Evaluation of Different Planting Methods against Major Diseases of Selected Boro Rice Varieties

ABU JAFOR MOHAMMAD MOIN UDDIN

DEPARTMENT OF PLANT PATHOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER 2021

Evaluation of Different Planting Methods against Major Diseases of Selected Boro Rice Varieties

ABU JAFOR MOHAMMAD MOIN UDDIN

DEPARTMENT OF PLANT PATHOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER 2021

Evaluation of Different Planting Methods against Major Diseases of Selected Boro Rice Varieties

ABU JAFOR MOHAMMAD MOIN UDDIN
REGISTRATION NO. 26176/ 00470

A Thesis

Submitted to the faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka

In partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE
IN
PLANT PATHOLOGY.

SEMISTER: JULY-DECEMBER, 2021.

Approved by:

Prof. Dr. Md. Belal Hossain
Supervisor
Department of Plant Pathology.
Sher-e-Bangla Agricultural University.

Prof. Dr. Md. Rafiqul Islam
Co-Supervisor
Department of Plant Pathology.
Sher-e-Bangla Agricultural University.

Prof. Abu Noman Faruq Ahmmed
Chairman
Examination Committee
Department of Plant Pathology.
Sher-e-Bangla Agricultural University.

CERTIFICATE

This is to certify that thesis entitled, “EVALUATION OF DIFFERENT PLANTING METHODS AGAINST MAJOR RICE DISEASES OF SELECTED BORO RICE VARIETIES**”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M. S.) IN PLANT PATHOLOGY** embodies the result of a piece of bona fide research work carried out by a student, REGISTRATION NO. **26176/ 00470,** under my supervision and guidance. No part of this thesis has been submitted for any other degree.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Prof. Dr. Md. Belal Hossain
Supervisor
Department of Plant Pathology
Sher-e-Bangla Agricultural University

Dated: 31 July, 2022
Dhaka, Bangladesh.

DEDICATED

TO MY

BELOVED

PARENTS

ACKNOWLEDGEMENT

All praises and thanks are due to the supreme ruler of the universe, the almighty Allah, most beautiful and most merciful for His bestow upon the author for accomplishment of this research study.

The author expresses the deepest sense of respect and heartiest gratitude to his respected supervisor **Prof. Md. Dr. Belal Hossain**, Department of Plant Pathology, Sher-e- Bangla Agricultural University for his efficient and scholastic guidance, constructive criticism, valuable suggestion and immense help to carry out the research work toward successful completion and preparation of the thesis by necessary corrections and modification through reviewing the text.

The author wishes to express his sincere appreciation and heartfelt gratitude to his co-supervisor **Prof. Dr. Md. Rafiqul Islam**, Department of Plant Pathology, Sher-e- Bangla Agricultural University for his valuable suggestion, constant cooperation, inspiration and sincere advice to improve the quality of the thesis.

Cordial thanks to Prof. Abu Noman Faruq Ahmed, Chairman, Department of Plant Pathology and all respected teachers of Department of Plant Pathology, Sher-e- Bangla Agricultural University for their help and cooperation during the study and research.

The author is also grateful to Dr. ABM Anwar Uddin, SSO BRRI, Dr, Rafiqul Islam, SSO BRRI, Dr. Jahidul Islam, SSO, BRRI. Anjuman Ara, SSO BRRI, Afsana Akhter former student, Department of Plant pathology, SAU, Saniya Akhter Rozy, former student, Dept of Plant pathology, SAU, Arifuzzaman Shuvo former student, Dept of Plant pathology, SAU, for their immense help, valuable suggestions and direction to improve this thesis. The author deeply indebted to his father, mother, brothers and sisters, brother in laws, sister in laws for their moral support, encouragement and unquantifiable love with cordial understanding.

The author wish to thank the course mates, officers of Farm division, friends and well-wisher for their encouragement. Finally, the author would like to thank all officers and staffs of the department of plant pathology of SAU for their continuous help and support.

-The author

ABSTRACT

The System of Rice Intensification (SRI), an innovation that was first emerged in Madagascar in the 1980s and has now diffused to more than 50 countries. The present study was conducted as field experiment in the central farm of Sher-e-e Bangla Agricultural University (SAU) using RCBD design and the lab experiment was carried out in Molecular Biology and Plant Virology Laboratory under the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207. The experiment was carried out to adopt SRI as an alternative approach for management of major rice diseases in Bangladesh, during the period of November, 2020 to June, 2021. From the study it was revealed that all the selected planting methods gave the significantly effect on percent disease incidence (% DI) and severity (% DS) of major rice diseases viz. blast, brown spot, sheath blight and bacterial leaf blight in selected boro rice varieties (BRRI dhan 28, BRRI dhan 89, BRRI dhan 92 and purple rice). The highest disease incidence and severity was recorded in conventional planting method and the lowest in basic SRI method. The moderate disease incidence and severity was recorded in modern SRI method which was statistically non-significant with Basic SRI method but significant with conventional method. However, it is necessary for further trial in different variety and AEZs as field experiment. So, it may be recommended that the System of Rice Intensification (SRI) may be alternative for management of major rice diseases.

LIST OF CONTENTS

LIST OF MAPS

LIST OF PLATES

LIST OF TABLE

LIST OF FIGURE

INTRODUCTION

The world population is rapidly increasing and approaching about seven billion and about half of them depend on rice as their staple food (IRRI, 2010). More than 90 percent of the world's rice is produced and consumed in Asia where over half of the world population lives. The Food and Agriculture Organization (FAO) of the United Nations estimates that in 2013 more than 33 million metric tons (mt) of rice were devoted to feed, with the amount growing by 0.5 million mt per year since 2003, an average annual growth rate of 1.7 percent (Sharon, 2018). Bangladesh is one of the most important rice growing countries in Asia where the crop is grown throughout the year in three seasons. Rice is the staple food of about 165.1 million people of Bangladesh (BBS, 2022). It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country (Anwar, 2018). Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh.

Almost all of the 16.56 million farm families of the country grow rice (Agro Statistics 2019, DAE 2022). Rice is grown on about 11.8 million hectares which is almost increasing over the past three decades. Rice occupies 74.77 per cent of the total cropped area and constitutes about 90 percent of the total food grains of Bangladesh (Anonymous, 2009). Rice provides 75 percent of the calories and 55 percent of proteins of the average daily diet of the people of Bangladesh (Bhuiyan, 2002). In several developed countries such as North

America and European Union (EU), rice consumption has also increased due to food diversification and immigration (Dubey, 2005). About 75% of the total cropped area and over 80% of the total irrigated area is used to produce rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh. With the continuously increase in the human population and losses of arable land of Bangladesh, about 2.7 per cent increase of rice production per year is required to feed its populations (Alam et. al., 2004).

World rice production is increasing. According to Food and Agricultural Organization (FAO) world rice production was about 509.87 million metric ton (M Ton) in 2021-22 whereas in the same time Bangladesh Produces about 36 million metric ton rice.

