus cucumeris* (Frank) Donk (*Rhizoctonia solani* Kuhn).

The disease was first identified in China by Wei (1934) and has since been observed in numerous Asian countries. While initially thought to be confined to the Orient, reports of the disease have emerged from Brazil, Surinam, Venezuela, Madagascar, and the United States, indicating its global presence.

The disease was reported in Sri Lanka by Park and Bertus (1932), who attributed the organism to *Rhizoctonia solani* Kuhn.

The disease was initially identified and named by Miyake (1910) in Japan, attributing it to the organism *Sclerotium irregulare*.

Palo (1926) discovered a similar disease in the Philippines, believed to be caused by a fungus from the *Rhizoctonia solani* group.

Sawada (1912) discovered that the fungus was identical to *Hypochnus sasakii*, which Shirai had described earlier in 1906.

2.4.2 Significance of sheath blight

Faheem and Mujeebur (2023) conducted an experiment in North India and estimated that sheath is the reason for crops losses from 14.3% to 39.7%.

Bashir *et al.* (2023) have indicated that numerous studies have demonstrated that this disease has the potential to decrease rice yield and grain quality by up to 50 percent.

According to Katoch *et al.* (2022) sheath blight of rice, which is caused by *Rhizoctonia solani* Kuhn (Teleomorph: *Thanatephorus cucumeris* (Frank) Donk), is a significant rice disease following rice blast. It's known to cause yield losses ranging from 1.2 to 69.0 percent.

Prasad *et al.* (2020) highlighted that the loss in yield due to sheath blight disease can vary from 5.2 to 50 percent. This range is influenced by factors such as environmental conditions, the stage of the crop when the disease strikes, cultivation methods, and the types of cultivars used.

Abbas *et al.* (2019) stated that sheath blight was a highly destructive disease affecting rice crops in Pakistan. The damage caused by this disease in the country ranges between 30% and 50% of the total yield.

According to Margani and Widadi (2018), several pathogens impact rice productivity, often causing significant production constraints. Among these, *Rhizoctonia solani,* which causes sheath blight (ShB), is particularly detrimental. This pathogen can lead to a yield loss of up to 45%.

Research conducted by Hossain *et al.* (2016) highlighted the substantial effect of sheath blight disease on rice cultivation in China. The disease had spread across an extensive area of 15 to 20 million hectares of rice fields. Consequently, there has been a significant reduction in the annual yield, with losses estimated to be around 6 million tons.

Xue-Wen *et al.* (2008) conducted a study in the United States found that cultivars susceptible to the disease could experience a productivity decrease of up to 50%.

Groth (2008) found that the process of inoculation notably heightened the severity and frequency of sheath blight. This led to a decrease in yield, with losses ranging from 8% in moderately resistant varieties to a substantial 40% in highly susceptible ones.

According to Groth and Bond (2007), the act of inoculation notably escalated the severity and occurrence of sheath blight, leading to a yield reduction ranging from 4% in moderately susceptible varieties to as high as 21% in highly susceptible ones.

Wan-zhong TAN *et al.* (2007) found that sheath blight infection significantly reduced rice yield, with a substantial 40% decrease observed in crops with the highest density of inoculum.

Singh *et al*. (2004) observed that the losses in crop yield can range from 0 to 50%, depending on factors such as the severity of the disease, the stage of the crop when it gets infected, and the prevailing environmental conditions.

Chahal *et al.* (2003) reported that due to the extensive occurrence of the sheath blight disease, rice yield has suffered economic losses of up to 58%.

Qingzhong *et al.* (2001) noted that Sheath blight had a significant impact on China's rice production. Each year, it damaged between 15 to 20 million hectares of rice fields, resulting in an annual grain loss of about 6 million tons.

Laha and Venkataraman (2001) observed that the losses in crop yield could be anywhere from negligible to 50%. This range was influenced by factors such as the severity of the disease, the stage of the crop when the disease manifested, and the environmental conditions.

Candole *et al*. (2000) found that sheath blight generally led to a decrease in kernel bulk density, although it didn't significantly impact the head rice yield of the cultivars in 1997 and 1998. Additionally, there was a noticeable trend towards higher occurrences of unfilled, chalky, and fissured kernels in samples infected with sheath blight.

Naidu (1992) observed that there had been numerous reports indicating that the decrease in yield due to sheath blight can vary between 5.2% and 69%.

According to Sugiyama (1988), the percentage of Japan's land impacted by sheath blight rose to 35% in the 1960s, 46% in the 1970s, and 48% in the 1980s.

Shahjahan *et al.* (1986) noted that for the varieties BR2 and BR3, which are susceptible to disease, there were yield losses of 31.0% and 28.7% respectively. These losses corresponded to mean disease indices (DI) of 4.8 and 5.0.

Tsai (1974) noted that there was a decrease in yield by 7.95%, 7.15%, 6.05%, 10.78%, 11.73%, and 1.85% respectively at 15, 30, 45, 60 days after seeding, at the booting stage, and the milk stage. The yield and its corresponding loss were found to be in line with the disease index at 15, 30, 45, 60 days post-seeding and at the booting stage. This decrease in yield was deemed to be highly significant.

2.4.3 Symptoms of sheath blight

Gopi *et al.* (2023) observed that the symptoms of the disease usually manifest during the later stages of tillering or the early stages of internode elongation. The disease is marked by water-soaked, discolored lesions that can be spherical, oval, or irregularly elongated in shape, and are greyish to light brown in color with a brown margin on the leaf sheath and blades. The infection can spread rapidly to the upper parts of the plant under favourable conditions.

Bashir *et al*. (2023) has noted that the initial signs of *Rhizoctonia solani* manifest as water-soaked spots on the leaf sheaths of rice plants. These spots can be oval, ellipsoid, or circular in shape and have a greenish-gray color.

Sudarsanam (2017) noted that the first signs of the disease can be seen on leaf sheaths near the water level. As these spots grow, they turn greyish white in the center with an irregular border that is blackish-brown or purple, brown. On the upper parts of the plants, these lesions can quickly spread to cover entire tillers up to the flag leaf.

According to Singh *et al.* (2016), the disease typically manifests as greenish-gray, water-soaked spots on the leaf sheath near the water level. These spots, which can be circular, oblong, or ellipsoid and roughly 1 cm in length, expand and take on an irregular shape. The center of these lesions turns grayish white, surrounded by brown edges.

As per an article Rice Sheath Blight (2015), the initial symptoms of the disease typically appear on the leaf sheaths at or just above the water line. These symptoms manifest as circular, oval, or ellipsoid spots that are water-soaked and greenish gray in color. As the disease progresses, these spots enlarge and tend to merge, forming larger lesions with grayish white centers surrounded by tan to dark brown irregular borders or outlines. The infection can spread to the leaf blades, causing irregular lesions with dark green, brown, or yellow-orange margins.

Acharya and Basu (2012) noted that during the stage of tillering, the fungus may manifest as elliptical or irregular spots of a greenish-gray hue with brown edges on the leaf sheath. These spots can range from 1-3 cm in length and, when abundant, can give the appearance of snake skin.

According to *Wu et al.* (2012), the disease manifests through visible symptoms such as lesions, plant lodging, and the emergence of empty grains. The presence of large lesions on the sheath of the lower leaf, which is diseased, could potentially weaken the stem of the plant, resulting in stem lodging.

Taheri and Tarighi's (2011) study found that sclerotia are the main source of the rice sheath blight (RSB) disease. These sclerotia can reach the rice plant's tillers during irrigation. If the conditions are right, the sclerotia will germinate, producing hyphae that infiltrate the rice sheaths and grow both inside and on the surface of the rice plant.

Hollier *et al.* (2009) observed that in severe instances, the disease can lead to the death of not just the entire leaf, but also the tiller and even the whole plant. At the field level, the disease typically affects plants in a circular pattern, a phenomenon often referred to as a 'bird's nest'.

Sarkar and Gupta (2002) conducted a studied and found that sandy soil promotes the growth of these diseases. After the pathogen penetrated the leaf sheaths, the infection spread rapidly.

Rangaswami and Mahadevan (1998) noted that the fungus, upon infection, can cause a variety of symptoms such as sheath blight, foliar blight, leaf blight, web blight, head rot, bottom rot, and brown patch in different crops. In the case of rice, *R. solani* primarily targets the leaf sheath and leaf blades, and in severe instances, it can affect the entire plant, including the emerging panicles.

Singh *et al.* (1988) found that symptoms of the disease can be seen on the affected plant within a span of 24 to 72 hours post-infection, with the exact timing being influenced by the surrounding environmental conditions. While the disease has the potential to strike at any stage of growth, it is during the tillering phase that rice crops are most susceptible.

2.4.4 Disease development of sheath blight

Abbas *et al.* (2021) research found that in greenhouse experiments, the spread of mycelial strands and disease progression is rapid vertically, with the hyphae moving both downwards and upwards from the point of inoculation. However, under field conditions, the spread of mycelial strands and disease progression occurs horizontally. The lesion expands to cover the entire leaf sheath and tillers.

Abbas *et al*. (2021) highlighted that the accumulation of the disease is a key characteristic of Rice Sheath Blight (RSB) epidemics and is crucial in evaluating resistance in rice crops. They found that the pathogenic variability of *R. solani* has significantly influenced the varying degrees of disease severity and incidence.

According to Abbas *et al.* (2019), the secondary propagation of the disease is largely dependent on the running hyphae. These hyphae originate from the initial lesions on the sheaths of the rice leaves and move towards the upper parts of the plant, such as the tillers and leaves. They can also spread to adjacent plant units. This results in both vertical and horizontal dissemination of the disease.

According to Feng *et al.* (2017) research, the sclerotia of *R. solani,* a type of fungus, can survive in soil for a period of 8 to 10 years without a host. This makes it a primary source of inoculum for *Rhizoctonia solani* sheath blight (RSB).

Feng *et al.* (2017) research indicated that Rice Sheath Blight (RSB) is more severe in environments with elevated levels of carbon dioxide. Their pot experiments showed that disease development and intensity were more pronounced in seedlings that were twenty to thirty days old under conditions of artificial inoculation.

Singh and Srivastava (2015) pointed out that secondary hosts, such as weeds, self-sown rice, and rice from the stubbles of previous crops, play a crucial role in triggering disease epidemics, especially in tropical climates. However, the exact contribution of primary inoculum from these secondary hosts has not been determined.

Singh and Srivastava's (2015) research suggested that the beginning of sclerotial formation is determined by a variety of environmental cues. These cues encompass elements such as a lack of nutrients, the strength and quality of light, pH balance, temperature, antioxidant levels, and alterations in aeration.

Singh, Sunder, and Dodan (2012) noted that *R. solani* had been found to infect over 250 plant species, including significant crops.

Su *et al*. (2012) observed that temperature and humidity are key environmental factors influencing the onset and progression of Rice Sheath Blight (RSB). The disease thrives in conditions with a humidity level of 96-100% and a temperature range of 28-32°C.

According to Wu *et al*. (2012), the disease could impact both seeds and fully grown plants, leading to yield losses ranging from small to large, depending on which part of the plant was affected. The transport of water, minerals, and carbohydrates through the xylem and phloem tissues could be significantly disrupted when the disease reaches epidemic proportions, affecting grain filling.

Biswas *et al.* (2011) observed that the rise in air temperature, increased moisture, and prolonged leaf wetness are all contributing factors to the proliferation of diseases in rice fields.

As stated by Anees *et al.* (2010), the pathogen was a typical saprotrophic organism found in the soil and does not rely on a host for survival.

Brooks (2007) found that one of the initial indicators of the disease are water-soaked abscesses on the leaf sheath, just below the water line. A secondary infection was characterized by hyphae penetrating healthy plant tissues, leading to the formation of new lesions and sclerotia on the leaf sheath.

Sivalingam *et al.* (2006) observed that the disease transmission from one plant to another and throughout fields is facilitated by sclerotia and mycelia that are carried by rainfall and irrigation water runoff. The primary source of inoculum for the disease's expansion to new regions is infected seeds.

Pasalu *et al.* (2004) research highlighted that the severity and incidence of the disease are significantly influenced by both the highest and lowest temperatures, as well as the evaporation rate. Of all the factors, relative humidity and temperature are seen as the most vital for the disease's progression. Furthermore, the disease is more likely to develop during the wet season than in the dry season.

Greer and Webster (2001) noted that fungal sclerotia could survive in the soil for a period of up to two years before they begin to spread. This spread is particularly prevalent during the preparation and irrigation of rice crops.

Tiwari and Chaure's (1997) study found that the growth of mycelia and the formation of sclerotia peak at temperatures between 25-30°C. Additionally, a relative humidity of 80-95% is considered optimal for the development of the disease.

Sumner (1996) noted that the fungus generates sclerotia or dormant mycelia, which could spread for up to two years via irrigation and field preparation. This allowed it to survive in harsh environments even in the absence of spores.

Savary *et al.* (1995) had suggested that Sheath blight had the potential to spread both horizontally and vertically, moving approximately 20 cm per day under typical conditions. The pathogen could travel from plant to plant and from one field to another through buoyant mycelia, sclerotia, or pathogen-bearing seed material.

The spread and intensity of Sheath Blight (SB) are influenced by various factors, according to Gangopadhyay and Chakrabarti (1982). These include the stages of rice infection, environmental conditions, resistance of the variety, seasonal and cultural practices, as well as the amount of disease inoculum present in plant waste from previous harvests in the crop's field or topsoil.

Marshall and Rush (1980) described that under suitable conditions, the sclerotia of *Rhizoctonia solani* germinate to form mycelia. When these mycelia come into contact with the surface of the rice plant, they grow and develop infection structures such as infection cushions and lobate appressoria. These structures facilitate the penetration of mycelia into the plant tissues. In some instances, infection can occur through the stomata, even in the absence of these infection structures.

Kozaka (1970) explained that *Rhizoctonia solani* was a pathogen that originates from seeds and soil, and it survived in tropical environments through sclerotia and mycelia present in infected seeds or soil. The major carrier in soil was infected plant debris, which could come from rice or weed hosts.

2.4.5 Sheath blight incidence and severity

According to Faheem and Mujeebur (2023) sheath blight severity remain 0.9 to 3.3 and incidence was quite intense from 7.2% to 38.9%.

In research conducted by Shivakumar and M. B. Patil (2023), it was discovered that the Yadgir district in Karnataka, India, had the highest average incidence of sheath blight disease, at 41.76%.

Raghunandana *et al.* (2023) found that the highest incidence of the disease was observed in the villages of Jeemarali (47.61%) and Bokkhalli (47.36%) in the Nanjangud taluk of the Mysuru district Karnataka, India. Among the districts, Mysuru had the highest average Disease Incidence (DI) at 37.47%, followed by Mandya at 27.70%, Haveri at 20.84%, and Uttara Kannada at 6.31%. The lowest severity of 6.04% was observed in Dharwad.

Rahman *et al.* (2022) observed that the incidence of sheath blight was found to be 39.40% under elevated carbon dioxide (CO_2) conditions, which is 17.36% lower than that observed in an open field environment.

Advslp *et al.* (2021) reported that the severity of sheath blight led to an increase in grain yields by 64.23% to 73.03% when compared to the untreated control.
The research conducted by Pratiwi *et al.* (2021) revealed that the Sumber Tani Talawi area in the Batubara district of Indonesia had the most significant incidence of disease, with a rate of 99.48%. Additionally, this area also had the highest severity of the disease, measured at 12.36%.

According to Pralhad (2018), the incidence of sheath blight disease was observed to reach up to 90% at 21 days after sowing (DAS).

In a study conducted by Yaduman *et al.* (2018), they examined the prevalence of sheath blight disease in rice crops across various regions of Allahabad, India. The survey revealed that the Bahadurpur block had the highest disease incidence at 42%. Across all the surveyed regions in Allahabad, the disease incidence varied from 15% to 42%.

Reddy *et al.* (2018) carried out a survey during the Kharif season of 2016-2017 to evaluate the incidence of sheath blight disease across nine districts in the state of Telangana. The percentage of disease incidence (PDI) observed during this period varied between 20% and 80%.

Lenka *et al.* (2008) conducted research and estimated that the incidence of disease escalated by 9.03%, 23.03%, and 61.05% in relation to the maximum, minimum, and evaporation rates in the field, respectively.

Sharma and Thrimurty (2006) noted that the highest incidence of disease is found in moist soils with water holding capacities of 50-60%, while the lowest incidence is observed in submerged soils with 100% water holding capacities. According to pot culture experiments, rice seedlings are significantly more susceptible to disease when they are 20-30 days old compared to when they are 30-40 days old if they are artificially infected.

Shahjahan *et al.* (1986) observed that BR2 and BR3 Showed a disease severity of 4.8 and 5.0 respectively toward sheath blight.

CHAPTER 3
MATERIALS AND METHODS

The details of the materials and methods of this research work are described in this chapter.

3.1 Experimental site

The experiment was conducted in the experimental field of the Department of Plant Pathology at the Hajee Mohammad Danesh Science and Technology University in Dinajpur, Bangladesh. The field is located at 25°037'N latitude and 88°039'E longitude and is 37.5 meters above sea level. The location of the experiment site is shown on the map of Dinajpur sadar upazila, with the research plot highlighted. (Appendix-I)

3.2 Experimental period

The experiment was carried out during the period of August 2023 to December 2023.

3.3 Agro-ecological region

The land belonged to the Old Himalayan Piedmont Plain Agro Ecological Zone (AEZ-1) (UNDP and FAO, 1988).

3.4 Soil type

The experimental field was on medium-high land with sandy loam soil that was slightly acidic (pH above 5.5). The top layer of soil (0-15 cm depth) contained 1.06% organic matter, 0.10% total nitrogen, 24.00 µg/g available phosphorus, 0.26 meq/100g available potassium, 3.2 µg/g available sulfur, 0.90 µg/g available zinc, 5.30 µg/g available iron, and 0.27 µg/g available boron. The soil characteristics were previously analyzed by the Soil Resource Development Institute (SRDI), Dinajpur (Appendix-II).

3.5 Climatic condition

The climatic condition of the research area was sub-tropical. The monthly mean of daily maximum, minimum and average temperature, relative humidity, monthly total rainfall, and sunshine hours received at the experimental site during the period of the study (August 2023 to December 2023) was collected from (Appendix III).

3.6 Varieties

Altogether 6 varieties were used in this experiment.

3.7 Treatments

Six Varieties were used in this experiment. Varieties were as follows –

V_1 = Binni Pakri

V_2 = Uknimodhu

V_3 = Sanla

V_4 = Bolder

V_5 = Zetha Katari

V_6 = Jira Katari

3.8 Seed collection

Seeds were collected from Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

3.9 Sprouting of seeds

Seeds were soaked in ten different plastic pots separately with tap water for 24 hrs. Before sowing in seed bed and earthen pot, seeds were taken out from water followed by put in ten different gunny bags and kept at room temperature for 72 hours for sprouting.

3.10 Seed bed preparation and sowing of sprouts seeds

Seed bed was prepared by paddling the soil with the help of power tiller and harrow in Genetics and plant breeding farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. As the land was rich in organic matters, therefore no manuring was done. Sprouted seeds were sown in wet seed bed on 15th July 2023. Seedlings were properly taken care of. Weeds were removed and irrigation was given in the seed bed as and when necessary.

3.11 Field experiment

3.11.1 Land preparation

The land was prepared with the help of power tiller and harrow. The land was first opened on 25 December 2013 and ploughed. The final ploughing was performed with the help of power tiller followed by laddering to level the soil surface. Weeds and stubbles were removed from the land.

3.11.2 Experimental design and layout

The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. Each replication was first divided into six (6) experimental plots according to the treatments randomly. Thus, the total number of unit plots was 18 (6×3=18). The size of a unit plot was 2m ×1.5m = 3m^2. The distance was maintained between plot to plot was 0.5m and block to block was 1m (Appendix IV).

3.11.3 Fertilizer application

Fertilizers were applied as per recommendation of BRRI (Modern Rice Cultivation, 2022). The following doses of fertilizers were applied to the plots are described in Table

Fertilizer	Dose (g/40.47m^2)	Doses (g/plot)
Urea	670	50
TSP	240	20
MP	425	30
Gypsum	270	20

3.11.4 Seedling transplantation

Seedlings were uprooted from the seed bed very carefully, and then transplanted on 17th 2023 in the main field. Row to row spacing was maintained as 20 cm and hill to hill 15 cm. Four seedlings were transplanted together in individual hill.

3.11.5 Intercultural operation

Weeding and irrigation was done in the field as and when necessary.

3.12 Assessment of the disease incidence and severity

The incidence and severity of Blast, Bacterial Leaf Blight and Sheath blight diseases were recorded for each plot through investigation. Visual observations of the common symptoms were used to record data. For determining the incidence and severity, affected plants were chosen from each unit plot. Six data sets (30, 40, 50, 60, 70 and 80 days) were recorded at 10-day intervals.

Incidence: % disease incidence was estimated by using the following formula (Rajput and Bartaria, 1995)

$$\text{Incidence} = \frac{\text{Number of infected leaves/tillers}}{\text{Total number of leaves/tillers}} \times 100$$

Severity: The disease severity was determined by the following formula according to Chiang *et al.* (2017).

$$\text{DSI (\%)} = \frac{Class\ frequency \times Score\ of\ rating\ class}{Total\ number\ of\ leaves \times Maximum\ scale} \times 100$$

Leaf blast: A random selection of each unit plot was used to assess the disease severity in the field, and the disease severity of rice leaf blast (*Pyricularia oryzae*) was calculated using 0-9 scale of IRRI-SES (IRRI, 2013).

Table A. Scale for scoring of rice leaf blast disease (IRRI, 2013)

Scale	Disease severity	Host Response
0	Lesions are not present	Resistant (R)
1	Small brown specks of pin point size or larger brown specks without sporulating center	Resistant (R)
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin. Lesions are mostly found on the lower leaves	Resistant (R)
3	Lesions type is same as in scale 2, but a significant number of lesions on upper leaf area	Resistant (R)
4	Typical susceptible blast lesions, 3 mm or longer infecting less than 4 % of leaf area	Moderately Resistant (MR)
5	Typical susceptible blast lesions infecting 4-10% of the leaf area	Moderately Resistant (MR)
6	Typical susceptible blast lesions infecting 11 – 25% of the leaf area	Moderately Susceptible (S)
7	Typical susceptible blast lesions infecting 26 - 50% of the leaf area	Susceptible (S)
8	Typical susceptible blast lesions infecting 51-75% of the leaf area and many leaves are dead	Susceptible (S)
9	More than 75% leaf area affected	Susceptible (S)

Neck blast: Singh (2000) documented the extent of neck blast disease (caused by *Pyricularia oryzae*) in rice by employing a scale ranging from 0 to 9, which specifically addressed the predominant lesion type.

0 = no lesion observed

1 = 1% neck area covered with small brown specks of pin-point size or
larger brown specks without sporulating center

3= 10% neck area covered with small, roundish to slightly elongated necrotic sporulating spots, about 1-2 mm in diameter with a distinct brown margin or yellow halo

5 = 25% neck area covered with narrow or slightly elliptical lesions, 1- 2 mm in breadth, more than 3mm long with a brown margin

7 = 50% neck area covered with broad spindle-shaped lesion with yellow, brown or purple margin

9 = more than 50% neck area covered with rapidly coalescing small, whitish, grayish or bluish lesions without distinct margins

Note: Lesion type 5, 7 and 9 are considered typical susceptible lesions.

Bacterial Leaf Blight: The severity of the disease was recorded by following 0 to 9 scale for BLB (Chaudhary, 1996).

Table B. Disease severity scale for bacterial leaf blight disease (Chaudhary, 1996).

Disease Score	Lesion area (%)	Disease Reaction
0	0	Highly Resistant (HR)
1	1-10	Resistant(R)
3	11-30	Moderately Resistant (MR)
5	31-50	Moderately Susceptible (MS)
7	51-75	Susceptible (S)
9	76-100	Highly Susceptible (HS)

Sheath Blight: Sheath Blight severity was recorded according to the following scale described by IRRI (2014).

Table C. Sheath blight Disease severity scale (IRRI, 2014)

0	No infection
1	Lesion limited to the lower 20% of the plant height
3	Lesion limited to the lower 20-30% of the plant height
5	Lesion limited to the lower 31-45% of the plant height
7	Lesion limited to the lower 46-65% of the plant height
9	Lesion more than 65% of the plant height

3.13 Isolation of *Pyricularia oryzae*

Spore drops method modified from a method described by Choi *et al*. (1999) was used. Leaves with blast symptoms were cut into small pieces with healthy portions. The specimens were surface sterilized with 1% Clorox containing 5.25% sodium hypochlorite for 1 minute and washed it in sterilized distilled water for 3 times. Then it was placed in a petridish containing blotter paper and incubated at 25±1 ºC for 48 hours, conidia were collected and transferred to water agar by inspecting the plate under a stereo microscope (Motic SMZ-168). After that, a mycelia tip was sub cultured and incubated at 25°±1°C for 7 to 10 days after being transferred from water agar to oatmeal agar medium. Based on physical and cultural traits, the isolates were identified.

3.14 Identification and characterization of *Pyricularia oryzae*

On the PDA medium, the morphological growth pattern of *Pyricularia* was used to identify them. These morphological variations were analyzed and classified based on the conidial structure (conidia's size, shape, color, and septation). Under light microscope, mycelial growth, conidiophores, and conidia were examined initially with low-power and then with high-power objective lenses.