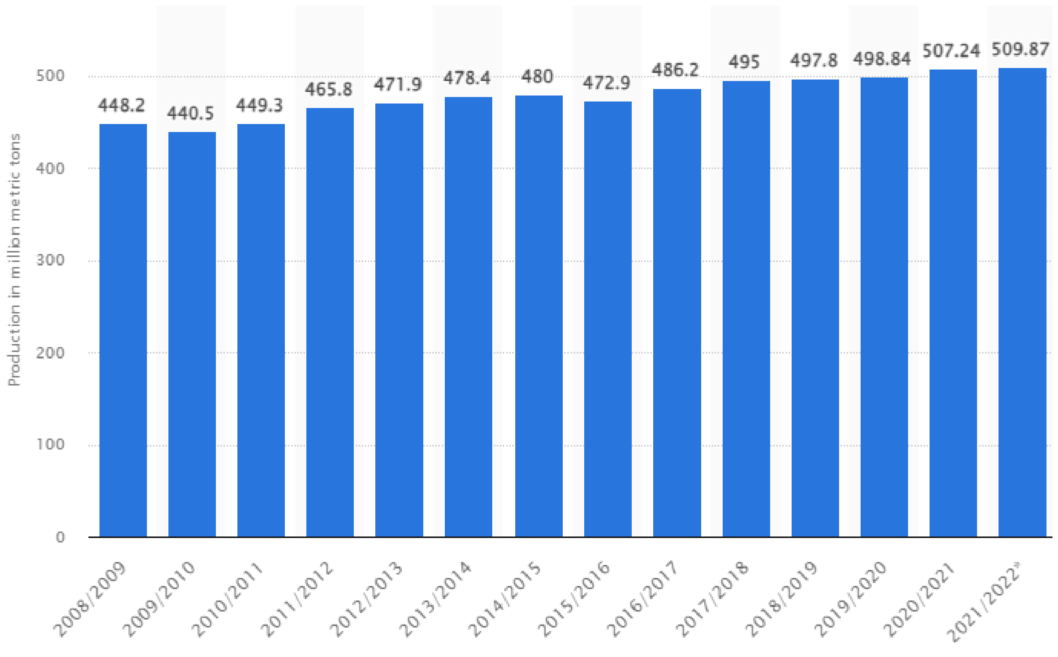


Figure 1: World Rice Production (Million Metric Ton)

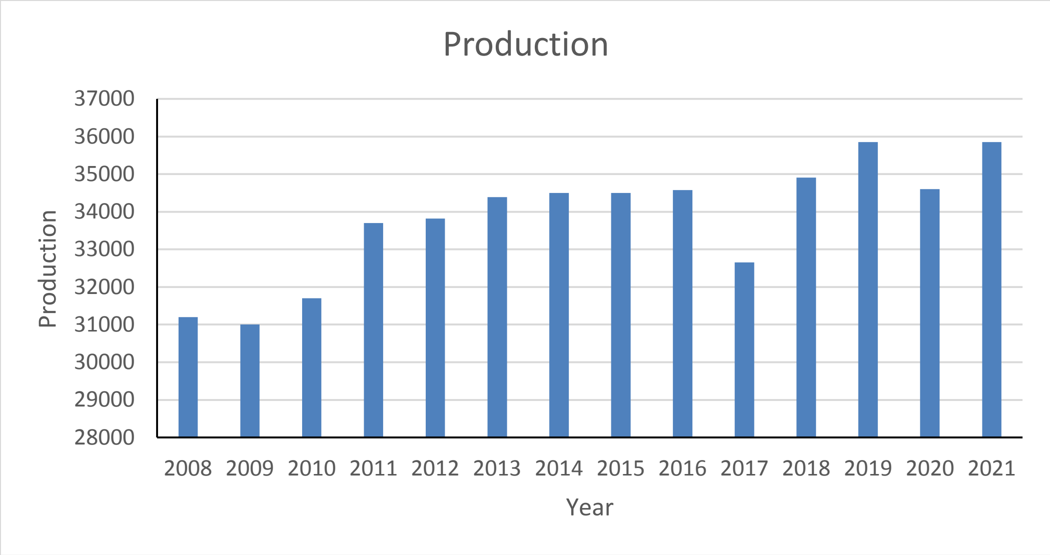


Figure 2: Rice Production in Bangladesh (Million Metric Ton)

Average rice yield in Bangladesh is about 3.041 metric ton/ hectare (BBS,2018). On the other hand, Asia's average yield is about 3.6 metric ton/ hectare and world average yield is 4.4 metric ton/ hectare (Dastagir, 2013). Our population is increasing and arable land is decreasing and we need to increase 2.7% production yearly. Objectives of Sustainable Development Goal (SDG) and 8th five year plan are to doubling agricultural productivity and ensure food security. We have taken lots of strategies to increase our rice production.

There are so many constraints in rice production in Bangladesh. Insect, pests and diseases are the important limiting factors of rice production in Bangladesh. Asia's hot and humid climate during the long and heavy monsoon season provide the most favorable agro ecological environment for rice cultivation as well as diseases development. A total of 79 rice diseases were recorded worldwide (Ou, 1985). In Bangladesh, there are 10 rice diseases considered as major, which cause economic loss in farmers' fields (Khatun et.al. 2021). Rice diseases, caused by different groups of microorganisms are grouped into fungi, bacteria, virus and nematodes. Thirty six fungal, six bacterial, twenty one viral and five nematode diseases are recorded in rice (Ou, 1985). So far in Bangladesh, about 31 diseases are recorded to occur in rice including 10 major diseases (Shahjahan *et al.*, 1987). Major diseases are seedling blight, blast, brown spot, sheath blight and stem rot, false smut, bakanae disease, bacterial leaf blight (BLB), bacterial leaf streak, ufra and tungro disease.

The System of Rice Intensification (SRI) is a farming methodology aimed at increasing the yield of rice produced in farming. It is a low-water, labor-intensive method that uses younger seedlings singly spaced and typically hand weeded with special tools. SRI was developed in 1980's by Fr. Henri de Laulanié, S.J. and SRI was discovered by Prof. Dr. Norman Thomas Uphoff, CIIFAD, Cornll University, USA. It is just altering the management practice to make more productive phenotype from same genotype of rice. Artificial environment is created for growth and development of rice for exploitation of its full genetical potentiality. It promotes the growth of root systems, increase the abundance and diversity of soil organism. More output comes from less input here. Young seedlings are transplant here and provide wider spacing and one seedling per hill.

There are lots of methods for the management of rice diseases. Among them, chemical methods plays most important roll. But it needs cost and creates hazards for both man and environment. SRI can be used as a method for the management of rice diseases. According to some recent reports in the world and also in Bangladesh regarding the System of Rice Intensification, which known as SRI methodology, it is an innovation in rice production systems by raising productivity of the land, labor, water and capital, particularly focus on water management in irrigation based rice production. Worldwide, the agricultural sector makes the largest demand on our finite fresh water resources than any sector, and within this sector, irrigated rice production is the largest area of demand for fresh water. In this proposed study, we focus on adaptation of SRI methodology as an alternative approaches for management of major biotic stresses of rice production in Bangladesh as well as limiting water use in rice production. Wider spacing and use of organic manures for SRI results in healthy growth of the plants and incidence of the pests and diseases is naturally low. The ultimate goal of the proposed study is to manage the abiotic and biotic stresses of rice in Bangladesh against the climate change effect, i e., mitigation of climate change.

Objectives

The proposed research work was carried out to achieve the following specific objectives-

- To manage the major biotic stresses of rice in Bangladesh by adaptation of SRI methodology as alternative treatments
- To reduce the uses of chemicals (pesticides) and enhance the use of irrigated water efficiently

REVIEW OF LITERATURE

Rice is one of the major crops in the world. It suffers from many diseases. The literatures on incidence, severity, effect on the yield, yield contributing characters and screening of some boro varieties against major diseases are accumulated in this chapter

A. Disease

Rosy (2014) observed that disease incidence and severity increases gradually with the age of plant and minimum incidence and severity gives maximum yield.