3.15 Isolation of *Xanthomonas oryzae pv. Oryzae*

We poured some water over the infected leaves. The young lesions containing the healthy, green portions of the damaged leaves were then chopped into tiny pieces. After immersing them in a 5% sodium hypochlorite solution for two to three minutes, they were surface sterilized and then three times cleaned with sterile water. Following surface sterilization, the cut pieces were incubated for 30 minutes to allow for bacterial streaming and stock-building in a test tube holding 3–4 ml of sterile water. Using a sterile pipette, transfer 1 ml of the stock solution into the second test tube holding 9 ml of sterile water. Shake well to achieve a 10^{-1} dilution. A final dilution of 10^{-4} was also prepared. Leaf extract drops are streaked onto the NA medium plates and incubated for three days at 27 ± 2 °C. Single colonies were developed over the NA plate following the incubation time. For later usage, it was then stored in a refrigerator at 4° C. Identification of the pathogen causing bacterial leaf blight (BLB) disease of rice was determined by several identification tests.

3.16 Identification and characterization of *Xanthomonas oryzae pv. oryzae*

Bacterial isolates were characterized through a series of morphological, microscopic, biochemical, and physiological assessments, including gram staining, catalase hydrolysis test, oxidase test, KOH test, gelatin liquefaction test, starch hydrolysis test, casein hydrolysis test, and pectin hydrolysis test. The procedures followed were outlined in Bergey's Manual of Systematic Bacteriology (2001).

3.16.1 Morphological Characterization of *Xanthomonas oryzae pv. oryzae*

The colonial morphology of *Xanthomonas oryzae pv. oryzae* isolates was investigated following the established procedures outlined by Bradbury (1970) and Schaad (1992). Special attention was given to factors such as color, colony size, and outline, whether circular and entire, or indented, wavy, or rhizoid. The elevations of the colonies were noted, categorizing them as convex, flat, plate-like, or nodular, and their overall appearance was documented.

For the analysis, a loopful of the 24-hour-old culture was taken and shaken in a sterile water column (10 ml sterile water in a test tube). Subsequently, six dilutions (10^{-1} to 10^{-6}) were prepared by transferring 1 ml of the suspension to successive water columns. From the last two series of dilutions, 0.1 ml was taken and plated onto nutrient agar medium in petri dishes. These plates were then incubated at 27 ± 10°C for 48 hours, after which they were examined for the appearance of the colonies.

3.16.2 Gram staining

A slender bacterial film was applied onto a glass slide, heat-fixed, and subsequently treated with crystal violet stain for one minute. After rinsing with running tap water, the slide was saturated with iodine solution for a minute, followed by decolorization using 95% ethanol. Further washing with running tap water was performed, and the slide was then counter stained with safranin for 30 seconds. After another round of rinsing with running tap water, the slides were allowed to air-dry before being examined under a microscope using oil immersion (Muneer *et al*., 2007).

3.16.3 KOH (Potassium hydroxide) test

A clean glass slide was treated with a drop of 3% KOH solution, to which a loopful of a 24-hour-old bacterial culture cultivated on NA was added. The mixture was thoroughly stirred, and changes in viscosity, along with the formation of thread-like slime, were observed (Muneer *et al*., 2007).

3.16.4 Catalase test

On a sterile glass slide, a drop of hydrogen peroxide was added and a 24-hour-old bacterial culture was watched to see whether any bubbles formed. When bubbles formed, the enzyme was catalase positive; when none formed, the enzyme was catalase negative (Muneer *et al*., 2007).

3.16.5 Casein hydrolysis test

24 h old bacterial culture is streaked on agar medium of skim milk and incubated for 24 hours at 28±2 °C. Following incubation, plates are checked for zone of clearance (Muneer *et al*., 2007).

3.17 Isolation of *Rhizoctonia solani*

The experimental site's diseased sheaths were collected using polyethylene bags and subsequently transported to the Plant Pathology Laboratory at Hajee Mohammad Danesh Science and Technology University in Dinajpur. The infected sheath was then carefully dissected into small pieces, approximately 0.5-1 cm in size, extracted from the affected areas. These leaf fragments underwent surface sterilization by immersing them in a 10% sodium hypochlorite solution for 2-3 minutes or a 1% $HgCl_2$ solution for 30 seconds. Following sterilization, the leaf segments were washed three times with water and transferred to sterilized petridishes containing Potato Dextrose Agar (PDA) using sterile forceps. The dishes were then incubated at a temperature of 25±1°C for a period of 7-10 days.

Subsequently, the pathogen was isolated and purified using the hyphal tip culture method. The purified culture was grown on PDA media at a temperature of 25±1°C for an additional 2 weeks. After this incubation period, the pathogen was identified as *Rhizoctonia solani*. A slide was prepared from the medium and observed under microscope.

3.18 Identification and characterization of *Rhizoctonia solani*

According to Sneh (1991), physical traits of *Rhizoctonia* species are as follows: First, a septum forms in the branch close to the constriction; Second, the hyphae mature and become more rigid and uniform; Duggar (1915) noted that branches extend at right angles (90º) from the main hyphae; and Third, Butler and Bracker (1970) noted that branches also emerge at acute angles (45º) with respect to the main hyphae. New branches often start close to the distal end of most primary hyphal cells and may show switching. Duggar (1915) showed that the major hyphae close to the branches had either one septum or none. The primary septum is thicker at the connection with the cell wall, whereas the secondary septum is either thinner or of equal thickness to the cell wall. Secondary septa often occur in older hyphae.

The hyphae having morphological traits of *Rhizoctonia* species were cultured on potato dextrose agar (PDA) media after their characteristics were examined using hyphae derived from sick rice sheath and tissues, as previously mentioned. Following growth, the hyphae, mycelial traits, and sclerotia morphology were all inspected and described.

3.19 Collection of data

3.19.1 Growth parameters

- Plant height
- Number of tillers of per hill
- Number of leaves per hill
- Panicle length

3.19.2 Disease related parameters

- Number of spots per leaves
- Number of infected leaves per hill
- Number of infected tillers per hill
- Disease incidence
- Disease severity

3.19.3 Yield related parameters

- Number of grains per panicle
- Yield (g/hill)
- Yield (kg/plot)
- Yield (t/ha)

- 1000 grain weight (g)

3.20 Procedure of data collection

3.20.1 Plant height (cm)

Plant height was determined based on average height of ten plants randomly selected from each plot and measured in centimeter (cm).

3.20.2 Number of tillers

In total ten hills were collected from each plot. The total number of tillers was calculated and their average value was recorded for each plot.

3.20.3 Total number of leaves

Number of leaves per hill was determined based on average of ten hills randomly selected from each replication.

3.20.4 Panicle length

Ten panicles were randomly chosen from each plot, and their average length was used to calculate the panicle length, which was expressed in centimeters (cm).

3.20.5 Number of blast infected leaves

Number of blast infected leaves were determined by selecting ten hills randomly and determined the total number of blast infected leaves of the selected hills.

3.20.6 Number of bacterial leaf blight infected leaves

Using a random selection process, ten hills were chosen, and the total number of bacterial blight infected leaves on each hill was counted.

3.20.7 Number of sheath blight infected tillers

By choosing 10 hills at random and counting the total number of blight-infected tillers on those hills, the number of sheath blight-infected tillers was determined.

3.21 Harvesting and collection of data on yield and yield contributing parameters

3.21.1 Number of grains per panicle

The number of grains per panicle was recorded by collecting 10 panicles randomized from each plot and counted the number of grains of each panicle.

3.21.2 Yield

First of all, 10 hills were selected and harvested from each plot. Then the total weight of grains per hill was recorded in grams. After harvesting and threshing plot yield and yield per hectare were recorded too.

3.21.3 Thousand seeds weight

Thousand seeds were selected from each plot and weighted in grams.

3.22 Data analysis

The data was analyzed by using the "Statistix 10" Software (Statistix R, 2013). The mean value was compared according to LSD range test at 5% level of significance.

CHAPTER 4
RESULTS

This study's major goal was to identify resistant rice varieties against rice diseases including Blast and bacterial leaf blight and sheath blight and identification and characterization of these diseases' causal organisms known as *Pyricularia oryzae, Xanthomonas oryzae pv. oryzae* and *Rhizoctonia solani* respectively. The disease incidence and severity were estimated at various DAT to achieve this objective. The incidence of leaf blast and bacterial leaf blight were determined by analyzing the infected leaves, while the severity was determined by analyzing the infected leaf areas. The incidence of sheath blight was determined by analyzing the infected tillers and the severity was determined by analyzing the infected areas of sheaths. The causal organisms of those diseases were isolated and characterized according to referral literatures.

4.1 Effect of different varieties on incidence of blast of rice in leaf at field condition

The effect of different varieties on the incidence of blast of rice in leaf was recorded at 30, 40, 50, 60, 70 and 80 days after transplanting (DAT). The incidence of blast showed significant variants among the varieties at 30 DAT and ranged from 1.46% to 24.18%. Among the varieties, the highest incidence was recorded in Sanla (24.18%) which was statistically different from other varieties and the lowest incidence was found in Bolder (1.46%). The disease incidence varied significantly at 40 DAT where the highest incidence was found in Sanla (25.68%) which was statistically different from other varieties and the lowest incidence was recorded in Bolder (2.05%) followed by Zetha Katari (2.19%), Binni Pakri (2.75%) and Uknimodhu (2.86%). At 50 days, Among the varieties, the highest incidence was recorded in Sanla (20.12%) which was statistically different from other varieties, and the lowest incidence was found in Binni Pakri (1.18%) among with Bolder (1.22%), Uknimodhu (1.37%) and Zetha Katari (1.46%). At 60 DAT, the highest incidence was found in Sanla (6.27%) and the lowest incidence was recorded in Binni Pakri (0.74%). At 70 DAT, among all those varieties the highest incidence was noted in Sanla (4.17%), and the lowest was noted in Binni Pakri (0.52%). The final data was recorded in 80 DAT and the highest incidence was noted in Sanla (3.34%) and the lowest incidence was recorded in Binni Pakri (0.32%) and Uknimodhu (0.35%). It was found that the leaf blast incidence gradually increased in 30 DAT and 40 DAT then gradually decreased in 50 DAT, 60 DAT, 70 DAT, and 80 DAT (Table 1).

Table 1. Effect of different varieties on incidence of blast of rice in leaf at different days after transplanting

Variety	% incidence in leaf					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	2.54 c	2.75 c	1.18 c	0.74 d	0.52 e	0.32 d
Uknimodhu	2.46 c	2.86 c	1.37 c	1.01 c	0.70 d	0.35 d
Sanla	24.18 a	25.68 a	20.12 a	6.27 a	4.17 a	3.34 a
Bolder	1.46 d	2.05 c	1.22 c	1.08 c	1.00 c	0.54 cd
Zetha Katari	1.93 cd	2.19 c	1.46 c	0.99 cd	0.92 c	0.78 c
Jira Katari	10.03 b	10.14 b	10.06 b	4.26 b	3.11 b	2.59 b
$LSD_{0.05}$	0.97	1.03	1.41	0.26	0.15	0.35
CV (%)	7.54	7.45	13.13	5.90	4.61	14.48

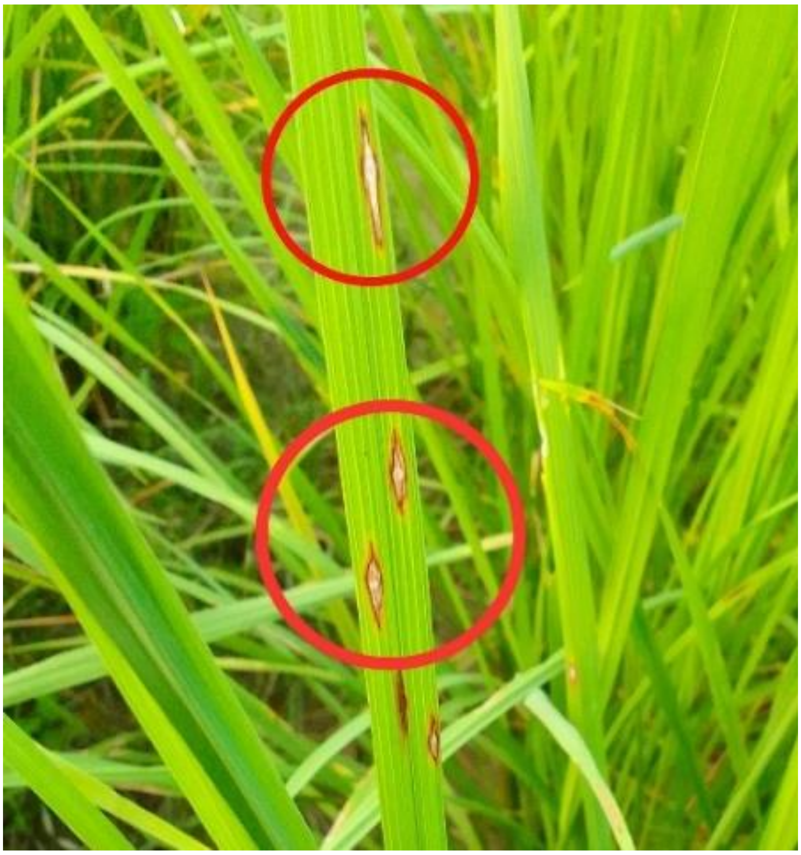

Figure 1. Typical leaf blast symptoms with distinct diamond shaped lesions

4.2 Effect of different varieties on severity of blast of rice in leaf at field condition

The impact of different rice varieties on leaf blast severity was observed at various time points, specifically at 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). Notably, significant variations were observed among the varieties. At 30 DAT, the severity of blast ranged from 0.44% to 10.15%, with Sanla showing the highest severity (10.15%) a statistically significant difference from other varieties and Binni Pakri exhibiting the lowest severity (0.44%) followed by Uknimodhu (0.45%), Zetha Katari (0.49%) and Bolder (0.56%). Subsequently, at 40 DAT, Sanla again demonstrated the highest severity (10.32%), significantly different from other varieties, while Binni Pakri had the lowest severity (0.57%) among with Bolder (0.83%), Zetha Katari (0.86%) and Uknimodhu (0.96%). Moving to 50 DAT, Sanla maintained the highest severity (8.47%), statistically distinct from other varieties, and Binni Pakri exhibited the lowest severity (0.24%). At 60 DAT, Sanla still had the highest severity (3.20%), and Binni Pakri displayed the lowest severity (0.15%). Similarly, at 70 DAT, Sanla recorded the highest severity (2.23%), while Binni Pakri and Uknimodhu had the lowest (0.10%) and (0.22%) respectively. Finally, at 80 DAT, Sanla continued to have the highest severity (1.63%), and Binni Pakri and Uknimodhu exhibited the lowest (0.05%) and (0.13%) respectively. The trend in leaf blast severity revealed an initial increase at 30 DAT and 40 DAT, followed by a gradual decrease at 50 DAT, 60 DAT, 70 DAT, and 80 DAT (Table 2).