Baranwal et al., (2013) reported that the disease especially occurs in environment where water supply is scarce combined with nutritional imbalance particularly lack of nitrogen.

Khalil et al., (2012) reported that the disease has been found to occur in all the rice growing countries including Japan, China, Burma, Sri Lanka, Bangladesh, Iran, Africa, South America, Russia, North America, Philippines, Saudi Arabia, Australia, Malaya and Thailand.

Dallagnol et al., (2011) reported that the survival of fungus in seed and soil influence by environmental factors. The temperature and relative humidity at which seeds are stored influence the variability of the pathogen.

Kamal and Mia (2009) observed that yield was reduced ranged from 18.75-22.50%. Glume blotch phase of the disease has been reported to cause more damage (Kulkarni et al., 1986) and reduce seed germinability (Hiremath et al., 1983).

Savary et al., (2006) reported that brown spot yield losses occurred due to a number of damage mechanisms, in addition to leaf area index (LAI) reduction and presumably self shading of lesions on underlying canopy.

Pannu et al., (2005) found that within a 5-year period (2000– 2004) two rainy season crops (2001 and 2003) in India led to terminal severities of 9.2 to 8.8 %, corresponding to accumulated rainfalls of 410.5 to 502.0 mm, respectively. However, in 2002 lower rainfall corresponded with higher severity.

Jha (2001) reported that plants are more susceptible during dough and mature stages.

Jha et al., (2004) observed a higher disease severity in direct sown plants than in transplanted crop. Holanda et al., (2002) reported that this disease occurs more frequently in soils with high pH, low organic matter and low levels of N, K, Mn, Si and free Fe and low CEC.

Minnatullah and Sattar (2002) reported that temperature and humidity, in the form of leaf wetness, interact on infection efficiency. This may explain why decreasing daily minimum temperatures (9.3 to 7.5 0C) lead to more severe epidemics.

Singh et al., (2000) and Jha (2001) observed that the disease severity was more in late sown crop as compared to early planted crop.

Akhtar et al., (2011) reported that the disease reduces grain yield to varying levels depending on the stage of the crop, degree of cultivar susceptibility and a great extent to the conduciveness of the environment in which it occurs.

Veena et al., (2000) reported that in India, the yield loss due to this disease is up to 81.3%.

B. Blast

Vu-Van and Sangchote (2006) found the highest incidence of Bipolaris oryzae in rachilla followed by sterile lemma, palea, embryo and endosperm of rice kernels with typical brown spot.

Rice blast is one of the most important diseases of rice, caused by the fungus *Pyricularia oryzae* B. C. Couch (Couch and Kohn, 2002).

Blast disease causes yield losses from between 1- 100% in Japan (Kato, 2001), 70% in China, 21-37% in Bali Indonesia (Suprapta and Khalimi, 2012), 30-100% in Bangladesh (Singh G. and Prasad C.S. 2015) and 30-50% in South America and Southeast Asia (Baker et al., 1997; Scardaci et al., 1997).

The fungus *Pyricularia oryzae* attacks at all stages of the crop and symptoms appear on leaves and nodes (Seebold et al., 2004).

In West Africa, the largest area of African production, this pathogen is the main restraint to production with yield losses ranging from 4-77%. The fungus is able to infect plants at all stages of growth and development in both upland and lowland rice production systems. Lowland rice produced in temperate and subtropical climates of Asia are highly susceptible to the pathogen, while tropical upland areas are susceptible only under irrigation (Nutsugah et al. 2008).

Ali et. al. (2009) reported that in Pakistan during the last two decades, rice blast mostly common in 6 districts of Faisalabad, Toba Tek Singh, Vehari and place like Gaggoo Mandi.

Bonman et al. (1989) observed that the symptoms are more severe in case of neck blast that is characterized by the infection at the panicle base and it's rotting.

Magnaporthe 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). The Blast disease causes yield losses from between 1- 100% in Japan (Kato, 2001), 70% in China, 21-37% in Bali Indonesia (Suprapta and Khalimi, 2012), 30-100% in Bangladesh (Singh G. and Prasad C.S. 2015) and 30-50% in South America and Southeast Asia (Baker et al., 1997; Scardaci et al., 1997).

Rice blast is one of the most important diseases of rice, caused by the fungus *Pyricularia oryzae* B. C. Couch (Couch and Kohn 2002). One of the main limitations in production is rice blast disease caused by the fungus *Pyricularia oryzae*. Annual rice losses caused by this fungus during 90's had been estimated at 35% of the worldwide production (Oerke and Dehne, 2004).

In West Africa, the largest area of African production, this pathogen is the main restraint to production with yield losses ranging from 4-77%. The fungus is able to infect plants at all stages of growth and development in both upland and lowland rice production systems. Lowland rice produced in temperate and subtropical climates of Asia are highly susceptible to the pathogen, while tropical upland areas are susceptible only under irrigation (Nutsugah et al. 2008).

Blast disease caused by *Pyricularia oryzae* Cavara [Synonym *Pyricularia grisea Sacc*., the anamorph of *Magnaporthegrisea*, upsets production statistics of rice in Pakistan (Tirmali A.M. and Patil B.K. 2000). In Pakistan during the last two decades, rice blast is 6 mostly found in districts of Faisalabad, Toba Tek Singh, Vehari and place like GaggooMandi (Ali et al., 2009).

The fungus *Pyriculariaoryzae* attacks at all stages of the crop and symptoms appear on leaves and nodes (Seebold et al., 2004).

The symptoms are more severe in case of neck blast that is characterized by the infection at the panicle base and it's rotting (Bonmanet al., 1989).

Heavy yield losses have been reported in many rice growing countries. For example 95, 50 and 40 percent grain loss may occur in Bangladesh and India (Padmanabhan, 1965), Philippines (Ou, 1985) and Nigeria (Arshad, 2008).

The most usual approaches for the management of rice blast disease include planting of resistant cultivars, application of fungicides and manipulation of planting times, fertilizers and irrigations (Georgopoulos and Ziogas, 1992; Mbodi et al., 1987; Naidu and Reddy, 1989).

Blast is known to attack nearly all above ground parts as well as during all growth stages of plant. Recent reports have shown that the fungus has the capacity to infect plant roots also (Shafaullah et al.,2011).

The infection of rice blast occur when fungal spores land and attach themselves to leaves using a special adhesive released from the tip of each spore (Hamer, Howard, Chumley, &Valent, 1988).

The germinating spore develops an aspersorium, a specialized infection cell which generates enormous turgor pressure (up to 8MPa) that ruptures the leaf cuticle, allowing invasion of the underlying leaf tissue (Dean, 1997; Hamer et al., 1988).

C. Brown Spot

There is indication that brown spot is becoming more frequent and severe as drought is becoming more frequent (Savary et al., 2005), perhaps due to increased variability in rainfall consider brown spot as a model pathosystem for a synergistic understanding on a range of diseases (Savary et al., 2011).

Brown spot is still widely reported across India and more generally in the South and South-East Asian countries (Savary et al., 2000). Brown spot causes yield losses that, on average, are in the range of 10 % of the attainable yield wherever it occurs (Savary et al., 2000, 2006) in the lowlands of tropical and subtropical Asia.

Igawa et al., (2005) Timmusk and Wagner (1999) reported that, brown spot might be strongly associated with the combined plant physiological disorders, disease development processes, and disease resistance mechanisms. This association between exposure to physiological stresses and disease development brings about generic and important questions pertaining to interacting metabolic pathways, their genetic bases and the interaction amongst genes or clusters of genes.