Table 2. Effect of different varieties on severity of blast of rice in leaf at different days after transplanting

Variety	% severity in leaf					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	0.44 c	0.57 c	0.24 d	0.15 d	0.10 d	0.05 d
Uknimodhu	0.45 c	0.96 c	0.50 c	0.33 c	0.22 d	0.13 d
Sanla	10.15 a	10.32 a	8.47 a	3.20 a	2.23 a	1.63 a
Bolder	0.56 c	0.83 c	0.39 cd	0.40 c	0.49 c	0.39 c
Zetha Katari	0.49 c	0.86 c	0.45 c	0.34 c	0.39 c	0.34 c
Jira Katari	3.14 b	3.40 b	3.18 b	1.43 b	1.15 b	0.98 b
$LSD_{0.05}$	0.34	0.47	0.18	0.12	0.16	0.12
CV (%)	7.30	8.96	4.39	6.91	11.23	11.42

4.3 Effect of different varieties on incidence of blast of rice in neck at field condition

Variations in the disease incidence of neck blast were investigated among different rice varieties at various time points, specifically at 80, 85, and 90 days after transplanting (DAT). There were notable differences in outcomes among the varieties. At 80 DAT, the severity of neck blast ranged from 0.00% to 15.55%, with Sanla exhibiting the highest disease incidence (15.55%), a statistically significant difference from other varieties, while Binni Pakri had the lowest incidence (0.00%). Similarly, at 85 DAT, Sanla again showed the highest disease incidence (24.10%), significantly different from other varieties, whereas Binni Pakri displayed the lowest incidence (1.35%). Moving to 90 DAT, Sanla maintained the highest disease incidence (29.54%), statistically distinct from other varieties, and Binni Pakri displayed the lowest incidence (1.87%). The incidence of neck blast of rice followed a gradual rise observed at 80, 85, and 90 days after transplanting (DAT) (Table 3).

Table 3. Effect of different varieties on incidence of neck blast of rice in neck at different days after transplanting

Variety	% incidence in neck		
	80 DAT	**85 DAT**	**90 DAT**
Binni Pakri	0.00 d	1.35 f	1.87 f
Uknimodhu	1.68 c	5.07 c	7.87 c
Sanla	15.55 a	24.10 a	29.54 a
Bolder	1.04 c	2.05 e	3.54 e
Zetha Katari	1.34 c	4.54 d	5.10 d
Jira Katari	12.81 b	17.85 b	20.56 b
LSD $_{0.05}$	0.66	0.25	1.08
CV (%)	6.72	1.51	5.20

Figure 2. Typical symptoms of neck blast of rice

4.4 Effect of different varieties on severity of blast of rice in neck at field condition

The influence of various rice varieties on neck blast severity was examined at different time points, specifically at 80, 85, and 90 days after transplanting (DAT). Notably, there were significant variations among the varieties. At 80 DAT, the severity of neck blast ranged from 0.00% to 2.32%, with Sanla having the highest disease severity (2.32%), a statistically significant difference from other varieties, while Binni Pakri displayed the lowest severity (0.00%). Similarly, at 85 DAT, Sanla once again exhibited the highest disease severity (7.01%), significantly differing from other varieties, whereas Binni Pakri showed the lowest severity (0.15%). Progressing to 90 DAT, Sanla maintained the highest disease severity (13.93%), statistically distinct from other varieties, and Binni Pakri demonstrated the lowest severity (0.24%). The severity of neck blast increased gradually at 80, 85, and 90 days after transplanting (DAT) (Table 4).

Table 4. Effect of different varieties on severity of neck blast of rice in neck at different days after transplanting

Variety	% severity in neck		
	80 DAT	**85 DAT**	**90 DAT**
Binni Pakri	0.00 d	0.15 f	0.24 e
Uknimodhu	0.23 c	0.90 c	2.09 c
Sanla	2.32 a	7.01 a	13.93 a
Bolder	0.18 c	0.54 e	0.77 d
Zetha Katari	0.19 c	0.69 d	1.02 d
Jira Katari	1.78 b	5.12 b	8.78 b
$LSD_{0.05}$	0.08	0.15	0.36
CV (%)	5.75	3.41	4.40

4.5 Effect of different varieties on incidence of bacterial leaf blight of rice in leaf at field condition

The effects of different rice varieties on the incidence of bacterial leaf blight were evaluated at various stages of growth, namely 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). The varieties showed significant differences in their susceptibility to the disease. No signs of bacterial leaf blight were observed at 30 DAT. At 40 DAT, the disease incidence ranged from 0.00% to 0.73%, with Sanla having the highest incidence (0.73%), which was statistically different from the other varieties, and Binni Pakri having the lowest incidence (0.00%). At 50 DAT, Sanla had the highest incidence (2.02%), which was also statistically distinct from the other varieties, and Binni Pakri had the lowest incidence (0.99%). At 60 DAT, Zetha Katari and Jira Katari had the highest incidence (2.50%) and ((2.51%) respectively, while Uknimodhu had the lowest incidence (1.25%). Likewise, at 70 DAT, Binni Pakri had the highest incidence (3.82%), while Bolder and Sanla had the lowest incidence (2.24%) and (2.36%) respectively. Finally, at 80 DAT, Binni Pakri still had the highest incidence (5.57%), and Bolder and Sanla had the lowest incidence (2.31%) and (2.50%) respectively. The pattern of bacterial leaf blight incidence was marked by a gradual increase from 30 DAT to 80 DAT (Table 5).

Table 5. Effect of different varieties on incidence of bacterial leaf blight of rice in leaf at different days after transplanting

Variety	% incidence in leaf					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	0.00	0.00 d	0.99 e	2.02 b	3.82 a	5.57 a
Uknimodhu	0.00	0.47 c	1.19 d	1.25 c	2.40 cd	3.31 c
Sanla	0.00	0.73 a	2.02 a	2.12 b	2.36 d	2.50 d
Bolder	0.00	0.51 b	1.82 b	2.04 b	2.24 d	2.31 d
Zetha Katari	0.00	0.50 bc	1.59 c	2.51 a	3.19 b	4.47 b
Jira Katari	0.00	0.50 bc	1.83 b	2.50 a	2.79 bc	3.41 c
$LSD_{0.05}$	0.00	0.03	0.18	0.12	0.40	0.38
CV (%)	0.00	4.05	6.31	3.20	7.85	5.83

Figure 3. Typical symptoms of bacterial leaf blight in rice

4.6 Effect of different varieties on severity of bacterial leaf blight of rice in leaf at field condition

Various rice varieties underwent examination to assess their impact on bacterial leaf blight severity at distinct time points specifically, at 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). Notable variations were observed among the varieties. At 30 DAT, no indications of bacterial leaf blight were detected. Advancing to 40 DAT, bacterial leaf blight severity ranged from (0.00%) to (0.15%), with Uknimodhu displaying the highest severity (0.15%) a statistically significant difference from other varieties while Binni Pakri exhibited the lowest severity (0.00%). Moving to 50 DAT, the highest severity was identified in Sanla (0.72%), statistically distinct from other varieties, and Zetha Katari and Uknimodhu showcased the lowest severity (0.34%) and (0.38%) respectively. At 60 DAT, Binni Pakri exhibited the highest severity (1.24%), with Bolder displaying the lowest severity (0.83%). Similarly, at 70 DAT, Binni Pakri recorded the highest severity (1.40%), while Bolder had the lowest (1.00%). Finally, at 80 DAT, Binni Pakri and Jira Katari had the highest severity (1.90%) and (1.89%), and Bolder exhibited the lowest (1.25%). The trend in bacterial leaf blight severity was characterized by a gradual increase at 30 DAT, 40 DAT, 50 DAT, 60 DAT, 70 DAT, and 80 DAT (Table 6).

Table 6. **Effect of different varieties on severity of bacterial leaf blight of rice in leaf at different days after transplanting**

Variety	% severity in leaf					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	0.00	0.00 e	0.48 d	1.24 a	1.40 a	1.90 a
Uknimodhu	0.00	0.15 a	0.38 e	0.45 d	0.58 d	0.75 d
Sanla	0.00	0.10 c	0.72 a	0.84 c	1.02 c	1.38 b
Bolder	0.00	0.08 d	0.61 b	0.83 c	1.00 c	1.25 c
Zetha Katari	0.00	0.13 b	0.34 e	1.21 a	1.28 b	1.38 b
Jira Katari	0.00	0.08 d	0.54 c	1.17 c	1.31 b	1.89 a
$LSD_{0.05}$	0.00	0.02	0.05	0.03	0.07	0.09
CV (%)	0.00	11.80	5.01	1.88	3.47	3.48

4.7 Effect of different varieties on incidence of sheath blight of rice in sheath at field condition

The impact of various rice varieties on the incidence of sheath blight was observed at several growth stages, specifically 30, 40, 50, 60, 70, and 80 days after transplantation. At 30 days, only Bolder showed disease symptoms (1.17%). By 40 days, the disease incidence varied significantly, with Uknimodhu having the highest disease incidence (1.92%), which was statistically distinct from the other varieties, and Zetha Katari (0.00%) and Jira Katari (0.00%) showing no disease symptoms. At 50 days, Uknimodhu continued to have the highest disease incidence (7.73%), while Zetha Katari had the lowest (1.17%). By 60 days, Uknimodhu still had the highest disease incicence (9.23%), and Zetha Katari had the lowest (1.61%). At 70 days, Uknimodhu had the highest disease incicence (13.59%), and Zetha Katari had the lowest (1.73%). Finally, at 80 days, Uknimodhu maintained the highest disease incicence (15.20%), while Zetha Katari had the lowest (1.93%). The disease incidence showed a steady increase from 30 to 80 days post-transplantation (Table 7).

Table 7. Effect of different varieties on incidence of Sheath blight of rice in sheath at different days after transplanting.

Variety	% incidence in sheath					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	0.00 b	0.79 c	2.92 b	4.22 c	5.04 c	5.85 c
Uknimodhu	0.00 b	1.92 a	7.73 a	9.23 a	13.59 a	15.20 a
Sanla	0.00 b	0.77 c	1.68 cd	2.70 d	2.93 d	3.57 d
Bolder	1.17 a	1.81 b	2.99 b	4.58 b	5.57 b	7.98 b
Zetha Katari	0.00 b	0.00 d	1.17 d	1.61 e	1.73 e	1.93 e
Jira Katari	0.00 b	0.00 d	1.79 c	2.58 d	2.81 d	3.23 d
$LSD_{0.05}$	0.06	0.11	0.53	0.30	0.28	0.53
CV (%)	15.81	6.81	9.65	3.95	2.80	4.66

Figure 4. Typical symptoms of sheath blight with cobra snake skin like lesions.

4.8 Effect of different varieties on severity of sheath blight of rice in tiller at field condition

The impact of different rice varieties on the disease severity of sheath blight was noted at various growth stages specifically, at 30, 40, 50, 60, 70, and 80 days after transplantation. At the initial stage (30 days), only Bolder (0.13%) exhibited disease severity. By days 40, there was a notable variation in disease severity, with Bolder displaying the highest disease severity (0.19%), significantly different from other varieties, while Zetha Katari (0.00%) and Jira Katari (0.00%) showed no signs of the disease. At 50 days, Uknimodhu showed the highest disease severity (0.76%), with Zetha Katari having the lowest disease severity (0.14%). This trend persisted at 60 days, with Uknimodhu maintaining the highest disease severity (2.43%) and Zetha Katari the lowest severity (0.19%). At 70 days, Uknimodhu still recorded the highest disease severity (2.95%), while Zetha Katari had the lowest (0.20%). Finally, at 80 days, Uknimodhu sustained the highest disease severity (3.45%), with Zetha Katari exhibiting the lowest (0.31%). The disease severity demonstrated a consistent increase from 30 to 80 days after transplantation (Table 8).

Table 8. Effect of different varieties on severity of sheath blight of rice in sheath at different days after transplanting.

Variety	% severity in sheath					
	30 DAT	**40 DAT**	**50 DAT**	**60 DAT**	**70 DAT**	**80 DAT**
Binni Pakri	0.00 b	0.09 c	0.64 b	0.67 d	0.72 d	1.24 d
Uknimodhu	0.00 b	0.17 b	0.76 a	2.43 a	2.95 a	3.45 a
Sanla	0.00 b	0.18 ab	0.54 c	1.29 b	1.47 b	1.73 b
Bolder	0.13 a	0.19 a	0.52 c	1.05 c	1.13 c	1.49 c
Zetha Katari	0.00 b	0.00 d	0.14 e	0.19 f	0.20 f	0.31 f
Jira Katari	0.00 b	0.00 d	0.27 d	0.41 e	0.62 e	0.68 e
$LSD_{0.05}$	0.004	0.02	0.08	0.11	0.06	0.11
CV (%)	10.35	9.23	9.39	6.25	2.91	4.04

4.9 Growth performance of different varieties of rice against blast, BLB, and sheath blight at field condition

4.9.1 Plant Height

The average height of various plant varieties was measured at different stages: 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). At 30 and 40 DAT, there was a significant difference in plant heights among the different stages. Binni Pakri had the tallest plants, measuring 84.00 cm and 94.97 cm respectively, while Jira Katari had the shortest plants, measuring 76.83 cm and 87.90 cm respectively. At 50 DAT, Binni Pakri again had the tallest plants (112.72 cm), but this time, the shortest plants were found in Zetha Katari (98.53 cm) and Jira Katari (98.83cm). However, from 60 DAT onwards, there was no significant difference in plant heights among the different stages. Binni Pakri consistently had the tallest plants (116.73 cm, 116.83 cm, and 116.93 cm at 60, 70, and 80 DAT respectively), while Zetha Katari had the shortest plants (102.42 cm, 102.50 cm, and 102.70 cm at 60, 70, and 80 DAT respectively) (Table 9).

Table 9. Height of the plant of different varieties at different days after transplanting.

Variety	Height of the plant in cm					
	30 DAT	**40 DAT**	**50 DAT**	**60 DAT**	**70 DAT**	**80 DAT**
Binni Pakri	84.00 a	94.97 a	112.72 a	116.73 a	116.83 a	116.93 a
Uknimodhu	83.47 a	94.15 ab	105.70 b	108.78 b	108.95 b	109.10 b
Sanla	78.63 c	89.22 cd	101.27 c	105.43 cd	105.57 cd	105.63 cd
Bolder	81.83 b	91.68 bc	102.05 c	106.05 c	106.13 c	106.27 c
Zetha Katari	78.08 cd	88.98 d	98.53 d	102.42 e	102.50 e	102.70 e
Jira Katari	76.83 d	87.90 d	98.83 d	102.95 de	103.17 de	103.23 de
$LSD_{0.05}$	1.53	2.57	1.76	2.73	2.76	2.81
CV (%)	1.04	1.55	0.94	1.40	1.41	1.44

4.9.2 Number of tillers per hill

The average number of tillers per hill for different plant varieties was recorded at various intervals: 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). During the initial stages at 30 and 40 DAT, the tiller count per hill did not significantly vary among the varieties. The variety Bolder had the most tillers, with counts of 15.93 and 16.40 respectively, while Zetha Katari had the fewest, with counts of 11.13 and 12.87 respectively. At 50 DAT, Bolder continued to have the most tillers (17.83), but Zetha Katari had the fewest (14.17). From 60 DAT onwards, the tiller count per hill did not significantly differ among various intervals. Bolder consistently had the most tillers (19.83, 20.00, and 20.17 at 60, 70, and 80 DAT respectively), while Zetha Katari consistently had the fewest (16.13, 16.23, and 16.37 at 60, 70, and 80 DAT respectively) (Table 10).

Table 10. Number of tillers per hill of different varieties at different days after transplanting.

Variety	Number of tillers per hill					
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Binni Pakri	11.63 c	12.77 cd	14.30 cd	16.30 cd	16.33 cd	16.43 c
Uknimodhu	13.47 b	14.43 b	15.63 b	17.77 b	17.90 b	17.93 b
Sanla	12.77 b	13.83 bc	15.17 bc	17.10 bcd	17.33 bc	17.43 bc
Bolder	15.93 a	16.40 a	17.83 a	19.83 a	20.00 a	20.17 a
Zetha Katari	11.13 c	12.37 d	14.17 d	16.13 d	16.23 d	16.37 c
Jira Katari	12.87 b	13.83 bc	15.43 b	17.30 bc	17.50 b	17.60 b
$LSD_{0.05}$	1.07	1.13	0.92	1.00	1.04	1.07
CV (%)	4.54	4.46	3.28	3.17	3.27	3.33

4.9.3 Number of leaves per hill

The average leaf number of different plant varieties was recorded at various time points: 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). At 30 DAT, Uknimodhu had the most leaves, with a count of 54.93, while Zetha Katari had the fewest, with a count of 33.97. At 40 DAT, Uknimodhu had the most leaves (62.93), and Zetha Katari had the fewest (42.33). At 50 DAT, Uknimodhu continued to have the most leaves (63.93), while Zetha Katari had the fewest (44.33). From 60 DAT onwards, there was no significant difference in the leaf count among the different stages. Uknimodhu consistently had the most leaves (73.07, 73.47, and 73.50 at 60, 70, and 80 DAT respectively), while Zetha Katari consistently had the fewest (54.83, 55.23, and 55.33 at 60, 70, and 80 DAT respectively) (Table 11).

Table 11. Number of leaves per hill of different varieties at different days after transplanting.

Variety	Number of leaves per hill					
	30 DAT	**40 DAT**	**50 DAT**	**60 DAT**	**70 DAT**	**80 DAT**
Binni Pakri	37.50 c	45.78 c	47.87 c	57.37 c	57.87 c	57.93 c
Uknimodhu	54.93 a	62.93 a	63.93 a	73.07 a	73.47 a	73.50 a
Sanla	47.13 b	55.30 b	56.50 b	66.47 b	66.83 b	66.93 b
Bolder	54.50 a	61.30 a	63.00 a	72.63 a	72.90 a	72.97 a
Zetha Katari	33.97 c	42.33 c	44.33 c	54.83 c	55.23 c	55.33 c
Jira Katari	52.46 a	60.04 ab	62.40 a	70.37 ab	70.70 ab	70.7 ab
$LSD_{0.05}$	4.30	4.83	3.91	5.10	5.04	5.07
CV (%)	5.05	4.86	3.82	4.26	4.19	4.20

4.10 Yield performance of different varieties of rice against blast, BLB and sheath blight at field condition

4.10.1 Panicle length

Various plant varieties were assessed for their average panicle length at three different stages: 70, 80, and 90 days after transplanting (DAT). Binni Pakri exhibited the greatest panicle length at 70 DAT, measuring 29.00 cm, while Zetha Katari had the smallest at 24.73 cm. At 80 DAT, Binni Pakri maintained its position with the highest panicle length of 29.60 cm, and Zetha Katari remained the lowest at 25.33 cm. In the final stage, 90 DAT, Binni Pakri still had the highest panicle length at 29.70 cm, while Zetha Katari had the lowest at 25.40 cm (Table 12).

Table 12. Length of the panicle.

Variety	Length of the panicle per hill in cm		
	70 DAT	80 DAT	90 DAT
Binni Pakri	29.00 a	29.60 a	29.70 a
Uknimodhu	26.40 bc	27.00 b	27.10 b
Sanla	26.43 bc	27.10 b	27.13 b
Bolder	26.5 b	27.07 b	27.17 b
Zetha Katari	24.73 d	25.33 d	25.40 d
Jira Katari	26.00 c	26.567 c	26.67 c
LSD $_{0.05}$	0.45	0.36	0.19
CV (%)	0.93	0.72	0.86

4.10.2 Grain per panicle

The grain per panicle of various plant varieties was counted after harvesting. Binni Pakri showed the highest number of grains (328) which is significant with other varieties and Jira Katari had the lowest number of grains (156.33) per panicle (Table 13).

Table 13. Number of average grains per panicle.

Variety	Grains per panicle
Binni Pakri	328 a
Uknimodhu	264 b
Sanla	236 c
Bolder	230.67 c
Zetha Katari	230.33 c
Jira Katari	156.33 d
$LSD_{0.05}$	13.16
CV (%)	3.00

4.10.3 Yield

Various varieties yield was measured in three parameters such as yield per hill in gram, yield per plot in kilograms and yield per hectare in tons. In yield per hill, Binni Pakri and Uknimodhu showed the highest yield 40.25 g and 38.57 g respectively and lowest yield observed in Bolder 19.99 g. At yield per plot , Binni Pakri continued to have the highest 1.10 kg and Sanla showed the lowest 0.73 kg. At the last in yield per hectare, Binni Pakri remained the highest 3.67 tons per hectare yield, and Sanla showed the lowest 2.44 tons (Table 14).

Table 14. Yield of rice.

Variety	Yield		
	Yield per hill (g)	Yield per plot (kg)	Yield per hectare (tons)
Binni Pakri	40.25 a	1.10 a	3.67 a
Uknimodhu	38.57 a	0.85 bc	2.83 bc
Sanla	23.07 c	0.73 c	2.44 c
Bolder	19.99 d	0.98 ab	3.28 ab
Zetha Katari	28.87 b	1.00 ab	3.33 ab
Jira Katari	30.11 b	0.85 bc	2.83 bc
$LSD_{0.05}$	2.54	0.25	0.82
CV (%)	4.63	14.65	14.65

4.10.4 Thousand seeds weight

Thousand seeds were taken from each variety and measured the weight of the seeds. Uknimodhu showed the highest value of 17.59 g among with Binni Pakri (17.28g) and Bolder (16.86g) and Sanla showed the lowest 10.40 g (Table 16).

Table 15. Average thousand seed weight.

Variety	Weight in gram
Binni Pakri	17.28 a
Uknimodhu	17.59 a
Sanla	10.40 d
Bolder	16.86 a
Zetha Katari	15.36 b
Jira Katari	12.75 c
$LSD_{0.05}$	0.92
CV (%)	3.36

4.11 Isolation and pure culture of *Pyricularia oryzae*

Infected leaves and necks were collected from the experimental field. After surface sterilization, infected leaves were cut into small pieces and incubated for 2 days in blotter paper containing petridishes. Then the mycelium of *P. oryzae* transferred to water agar media with the help of stereo microscope. After that the mycelia tip was sub cultured onto oatmeal agar medium and incubated for 10 days.

4.12 Identification and characterization of *Pyricularia oryzae*

The isolates were initially identified based on spore morphology, and this identification was later confirmed using a molecular-based method. The spores observed were pear-shaped, with a narrow apex and a wide base, and were hyaline in color(Figure 5). They were two-septate and three-celled. These spores were found along the conidiophore, with the base of the spore attached to the tip of the conidiophore branches.