Brown spot is generally not observed in years with regular rainfall (Singh et al., 2005) whereas seasons with limited rainfall but heavy dew are conducive to stronger epidemics (Sherf et al., 1947).

Igawa et al., (2005) Timmusk and Wagner (1999) reported that, brown spot might be strongly associated with the combined plant physiological disorders, disease development processes, and disease resistance mechanisms. This association between exposure to physiological stresses and disease development brings about generic and important questions pertaining to interacting metabolic pathways, their genetic bases and the interaction amongst genes or clusters of genes.

D. Sheath Blight

Rashid et. al. (2020) reported that among the major rice diseases sheath blight (ShB) caused by the fungal pathogen *Rhizoctonia solani* (*R. solani*) is one of the most economically important diseases in Bangladesh and the world.

Singh et. al. (2001) reported that sheath blight caused by *Rhizoctonia solani* Kühn is one of the most widespread diseases of rice and causes serious yield losses under favorable environmental condition.

Brooks (2007) reported that the disease (Sheath blight) occurs in most rice-producing areas and is second in importance only to rice blast (20).

Groth et. al. (2007) reported that under conditions favorable for disease development, rice grain yield losses, ranging from 4% to 50%, have been attributed to sheath blight.

Eizenga *et. al.* (2002) reported rhat this disease (Sheath Blight), which is caused by *Rhizoctonia solani* Kühn (teleomorph: *Thanatephorus cucumeris* (Frank) Donk), was first reported in 1910 and now occurs throughout temperate and tropical production areas, being most prominent where rice is grown under intense, high-fertility production systems.

Jia *et. al.* (2007) reported that in the United States, Sheath Blight disease has been reported to cause yield losses up to 50% under environmental conditions favoring disease development

Nadarajah *et. al.*(2014) erported that *Rhizoctonia solani* K¨uhn (teleomorph: *Thanatephorus cucumeris* (Frank) Donk) is a soil-borne pathogen that causes a wide variety of diseases in economically important crop species.

Li *et. al.*, (2012) reported that sheath blight is considered as the most damaging major epidemic disease of rice.

Ali *et al.*, (2003) reported that the average incidence of ShB in Bangladesh is about 20.3%.

Shahjahan *et. al.*, (1986) reported that the yield loss caused by ShB in Bangladesh ranged from 14 to 31% under farmer's field.

E. Bacterial Leaf Blight (BLB)

Basso *et. al.*, (2011) reported that recent studies in West African countries such as Burkina Faso, Niger and Mali revealed the occurrence of BLB causing significant crop damages.

Roy *et. al.* (2014) reported that Bacterial Leaf Blight (BLB) is a major disease of rice in tropical monsoon and sub tropical rice growing regions of the world.

Fahad *et. al.* (2019) reported that the symptoms of sheath blight can be observed in temperate, tropical, and subtropical regions on rice crops from tillering to milk stages.

Ansari *et. al.* (2019) reported that in the last few decades BB of rice is considered as a major bacterial disease in Bangladesh. It is caused by a

Gram-negative bacterium *Xanthomonas oryzae* pv. o*ryzae (Xoo)*. According to the IRRI report sheath blight causes a yield loss of about 6% across lowland rice areas in tropical Asia.

Kadai (2010) reported that occurrence of bacterial leaf blight in most of rice growing eco zones of Togo with high incidence and severity, and the virulence of the pathogen was determined.

Waheed *et. al*., (2009) reported that Bacterial leaf blight has the potential to become a destructive bacterial disease of rice in Pakistan and can cause huge losses mainly because of the lack of information regarding the pathogen and its effective measure of control.

Dai *et. al*., (2007) reported that Bacterial Leaf Blight Disease (BLB), one of the major diseases of rice, known to occur in epidemic proportion in many part of the world, can reduce production by more than 50%.

Sere *et. al*., (2005) reported that BLB was observed to occur in fields with high incidence of 70 to 80% in several West African countries.

Bacterial leaf blight of rice (BLB), caused by Xanthomonas oryzae pv. oryzae (Swings et al., 1990), is one of the most widespread and destructive diseases of rice in several countries in tropical rice-growing areas of Asia, Australia, United States, Latin America and Africa (Mew, 1987, 1989; Mew et al., 1993; Sere et al., 2005).

Ou (1985) and Sere *et. al*., (2005) reported that Yield losses due to BLB ranging from 50 to 90%.

Ezuka and Kaku (2000) reported that BLB occurrence reported from Australia, Bangladesh, Cambodia, Indonesia, India, Korea, Mainland China, Malaysia, Srilanka, Thailand, Philippines, USA, West Africa and Vietnam.

F. System of Rice Intensification (SRI)

Selvaraju (2013) reported that SRI as an agro-ecological methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients.

Gujja and Thiyagarajan (2009) reported that SRI is a package of agronomic practices which exploits the genetic potential of rice plants, creates a better growing environment (both above and below ground), enhances soil health, reduces inputs such as seeds, fertilizers, water, and labour requirements for planting.

Siopongco *et. al*., *(*2013) reported that SRI reduces fuel consumption for pumping water by 30 litres/ha.

Lakshmanan *et. al*. (2012) reported that SRI can reduce water consumption by 22 to 25 percent, compared to paddy rice.

Jain *et al.*, (2013) & Rajkishore *et al.*, (2013) reported that fields with SRI could reduce CH4 production by about 30–60 percent and lower the Global Warming Potential significantly.

Lakshmi *et. al.* (2016) reported that SRI has outperformed conventional rice cultivation with respect to increasing adaptation to CC impacts, reducing GHG emissions, particularly CH4, and increasing yield System of rice intensification- Climate-smart rice cultivation system to mitigate climate change impacts in India. According to the Guideline on SRI Practice for Tropical Countries(2012), SRI can produce more paddy yield with less external inputs.

Barret *et. al.* (2012) reported that SRI is a combinatorial innovation involving a suite of principles designed to increase rice yields by changing the management of the plants, soil, and water.

According to the principle of SRI wider spacing at 25 cm x 25 cm. in square planting rather than in rows is required. Uphoff (2006) reported that farmers who grow irrigated rice with continuous flooding of their paddies have been wasting large volumes of water for centuries, even millennia.

MATERIALS AND METHODS

The present study entitled “Adoption of climate change and impact of the system of rice intensification (SRI) as an alternative approach for management of major rice diseases in Bangladesh” was carried out at Sher-e-Bangla Agricultural University, Dhaka. The details of the materials used and methodology adopted during the study are described below with some headings and sub-headings.

3.1. Experimental Site

The field experiment was conducted at central farm of Sher-e-Bangla Agricultural University and the lab experiment was done in Molecular Biology and Plant Virology Laboratory under the department of Plant Pathology. The experimental field area was situated at 23°46' N latitude and 90°22' E longitude at an altitude of 8.6 meter above the sea level /(Anon. 1988).

3.2. Experimental Duration

The experiment was carried out during the period of November, 2020 to June, 2021.

3.3. Soil Characteristics

The soil of the experimental site was a medium high land which belongs to the Madhupur tract, Agro Ecological Zone no. 28. The soil texture was silt loam, high level of nutrients, non-calcareous, acidic, brown or red soil of Tejgaon soil series with pH 6.7.