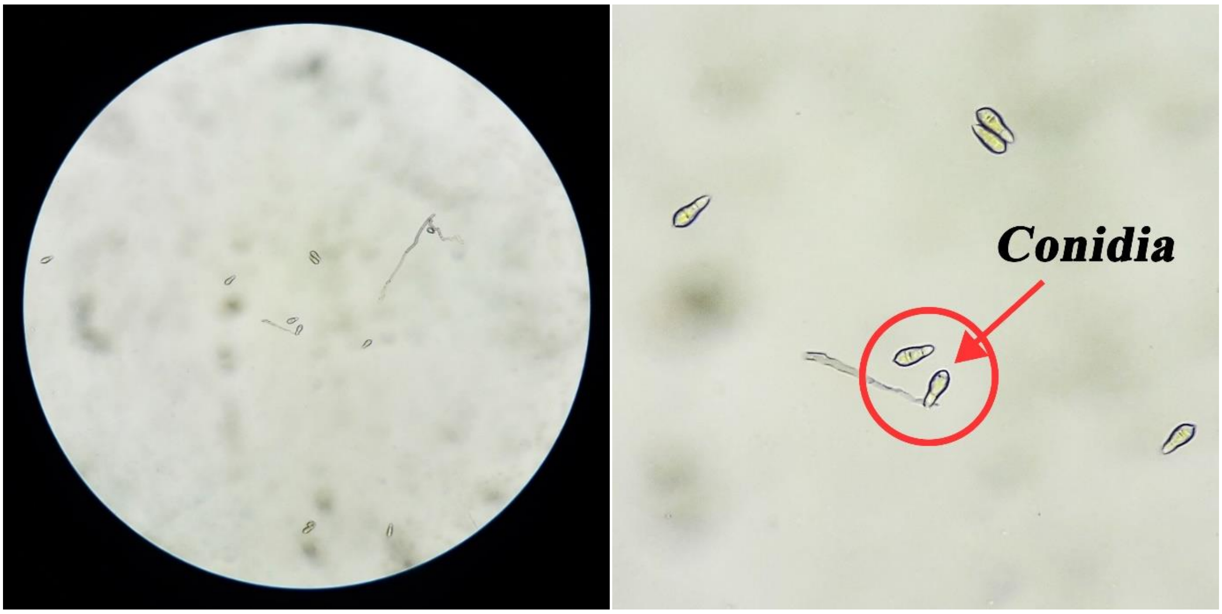

Figure 5. Conidiophore and conidia of *Pyricularia oryzae* viewed under microscope.

The surface of the isolate's colony exhibited a range of textures, from smooth and fluffy to rough and flat, with concentric rings visible. Aerial mycelia were also present. The isolate displayed a raised elevation when viewed from the side in the media. Regardless of the media used, the isolate had a circular shape and a smooth margin (Figure 6). The front of the colony was colored in shades of grey and light grey (Hussin *et al*.,2020).

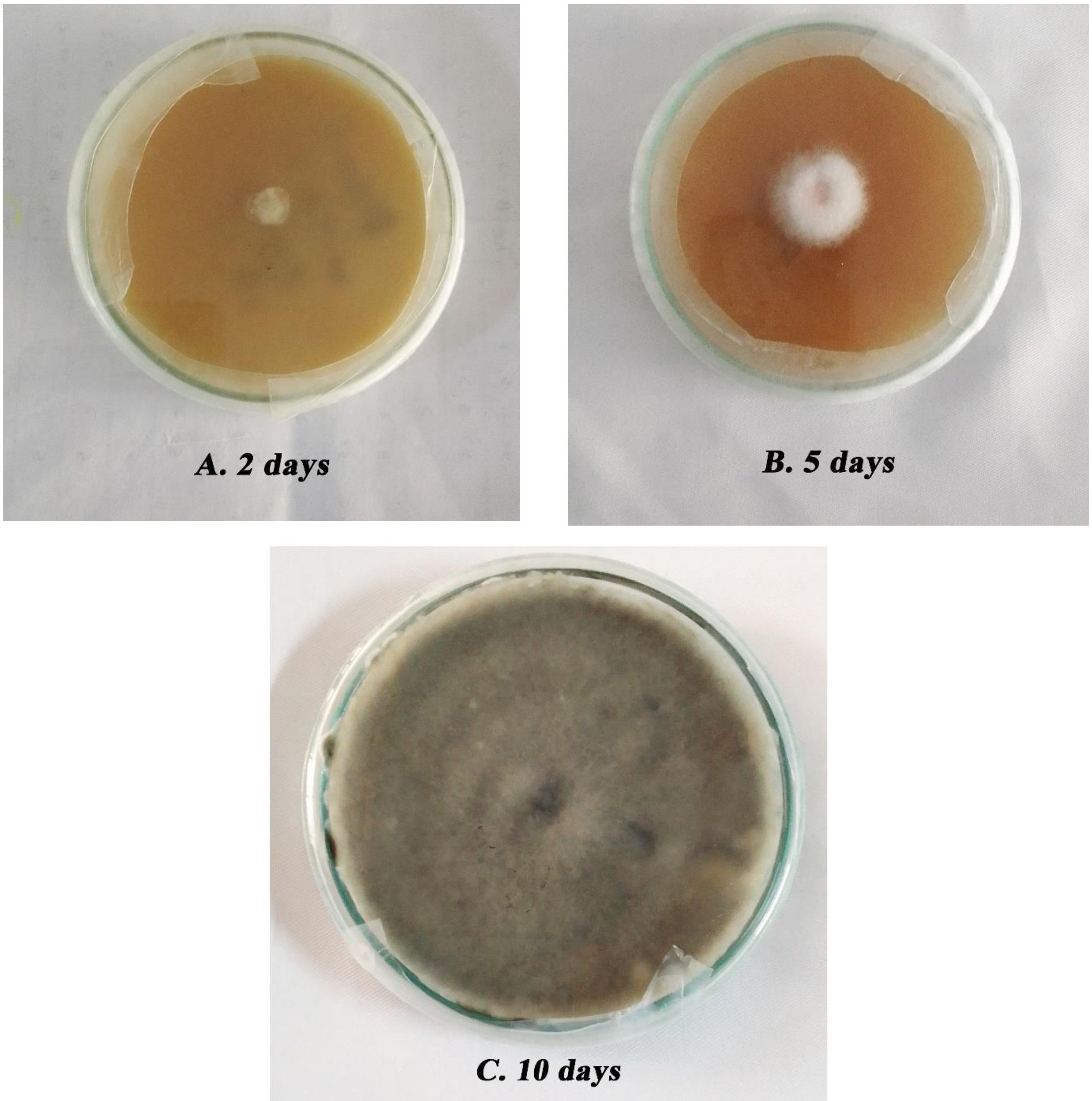

Figure 6. ***Pyricularia oryzae*** **culture with conidia on oatmeal agar medium at different days after incubation A. 2 days old culture, B. 5 days old culture and C. 10 days old culture (gray colored**).

4.13 Isolation and pure culture of *Xanthomonas oryzae pv. oryzae*

The infected leaves sample were collected from the experimental field and cut into small pieces. Then the pieces were sterilized with 5% sodium hypochlorite solution for two to three minutes and washed with distill water. After surface sterilization, bacterial streaming was prepared in test tube. Leaf extract drops were placed onto the NA medium and incubated for three days. Single colony were developed over NA plate.

4.14 Identification and characterization of *Xanthomonas oryzae pv. oryzae*

The samples that were collected and cultured bacteria that exhibited characteristics typical of Xoo bacteria.

4.14.1 Morphological Characterization of *Xanthomonas oryzae pv. oryzae*

Yellow color bacterial growth was observed in the NA plate and had some single colonies. These characteristics, as described by Jabeen *et al.* (2012), included a yellow hue and convex, mucoid colonies upon plating the samples (Figure 7).

Figure 7. **Single cells of *Xanthomonas oryzae pv. oryzae.***

4.14.2 Gram staining

The bacteria showed pink color at the end of the gram staining test which indicated that the bacteria were gram negative (Figure 8).

Figure 8. Gram staining test showed pink color as gram-negative.

4.14.3 KOH (Potassium hydroxide) test

In the potassium hydroxide test, it showed change in viscosity and formation of thread-like slime which indicated that it was positive in this test (Figure 9).

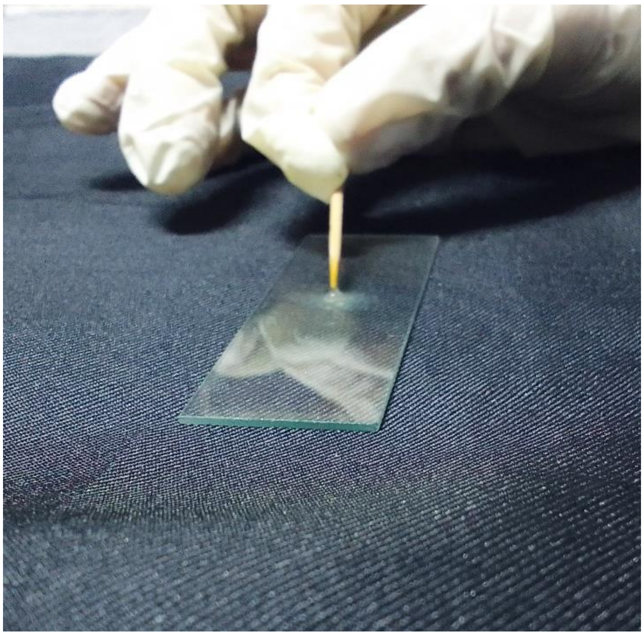

Figure 9. KOH test; Thread-like slime presence.

4.14.4 Catalase test

In catalase test, bubble formation was observed so it indicated that the test was catalase positive (Figure 10).

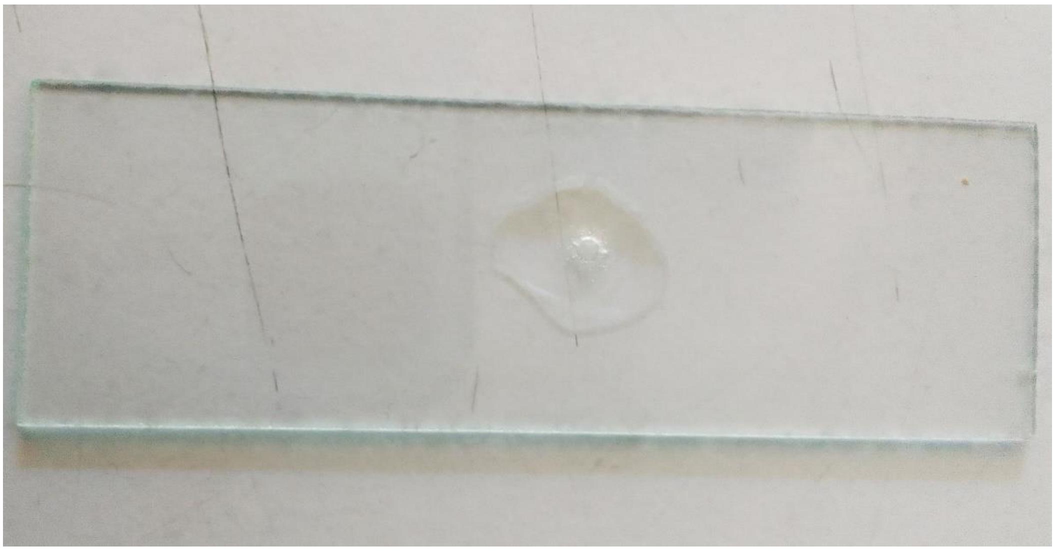

Figure 10. Catalase test; Bubble formation visible.

4.14.5 Casein hydrolysis test

In casein hydrolysis test, the clearance zone appeared around the bacterial colony. So, it showed positive result in casein test (Figure 11).

Figure 11. Casein hydrolysis test with zone of clearance around the bacterial colonies.

Table 16. Biochemical test result for *Xanthomonas oryzae pv. oryzae.*

Test	Result (positive/negative)
Gram staining test	Negative (-)
Potassium hydroxide test	Positive (+)
Catalase test	Positive (+)
Casein hydrolysis test	Positive (+)

Shobha *et al.* (2020) documented that *Xanthomonas oryzae pv. oryzae* showed positive in KOH test, catalase test and casein hydrolysis test and negative in gram staining test as it was a gram-negative bacterium. So, the bacteria that grew in the NA plate was *Xanthomonas oryzae pv. oryzae.*

4.15 Isolation and pure culture of *Rhizoctonia solani*

The fungal specimens underwent a re-culturing process to isolate the pure culture of *Rhizoctonia solani*. The youthful colonies of all isolates displayed uniform characteristics, appearing hyaline on PDA medium (Figure 12). The mycelium was generally very light brown or whitish, exhibiting a coarse or fine radiate pattern, with occasional moderate aerial white patches scattered across the surface (Figure 12). Initially, *R. solani* exhibited a silver colony that later transitioned to a white color, presenting a smooth appearance. The agar surface featured a variable number of sclerotia, ranging from few to abundant, typically with a diameter of about 1.5 mm to 2 mm. According to Dasgupta (1992), the hyphae in their early stages are hyaline, and pigmentation is limited to various shades of brown or silvery, ultimately turning brown as they mature. This aligns with the observations of Gnanamanickam (2009), who noted that *R. solani* isolates are recognized for their rapid growth, producing hyaline mycelia when young, which progressively changes from yellow to brown as they age (Figure 12).

Figure 12. Pure culture of *Rhizoctonia solani*

4.16 Identification and characterization of *Rhizoctonia solani*

The identification of the pathogen on potato dextrose agar (PDA) was based on the distinctive mycelial branching observed. Microphotographs were captured to showcase the characteristic microscopic features of the hyphae under a compound microscope. The mycelium exhibited branching predominantly near the distal end of a cell in both young and mature hyphae. In the case of young hyphae of *R. solani*, the branches formed angles of 45°, while more mature branches were perpendicular (90°) and of equal size (Figure 13). As the hyphae matured, they became rigid due to thickened cell walls (Figure 13). In aging hyphae, branching occurred at various points along the cell. Notably, young hyphal branches consistently displayed constriction at the junction with the main hypha, with a septum forming in the branch near this constriction point (Figure 13). This constriction and the presence of a septum at or near the branching junction hold significant taxonomical relevance. Microscopic examination revealed that all eight *R. solani* isolates in this study produced elongated multinucleate cells that grew roughly at right angles to the main hypha, featuring a slight constriction at the branching junction. These mycelial characteristics align with previous descriptions by Lal and Kandhari (2009), Vidhyasekaran et al. (1997), Parmeter et al. (1970), and Bracker and Butler (1963) in relation to rice sheath and plant debris. Variations in hyphal branching were also observed among the isolates, consistent with findings by Butler and Bracker (1970), who proposed the notion of *R. solani* species exhibiting young hyphae branching at acute to right angles, a slight constriction at the branching point, and the formation of a septum near the constriction point.

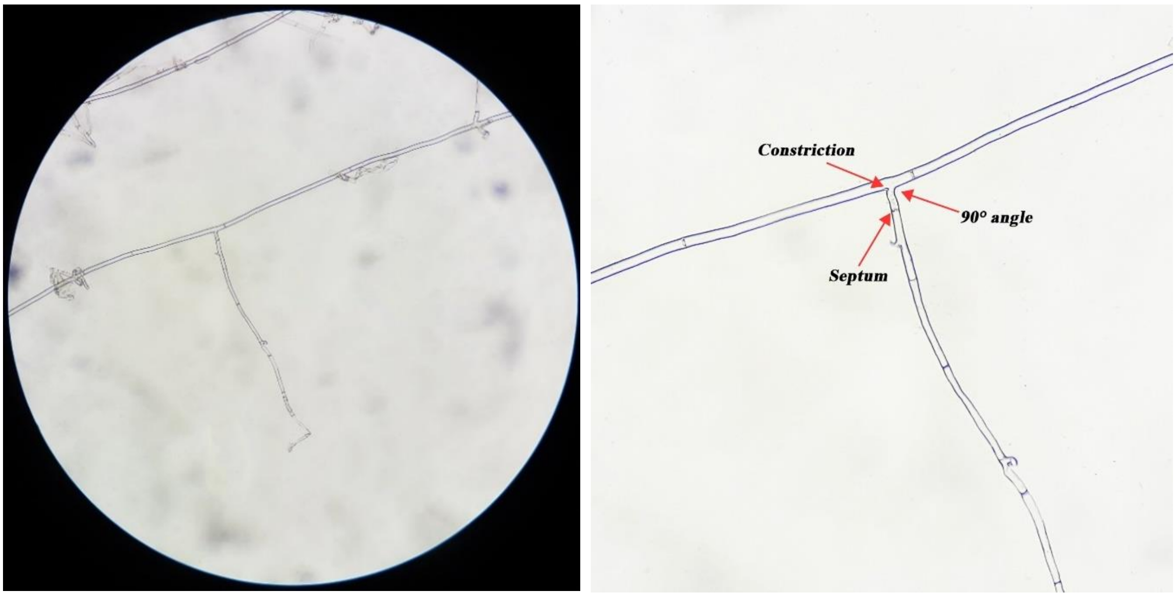

Figure 13. Microscopic examination at a 40× magnification of the isolates reveals distinct mycelial branching with an acute angle of 90°, accompanied by a slight constriction at the branching point, and the formation of a septum near the branching point.

CHAPTER 5

DISCUSSION

The present investigation sought to evaluate the influence of the incidence and severity of blast, bacterial leaf blight, and sheath blight diseases on different rice varieties and the identification and characterization of the causal organisms which were responsible for those diseases. The study was conducted in field conditions during the Aman season spanning from August 2023 to December 2023. Six distinct aromatic rice varieties, including Binni Pakri, Uknimodhu, Sanla, Bolder, Zetha Katari, and Jira Katari, were selected for this research.

Blast symptoms are visible on both leaves and necks. The leaves display brown, spindle-shaped spots with a grey center, which is a typical sign of blast. In cases of severe infection, these spots can merge and cause blight across the entire leaf surface. Neck blast symptoms are represented by dark brown to black lesions on base the infected panicle. Among the two types of symptoms, neck blast is the most damaging. It can occur independently of severe leaf blast and is considered the most destructive stage of the disease. The symptomology observed in this study aligns with findings from recent research (Zhu *et al*., 2005, Sreenivasa *et al*., 2011, Dissanayaka *et al*., 2022).

Blast disease was observed in all six varieties used in this research. The incidence of the rice leaf blast disease was observed six times at 30, 40, 50, 60, 70 and 80 days after transplanting (DAT) and neck blast incidence was observed three times at 80, 85 and 90 DAT. There were significant differences in disease incidence among the varieties, in leaf blast with rates ranging from 1.46% to 24.18% at 30 DAT, 2.05% to 25.68% at 40 DAT, 1.18% to 20.12% at 50 DAT, 0.74% to 6.27% at 60 DAT, 0.52% to 4.17% at 70 DAT and from 0.32% to 3.34% at 80 DAT. On the other hand, neck blast incidence was ranging from 0.00% to 15.55% at 80 DAT, 1.35% to 24.10% at 85 DAT and 1.87% to 29.54% at 90 DAT. Among all of those intervals highest leaf blast incidence was observed in 40 DAT at Sanla (25.68%) and lowest was at 80 DAT in Binni Pakri (0.32%). For neck blast, highest was at 90 DAT in Sanla (29.54%) and lowest was at 80 DAT in Binni Pakri (0.00). The severity of the rice leaf blast disease was monitored six times at intervals of 30, 40, 50, 60, 70, and 80 days after transplanting (DAT), while the severity of the neck blast was observed three times at 80, 85, and 90 DAT. There was a noticeable variation in disease severity among the different rice varieties. For leaf blast, the rates varied from 0.44% to 10.15% at 30 DAT, 0.57% to 10.32% at 40 DAT, 0.24% to 8.47% at 50 DAT, 0.15% to 3.20% at 60 DAT, 0.10% to 2.23% at 70 DAT, and 0.05% to 1.63% at 80 DAT. In contrast, the severity of neck blast ranged from 0.00% to 2.32% at 80 DAT, 0.15% to 7.01%

at 85 DAT, and 0.24% to 13.93% at 90 DAT. The highest severity of leaf blast was recorded at 40 DAT in Sanla (10.32%), and the lowest at 80 DAT in Binni Pakri (0.05%). For neck blast, the highest severity was observed at 90 DAT in Sanla (13.93%), while the lowest was at 80 DAT in Binni Pakri (0.00%). 0 to 9 scale used to determine the leaf blast severity recommended by IRRI (2013) and 0 to 9 scale used to determine the neck blast severity recommended by Singh (2000). Hossain and Ali (2017) in 2016, Bangladesh experienced significant yield losses due to a widespread outbreak of rice blast caused by *Pyricularia oryzae*. This affected various regions including Dinajpur, Rangpur, Thakurgaon, Panchagarh, Kushtia, Jashore, Pabna, Barishal, Mymensingh, Munshigonj, Chuadanga, and others. The production of boro rice and transplanted aman was notably reduced due to a blast infestation, with disease severity reaching 21.19% and 11.98% respectively. In the rain-fed ecosystem (T. Aman season), the cultivar BRRI dhan 34 and local aromatic varieties showed the highest disease incidence, ranging from 50.7% to 59.8%. Moderately susceptible cultivars, with a disease incidence of 10.2% to 22.1%, included BRRI dhan 33, BRRI dhan 39, and BRRI dhan 44. Cultivars BRRI dhan 49, BRRI dhan 40, BRRI dhan 46, and BRRI dhan 41 exhibited lower disease incidence, ranging from 4.9% to 9.3%.

In the research, the pathogen was isolated and cultivated in OMA media to encourage sporulation. The conidiophores were either individual or grouped, simple, infrequently branched, and exhibited sympodial growth. The conidia were pyriform (pear-shaped with a pointed end), narrowing towards the tip, rounded at the base, 2-septate, and hyaline in color with a distinct basal hilum. The conidia's size, measured using an ocular micrometer, ranged from 22.13 to 28.47 μm × 9.13 to 11.72 μm (average 25.30 × 10.43 μm). Bonman *et al.* (1992) carried out a study on *Pyricularia oryzae*. For the isolation of *Pyricularia oryzae*, leaves infected with rice blast were collected, and each lesion was placed in a moist petri dish and incubated at 25ºC for isolation. Hussin *et al*. (2020) used Oatmeal agar media (OMA) for Pyricularia isolation. OMA was also used by Teli *et al*. (2016), Yashaswini *et al*. (2017), Kulmitra *et al*. (2017) and Asfaha *et al*. (2015). In a study conducted by Gashaw *et al.* (2014), they examined the morphological and physiological differences among six isolates of *Pyricularia grisea*. They found that the most significant mycelial growth occurred on OMA (87.3 mm), characterized by a grey color, smooth edges, and substantial mycelial development. Leong (2004), Mukund Variar and others (2006), and Mebratu and others (2015) observed that the culture of *Pyricularia* was black to olive gray in color. Mijan Hossain (2000) also observed *Pyricularia* cultures and reported that the mycelia were initially hyaline in color, then turned olivaceous. It was noted that mostly 2-celled conidia were found from rice grain media and 3-celled conidia were found in infected leaf samples.

Bacterial blight manifests initially as streaks that are water-soaked, which originate from the tips and edges of the leaves. These streaks expand, eventually exuding a milky substance that dries into yellow droplets. As the infection progresses to its later stages, the leaves display greyish white patches, a characteristic sign of this disease. Adult plants may survive the infection, but the yield and quality of the rice are adversely affected. Same symptoms observed on the studies conducted by Sanya *et al.* (2022), Xu *et al.* (2022) and Gnanamanickam *et al.* (1999).

The incidence of the bacterial leaf blight disease in rice was monitored at six different stages: 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). The disease incidence varied significantly among the different rice varieties. For bacterial leaf blight, there was no disease incidence at 30 DAT. After that, the incidence rates ranged from 0.00% to 0.73% at 40 DAT, 0.99% to 2.02% at 50 DAT, 1.25% to 2.51% at 60 DAT, 2.24% to 3.82% at 70 DAT, and 2.31% to 5.57% at 80 DAT. The highest incidence of bacterial leaf blight was observed at 80 DAT in Binni Pakri (5.57%), while the lowest was at 80 DAT in Uknimodhu (0.47%). The severity of the disease was also tracked at the same intervals. There was a significant variation in disease severity among the rice varieties. The severity rates for leaf blast ranged from 0.00% to 0.15% at 40 DAT, 0.38% to 0.72% at 50 DAT, 0.45% to 1.24% at 60 DAT, 0.58% to 1.40% at 70 DAT, and 0.75% to 1.90% at 80 DAT. The highest severity of bacterial leaf blight was observed at 80 DAT in Binni Pakri (1.90%), and the lowest at 40 DAT in Bolder (0.08%) and Jira Katari (0.08%). Arshad *et al.* (2021) documented that The highest average incidence of 20-25% was noted in Faisalabad, Chiniot, and Sahiwal during at least one year of the rice season. Interestingly, no fields with BLB symptoms were observed in the districts of Okara, Khanewal, and Bahawalpur during the 2012 and 2013 rice seasons. Ahsan *et al*. (2021) estimated that the incidence of BLB disease varied across different regions. In Gujranwala, Sialkot, and Narowal, the disease incidence was recorded at 35%, 50%, and 21% respectively, with severity ranging from 0-80%, 0-70%, and 0-70% respectively.

These samples were placed on a media plate and incubated at a temperature of 28±2°C for a period of 72 hours. The bacterial cultures that were recovered from these samples exhibited characteristics typical of Xoo bacterial colonies, such as a yellow color and mucoid, convex colonies, upon plating the samples. Same media observed by Jabeen *et al*. (2012). The bacterial isolates that were tested showed positive results for catalase, oxidase, 3% KOH, and casein hydrolysis. However, the Gram's reaction test was negative for all the isolates, suggesting that they were gram-negative organisms stated by Arshad *et al.* (2015) and Shobha *et al.* (2020).

The initial symptom is a water-soaked, oblong lesion that appears on the leaf sheaths around or near the water line. Within a span of two to three days, the lesion develops a grayish-white center encircled by a dark purplish or reddish-brown border and can extend up to an inch in length. This lesion disrupts the transportation of water and nutrients to the leaf tip, which may result in the tip's death. These symptoms are often referred to as cobra skin-like lesions. Despite the presence of the lesion, the tissue underneath may retain its green color. Acharya and Basu (2012), Gopi *et al.* (2023), Sudarsanam (2017) and Singh *et al.* (2016) observed the same types of symptoms in their researches.