3.4. Climate

The climate of the Madhupur tract varies slightly from north to south, the northern partreaches being much cooler in winter. Average temperatures vary from 26.9° C to 36.5° C in summer, reducing to 15.3° to 26° C in winter, with extreme lows of 10° C. Rainfall ranges between 1,000 mm and 1,500 mm annually, heavy rainfall in kharif season (May-September) and scanty in rabi season (October-March) . Severe storms are unusual but tornadoes have struck the southern areas sometimes. During the month of December, January and February there was no rainfall. During the period of study the average maximum temperature was 36.3° C and average minimum temperature was 20° C. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the period of experiment were collected from Bangladesh Meteorological Department, Agargaon, Dhaka.

3.5. Variety selection

Four rice varieties were selected, all of those varieties are inbreed line. Those varieties were cultivated in Boro season in Bangladesh. The following varieties were selected BRRI Dhan 28, BRRI Dhan 89, BRRI Dhan 92 and Purple Rice (Wild variety).

3.6. Planting material

Seeds of all the selected varieties of rice were used as planting material.

3.7. Seed collection

Rice seeds were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. Purple rice seed was collected from local source (Farmers of Gaibandha).

3.8. Sprouting of seeds

Seeds were sown two times at an interval of 15 days. First time seeds were soaked in four different plastic pots separately with tap water for 24 hrs. Before sowing in seed bed, seeds were taken out from water and placed in four gunny bags in room temperature for 72 hours for sprouting. After sprouting, seeds were sown in the seed bed.

After 11 days of first sowing, seeds were again soaked in four different plastic pots separately with tap water for 24 hrs. Before sowing in seed bed, seeds were taken out from water and placed in four gunny bags in room temperature for 72 hours for sprouting. After sprouting, seeds were sown in plastic trays. Plastic trays were placed in the net house.

BRRI dhan 28

BRRI dhan 89

BRRI dhan 92

Purple (beguni) dhan

Plate 1: Sprouting of Selected Rice Seeds

3.9. Seed bed preparation and sowing of sprouted seeds

Seed bed was prepared by paddling the soil with the help of power tiller and harrow. Proper manuring was done in the seed bed. Sprouted seeds were sown in wet seed bed on 15 December, 2020. Seedlings were properly taken care, weeding and irrigation was given in the seed bed as and when needed.

Soil was mixed with manure and placed in the plastic trays with proper sprouting seeds were sown in the trays in line on 31 December, 2020

	
Spreading seeds in seedbed	Seeds sowing in plastic tray for modern SRI

Plate 2: Sprouting Seeds Sown in seed bed and tray

3.10. Field Experiment

3.10.1. Land preparation

The land was prepared with the help of power tiller and harrow. The land was first opened on 7th January, 2021 and ploughed. After manuring, final ploughing was performed with the help of power tiller followed by laddering in order to level the soil surface. Weeds and stubbles were removed from the land.

3.10.2. Fertilizer application

Fertilizers were applied as per recommendation of BRRI (Adhunik Dhaner Chas, 2020). All fertilizers except Urea and Zinc were incorporated with soil during final land preparation. Urea was applied in three equal installments. First dose were applied 7 days after transplanting, second dose were applied with Zinc fertilizer 22 after transplanting and final dose were applied 37 days after transplanting. The following doses of fertilizers were applied to the plots.

Table 1. Recommended Fertilizer with Dose for Rice Cultivation.

Fertilizer	Dose (kg/ha)
Urea	240
TSP	120
MP	120
Gypsum	85
Zinc sulphate	1.5
Magnesium Sulphate	1
Boron	1

3.10.3. Design and layout

The experiment was laid out in randomized complete block design (RCBD) with three replications. Blocks were representing the replication. Each block comprised four unit plots and total number of plots were 36 (3 X 4 X 3=36). Size of each unit plot was 1.0 X 2.0 = 2 m^2. The distances between unit plots were 0.5 m.

North (50 ft) (14.5M)

West (94 Ft, 28.5 M)

East (94 Ft, 28.5 M)

	Conventional		SRI		Modern SRI	
	(4.5 M)	(0.5 M)	(4.5 M)	(0.5 M)	(4.5 M)	BRRI Dhan 28 ((9 M))
BRRI Dhan 28 ((3+3+3 = 9 M))	T1 R1		T2 R1		T3 R1	
	T1 R1		T2 R1		T3 R1	
	T1 R1		T2R1		T3 R1	
(0.5 M)						
BRRI Dhan 89 ((9 M))	T1 R2	(0.5 M)	T2 R2	(0.5 M)	T2 R2	BRRI Dhan 89 ((9 M))
	T1 R2		T2 R2		T2 R2	
	T1 R2		T2 R2		T2 R2	
(0.5 M)						
BRRI Dhan 92 ((9 M))	T1 R3	(0.5 M)	T2 R3	(0.5 M)	T2 R3	BRRI Dhan 92 ((9 M))
	T1 R3		T2 R3		T2 R3	
	T1 R3		T2R3		T2 R3	
(0.5 M)						
Purple Rice ((9 M))	T1 R4	(0.5 M)	T2 R4	(0.5 M)	T3 R4	Purple Rice ((9 M))
	T1 R4		T2 R4		T3 R4	
	T1 R 4		T2 R4		T3 R4	
	Conventional		**SRI**		**Modern SRI**	

South (50 FT or 14.5M)

Figure 3. Layout of the experiment

3.10.4. Treatments (Planting method) of the experiment

The treatment of the experiment were three selected planting methods which are as follows

T1- Modern SRI method

T2 - Basic SRI method

T3 – Conventional method

3.10.5. Seedling transplantation

Seedlings were uprooted from the seedbed and tray very carefully and transplanted in the experimental field. Transplantation was done on 15th January, 2021.

3.10.5.1. In case of Modern SRI

In case of modern SRI method, 15 days old seedlings having 2-3 leaves were uprooted with soil very carefully from seedling trays. These seedlings transplanted in the selected plots in rows and only one seedling was placed per hill. Row to row distance and plant to plant distance were maintained 25 cm and 25 cm.

3.10.5.2. In case of Basic SRI

In case of basic SRI method, 30 days old seedlings having 5-6 leaves raised in the seed bed were transplanted in the selected plots in rows and only one seedling was placed in per hill. Row to row distance and plant to plant distance were maintained 25 cm and 25 cm respectively.

3.10.5. 3. In case of Conventional method

For conventional method 30 days old seedling having 5-6 leaves raised in the seed bed were transplanted in the selected plots. 3 to 5 seedlings were placed in each hill and distance between row to row and plant to plant were maintained 20 cm and 15 cm respectively. This is the common practice in farmer's field.

		
A	B	C
Transplantation for modern SRI seedlings	Transplantation for basic	Transplantation for conventional method

Plate 3: Different Planting Methods in Main Field.

3.10.6. Intercultural operation

3.10.6.1. Weeding

As there is no standing water in SRI method, weeds infestation was more compare to conventional method. There are several advantages of turning the weeds into the soil by using weeder. Weeding was done at 10^{th} and 20^{th} day after transplanting.

3.10.6.2. Gap filling

Gap filling were done where necessary.

3.10.6.3. Irrigation

SRI method does not require continuous flooding. Irrigation was given to maintain soil moisture near saturation initially and water was let in when surface soil develops hairline cracks. The irrigation intervals, however, vary with soil texture. Soils having low water holding capacity require frequent irrigation. As the soil was not flooded, the roots of the paddy plants grow healthy, deeply in all directions. The root growth was extensive also due to the wide spacing. As the field was intermittently irrigated and dried, the micro-organisms grow well which make nutrients available to the plants. This method also helps in better growth and spread of roots. The field was irrigated again when the soil develops hair line cracks. Depending upon the soil and the environment conditions, the frequency of irrigation was decided. At the time of weeding operation to avoid shoulder pain, the field was irrigated to have 2-3 cm of water. After completion of weeding the water was let out of the field. After the panicle initiation stage until maturity, one inch of water was maintained in the field until maturity.

3.10.6.4. Drainage

There was little rain during experiment time. But drain was ready to drain out excess water. Irrigated water was drained after 70 per cent of the grains in the panicle get hardened.

3.10.6.5. Fertilizer Application

Fertilizer was applied according to BRRI recommendation.

3.10.6.6. Pesticide Application

Our experiment is to find out alternate approach for the management of major diseases of rice in Bangladesh. So no pesticide was applied. But when rice leaf roller attacked in our experiment, Morter 48 EC was sprayed in the experiment field only for one time.

3.10.7. Parameter Assess

In this study the parameters were assessed i) Disease incidence (%), ii) Disease severity (%), iii) Plant height (cm), iv) Number of Tiller per Hill, v) Number of Panicle per Hill, vi) Day of maturation (days) vii) Panicle length (cm), viii) Grain/ panicle, ix) Weight of 1000 seed (gm), x) Yield/plot (kg) and xi) Yield/ ha (Ton)

3.10.7. 1. Assessment of the disease incidence and severity in the field

Each of the plots was investigated for recording the incidence and severity of major diseases. In total ten (10) hills were selected to take data from each plot. Data were recorded on visual observation on the basis of typical symptoms. In case of blast of rice, infected leave, node, and panicle were considered to record the disease incidence (%) and disease severity (%) of this disease. In case of brown spot, infected leaf and grain were observed to measure the disease incidence (%) and disease severity (%) of the disease. In case of sheath blight, infected leaf sheath was investigated to calculate disease incidence (%) and severity (%) of the disease at tillering to panicle initiation stage. In case of bacterial leaf blight, leave (leaf blade and flag leaf) were observed to measure at early morning and evening to measure disease incidence (%) and disease severity (%) of this disease.

Disease Incidence:

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

$$\% \text{ disease incidence} = \frac{\text{No. of infected hill or hill parts}}{\text{No. of inspected hill}} \times 100$$

Disease Severity:

Disease severity (%) was recorded by following IRRI recommended grading scale (0-5 scale of Standard Evaluation System for Rice, 1980, first used by American Scientist Dr. Horsfall and Barrett 1945) which is given below:

$$\% \text{ disease severity} = \frac{\text{No. of infected leaves/hill}}{\text{Total no of leaves/ hill}} \times 100$$

Table 2. Disease Ratting Table

% Leaf Area Disease (% LAD)	Rating/Grading
0	0
0.1-5.0	1
5.1-12.0	2
12.1-25.0	3
25.1-50.0	4
>50.0	5

3.10.7.2. Plant height

Plant height was measured after harvesting with a measuring scale.

3.10.7.3. Duration

Duration was calculated from the period of seed sowing to harvesting.

3.10.7.4. Number of Tiller

Number of tiller of selected hill was counted. Then mean data was taken.

3.10.7.5. Number of Panicle (active tiller)

Number of panicle of selected hill was counted and then mean data was taken.

3.10.7.6. Harvesting and data collection on yield and yield contributing parameters

Each variety of rice was harvested at full ripening stage. Moreover ten hills of each unit plot were selected randomly and harvested separately. Then thirty hills (As each variety consists three replication) from each variety were mix together for each treatments. The data on the following yield contributing parameters were recorded: number of panicle/plant, total grain/panicle, infected leaf (leaves)/panicle, total yield/variety in each method.

3.10.7.7. Grain/ panicle

A total of 10 panicles were selected to count grain per panicle. Then mean data was recorded.

3.10.7.8. Weight of 1000 seeds

1000 seeds were counted from each treatment and measured. Then mean data was recorded.

3.10.7.9: Yield/Plot

Weight of harvested rice of each treatment was measured and mean weight was recorded.

3.10.7.10. Yield/ha

Yield per ha was measured from yield per plot.

3.11. Lab Experiment

3.11.1. Isolation of fungi from samples collected from the experimental field

Fungi were isolated from infected leaves following tissue planting method (Agrios, 2006). Diseased rice leaves were collected from the field and cut into small pieces along with healthy portion. Cut pieces were sterilized by the surface disinfectants, 0.1% mercuric chloride for 30 seconds. After sterilization, the cut pieces were washed three times with sterile water and then placed on sterile blotter paper to remove excess water. After removal of excess water, the cut pieces were placed on the sterile Potato Dextrose Agar (PDA) media plate. The plates were labeled and placed in the incubation chamber at 25° C for 7 days. After 7 days of incubation, the fungus grown on culture media. A portion of culture was taken on slide and observed under compound microscope and identified the pathogenic structures with the help of relevant literature (Mew and Gonzales, 2002). A portion of culture was taken by inoculating needle on another sterile PDA plate. A small portion from the sub-culture was inoculated to another PDA plate for pure culture. The fungus, thus purified, was kept in refrigerator for future use. All these operations were done aseptically in the laminar air flow chamber. The pure culture was examined at 10x and 40x magnification to identify the fungus.

3.11.2. Isolation of bacteria from samples collected from the experimental field

The diseased leaves were washed under running water. Then the young lesions with green healthy portion of diseased leaves were cut into small pieces. Surface sterilize were done by soaking them in 5 % sodium hypochlorite solution for 2-3 minutes and then washed them three times with sterile water. After surface sterilization, the cut pieces were kept in a test tube containing 3-4 ml of sterile water and kept for 30 minutes for bacterial streaming and getting stock. One ml of this stock solution was transferred with the help of sterile pipette into the second test tube containing 9 ml sterile water and shaken thoroughly resulting 10-1 dilution. Similarly final dilution was made up to 10 Drops of leaf extract are streaked onto the NA media plates and incubated at 27 ± 2 °C for 3 days. After incubation period, single colonies were grown over the NA plate. Then, it was kept in refrigerator at 4° C for future use. Identification of the pathogen causing bacterial leaf blight (BLB) disease of rice was determined by gram's staining.

3.11.3. Gram's staining

A small drop of sterile water was placed on a clean microscope slide. Part of a young yellow colony (18-24 hours old) was removed with a cold, sterile loop from the nutrient agar medium and the bacteria were smeared onto the slide that was very thin. The thinly spreaded bacterial film was air dried. Underside of the glass slide was heated by passing it four times through the film of a spirit lamp for fixing the bacteria on it. Then the slide was flooded with crystal violet solution for one minute. It was rinsed under running tap water for a few seconds and excess water was removed by air. Then it was flooded with lugol's iodine solution for 1 minute. Then it was decolonized with 95 % ethanol for 30 seconds and again rinsed with running tap water and air dried. Then it was counter stained with 0.5% safranine for 10 seconds. It was rinsed under running tap water for a few seconds and excess water was removed by air. Then the glass slide was examined at 40x and 100x magnification using oil immersion.

3.12. Statistical analysis

Collected data was input in excel sheet and data was analyzed using computer based software Statistix 10. Range test was performed through the coefficient of variance test for LSD value. Analyzed data were presented in both tabulated and graphical form.

RESULTS

This chapter comprises the description and demonstration of the results obtained from the field experiment and the lab experiments on pathogens of major rice diseases. The result is being described in the following headings and sub-headings.