The sheath blight disease in rice was observed at six distinct stages: 30, 40, 50, 60, 70, and 80 days after transplanting (DAT). There was a significant variation in disease incidence among the different rice varieties. For sheath blight, only Bolder (0.17%) showed disease at 30 DAT. Following that, the incidence rates varied from 0.00% to 1.92% at 40 DAT, 1.17% to 7.73% at 50 DAT, 1.61% to 9.23% at 60 DAT, 1.73% to 13.59% at 70 DAT, and 1.93% to 15.20% at 80 DAT. The maximum incidence of sheath blight was noted at 80 DAT in Uknimodhu (15.20%), while the lowest was at 80 DAT in Sanla (0.77%). The severity of the disease was also monitored at the same intervals. There was a noticeable difference in disease severity among the rice varieties. The severity was only found at 30 DAT in Bolder (0.13%). The severity rates for leaf blast ranged from 0.00% to 0.19% at 40 DAT, 0.14% to 0.76% at 50 DAT, 0.19% to 2.43% at 60 DAT, 0.20% to 2.95% at 70 DAT, and 0.31% to 3.45% at 80 DAT. The highest severity of bacterial leaf blight was observed at 80 DAT in Uknimodhu (3.45%), and the lowest at 50 DAT in Zetha Katari (0.14%). According to Faheem and Mujeebur (2023) sheath blight severity remain 0.9 to 3.3 and incidence was quite intense from 7.2% to 38.9%. Pratiwi *et al.* (2021) revealed that the highest severity of the disease, measured at 12.36%.

Rhizoctonia solani, the organism responsible for the sheath blight disease in rice, was extracted from infected rice sheaths gathered from the experimental field. This was done using the tissue planting method in PDA (potato dextrose agar) medium. This organism has also been isolated from infected rice plants by Singh *et al.* (2003), Shahram *et al.* (2010), Bashar *et al.* (2010) and Yugander *et al.* (2015). Morphological tests were conducted to confirm the identity of *R. solani*. According to Sneh (1991) a septum is initially formed in the branch near the constriction. Following this, the hyphae undergo a maturation process, resulting in a more rigid and uniform structure. Butler and Bracker (1970) and Duggar (1915) stated that branches emerge from the main hyphae at a perpendicular angle, or 90 degrees.

In terms of yield-contributing factors, Binni Pakri demonstrated superior performance with the longest panicle length and the highest number of grains per panicle. It was observed that Binni Pakri produced the maximum yield of 3.67 tons per hectare. The yield was notably high due to the minimal incidence and severity of blast in Binni Pakri.

From the present study it has been found that all the rice varieties got infection by blast, bacterial leaf blight and sheath blight. Binni Pakri was the best indigenous rice cultivar against these three major diseases. Among those diseases leaf blast and neck blast caused maximum damages. So, different control measures should be taken to control the diseases and increase the yield of rice.

CHAPTER 6

SUMMARY AND CONCLUSION

Rice is a key dietary element in Bangladesh and carries substantial significance. The country's economy is profoundly impacted by the farming of this indispensable crop. Diseases of rice causes a great yield loss every year. Among all the rice diseases blast, bacterial leaf blight and sheath blight are most dangerous.

From the experiment, highest leaf blast incidence and severity was found in Sanla 25.68% and 10.32% and lowest found in Binni Pakri 0.32% and 0.05%. In neck blast the maximum incidence and severity observed in Sanla 29.54% and 13.93% and minimum in Binni Pakri 0.00%. For BLB, maximum incidence and severity noted in Binni Pakri 5.57% and 1.90% and minimum incidence observed in Uknimodhu 0.47% and minimum severity in Bolder 0.08%. At last, in sheath blight, maximum incidence and severity was recorded in Uknimodhu 15.20% and 3.45% and minimum incidence observed in Sanla 0.77% and minimum severity in Zetha Katari 0.14%. On the other hand, Binni Pakri variety showed the highest yield.

Among the three diseases, blast showed the maximum incidence and severity. As Binni Pakri noted as the lowest level of incidence and severity it showed the highest yield and Sanla showed the highest disease but in yield it was lowest. So, blast disease causes the maximum yield losses in this study.

More studies are required to find out the effect of different varieties on incidence and severity of blast, BLB and sheath blight disease of rice under different agro-ecological zones in the country.

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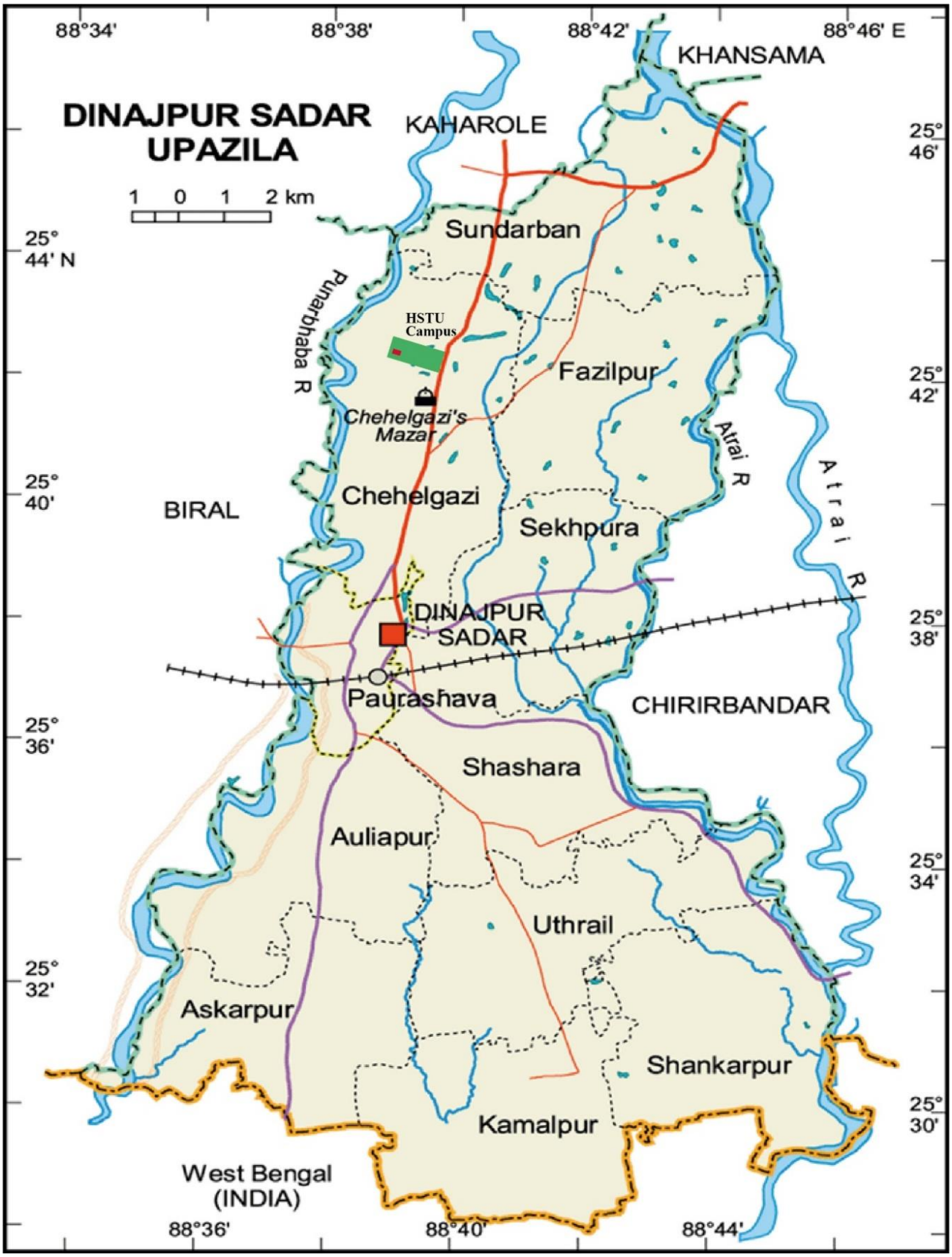
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot)



Appendix II. The physical and chemical properties of soil in the experimental field, HSTU, Sadar, Dinajpur-5200

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%)	30
Clay (%)	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
pH	5.35
Organic matter (%)	1.06
Total nitrogen (%)	0.10
Sodium (meq/ 100g)	0.06
Calcium (meq/ 100g)	1.30
Magnesium (meq/ 100g)	0.40
Potassium (meq/ 100g)	0.26
Phosphorus (μg/g)	24.0
Sulphur (μg/g)	3.2
Boron (μg/g)	0.27
Iron (μg/g)	5.30
Zinc (μg/g)	0.90

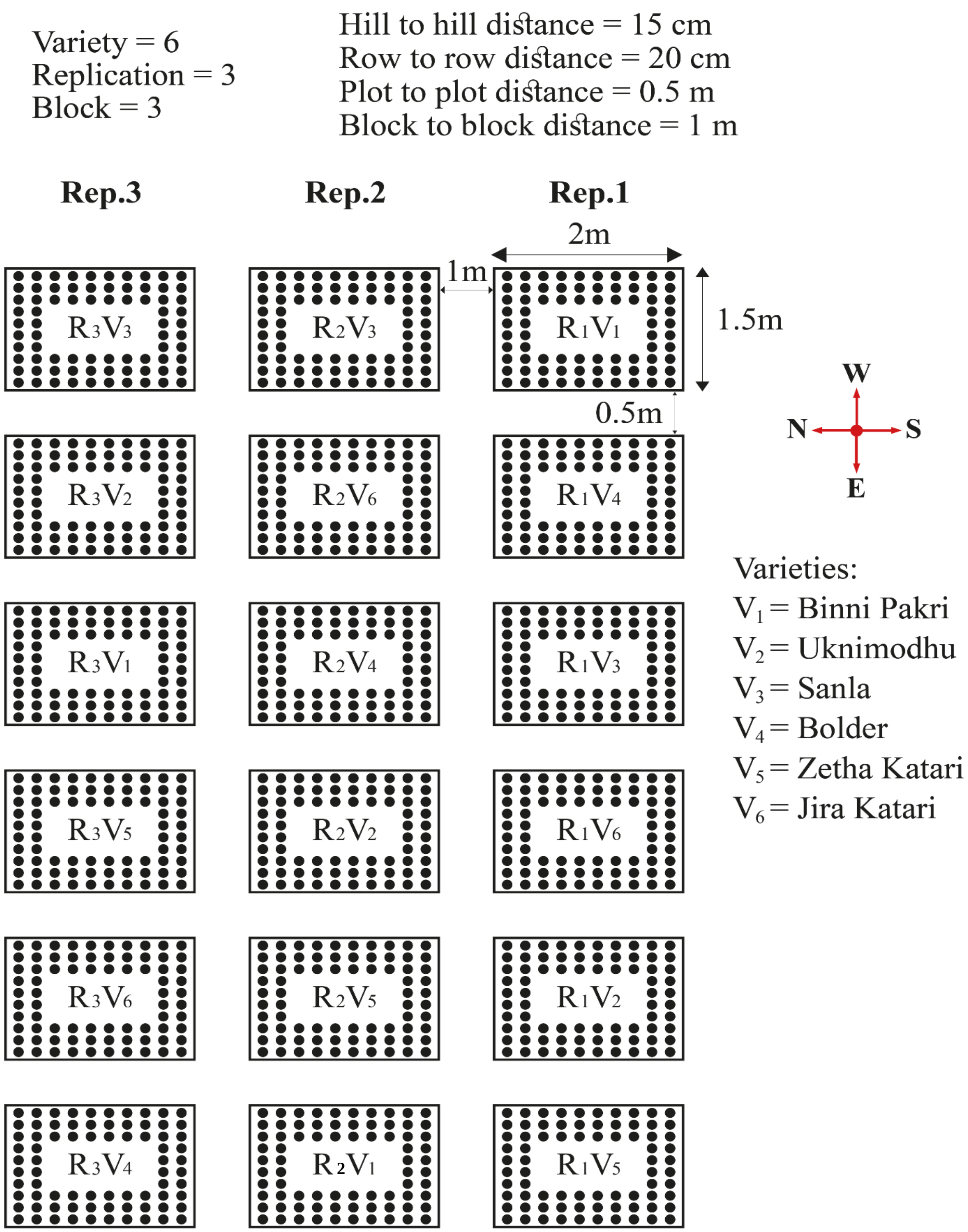
Source: Soil Resources Development Institute (SRDI), Dinajpur-5200

Appendix III. Weather data of the experimental site during the period from August to December 2023

Date	DAT	Temperature	Humidity
18 August 2023	0 Days	31ºC	84%
18 September 2023	30 Days	31ºC	83%
28 September 2023	40 Days	31ºC	81%
8 October 2023	50 Days	31.5ºC	70%
18 October 2023	60 Days	31ºC	63%
28 October 2023	70 Days	23ºC	89%
8 November 2023	80 Days	24ºC	69%

Collected from www.weather.com

Appendix IV. Layout of the experiment



Appendix V: Some photographs related to the research.

Plate 1. Some photographs related to the research.