4.1. Field experiment

4.1.1. Effect of selected planting methods on the percent disease incidence and severity of major rice diseases in BRRI dhan 28

In this study it was observed that the selected planting methods were gave significant effect on disease incidence and severity of major rice diseases viz. blast, brown spot, sheath blight and bacterial leaf blight in selected boro rice varieties. Disease incidence (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 28, the highest % disease incidence (27.78, 53.33, 29 and 35 respectively) was recorded in conventional planting method and the lowest % disease incidence (23.33, 23.33, 15.55 and 23.33 respectively) was found in Basic SRI method. The moderate % disease incidence (25.33, 28.33, 24.94, and 23.33 respectively) was recorded in modern SRI method which was higher than basic SRI method but lower to conventional method. Disease severity (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 28, the highest disease severity (28.39, 51.1, 24.97 and 33.27 respectively) was recorded in conventional planting method and the lowest % disease severity (14.73, 21.86, 17.6 and 27.00 respectively) was found in basic SRI method. The moderate % disease severity (18.85, 25.8, 22.24 and 16.42 respectively) was recorded in modern SRI method which was statistically non-significant with Basic SRI method but significant with conventional method.

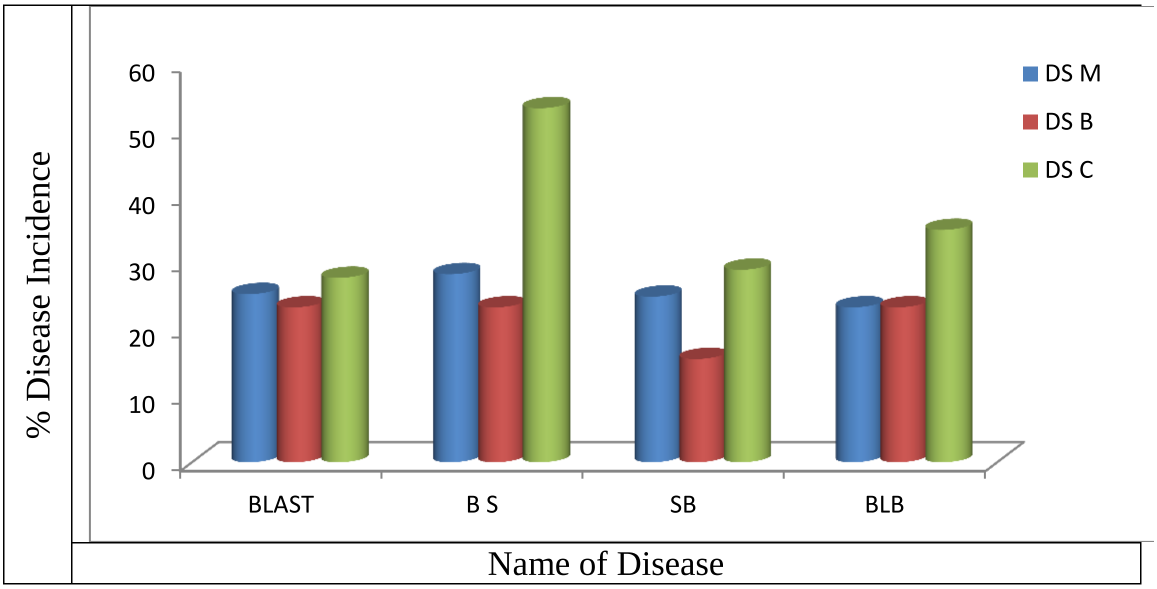


Figure 4. % Disease incidence of major rice diseases in BRRI dhan 28

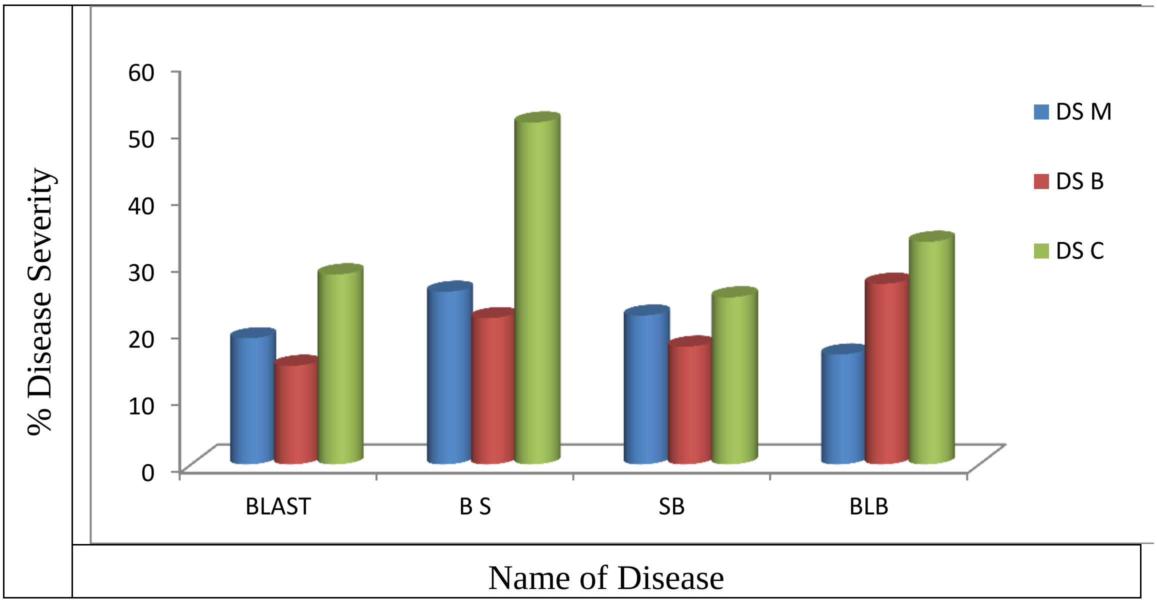


Figure 5. % Disease severity of major rice diseases in BRRI dhan 28

4.1.2. Effect of selected planting methods on the percent disease incidence and severity of major rice diseases in BRRI dhan 89

Disease incidence (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 89, the highest % disease incidence (26.67, 36.67, 33 and 21.33 respectively) was recorded in conventional planting method and the lowest % disease incidence (14.11, 16.67, 10.00 and 10.00 respectively) was found in Basic SRI method. In modern SRI method, the disease incidence (%) was found higher than basic SRI method and lower as compare to conventional method (22.22, 20.32, 17.78 and 19.00 respectively). Disease severity (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 89, the highest disease severity (18.6, 49.07, 18.09 and 27.16 respectively) was recorded in conventional planting method and the lowest % disease severity (5.88, 10.75, 12.32 and 11.44 respectively) was found in basic SRI method. The moderate % disease severity (10.86, 12.5, 10.99 and 11.28 respectively) was recorded in modern SRI method which was statistically non-significant with basic SRI method but significant with conventional method.

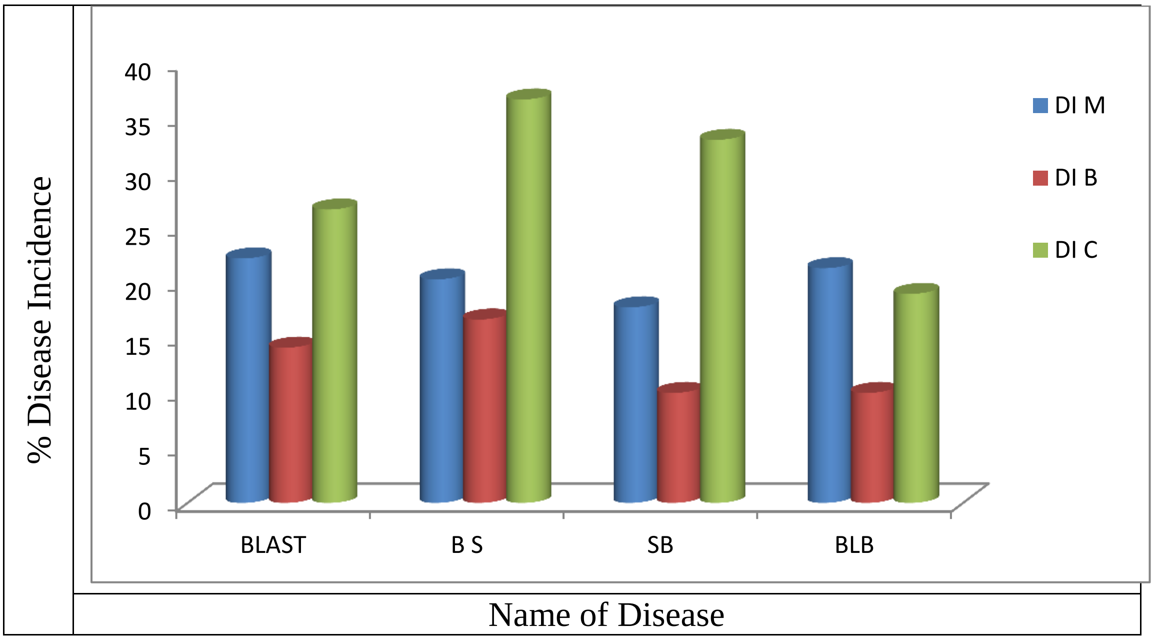


Figure 6. % Disease incidence of major rice diseases in BRRI dhan 89

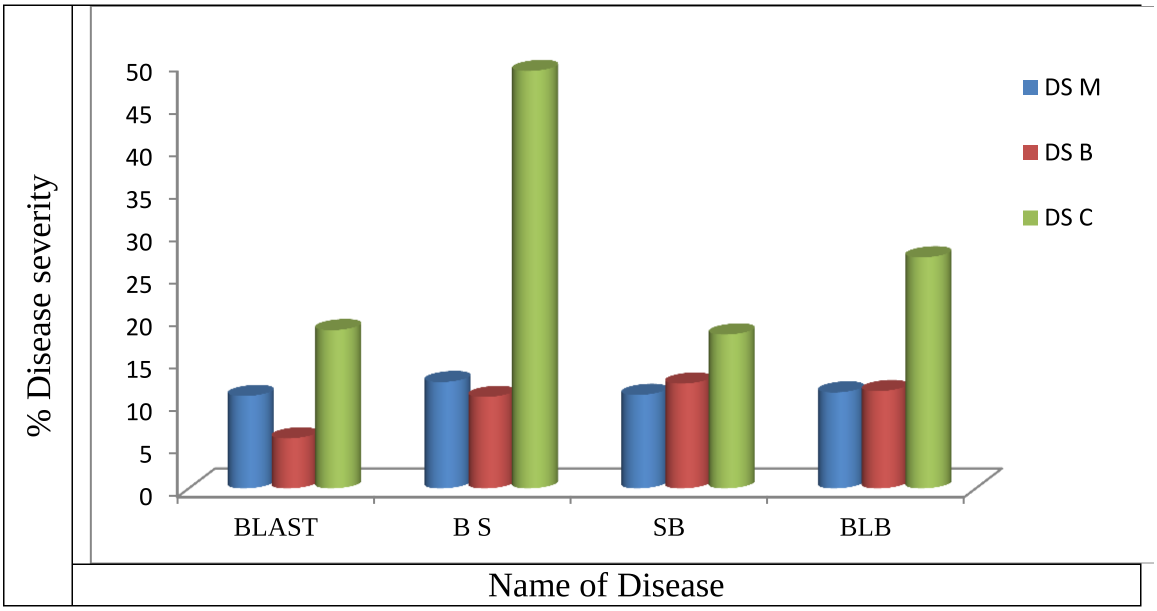


Figure 7. % Disease severity of major rice diseases in BRRI dhan 89

4.1.3. Effect of selected planting methods on the percent disease incidence and severity of major rice diseases in BRRI dhan 92

Disease incidence (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 92, the highest % disease incidence (25.55, 43.33, 38 and 23.33 respectively) was recorded in conventional planting method and the lowest % disease incidence (18.89, 22.22, 18.99 and 10.00 respectively) was found in Basic SRI method. In modern SRI method, the moderate % disease incidence (24.44, 23.33, 24.44 and 16.67 respectively) was recorded which was statistically non-significant with basic SRI method and significant with conventional method. Disease severity (%) of blast, brown spot, sheath blight and bacterial leaf blight in BRRI dhan 92, the highest % disease severity (22.34, 45.24, 26.39 and 34.71 respectively) was recorded in conventional planting method and the lowest % disease severity (16.57, 13.25, 14.76 and 13.65 respectively) was found in basic SRI method. The moderate % disease severity (20.45, 15.20, 14.86 and 15.00 respectively) was recorded in modern SRI method which was again statistically non-significant with basic SRI method and significant with conventional method.

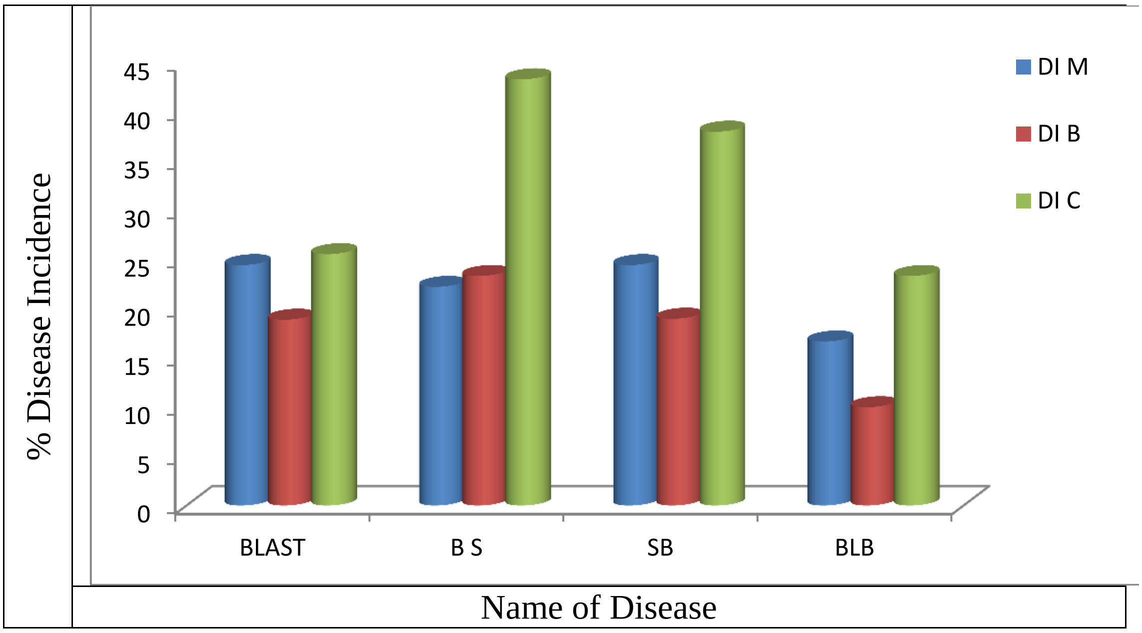


Figure 8. % Disease incidence of major rice diseases in BRRI dhan 92

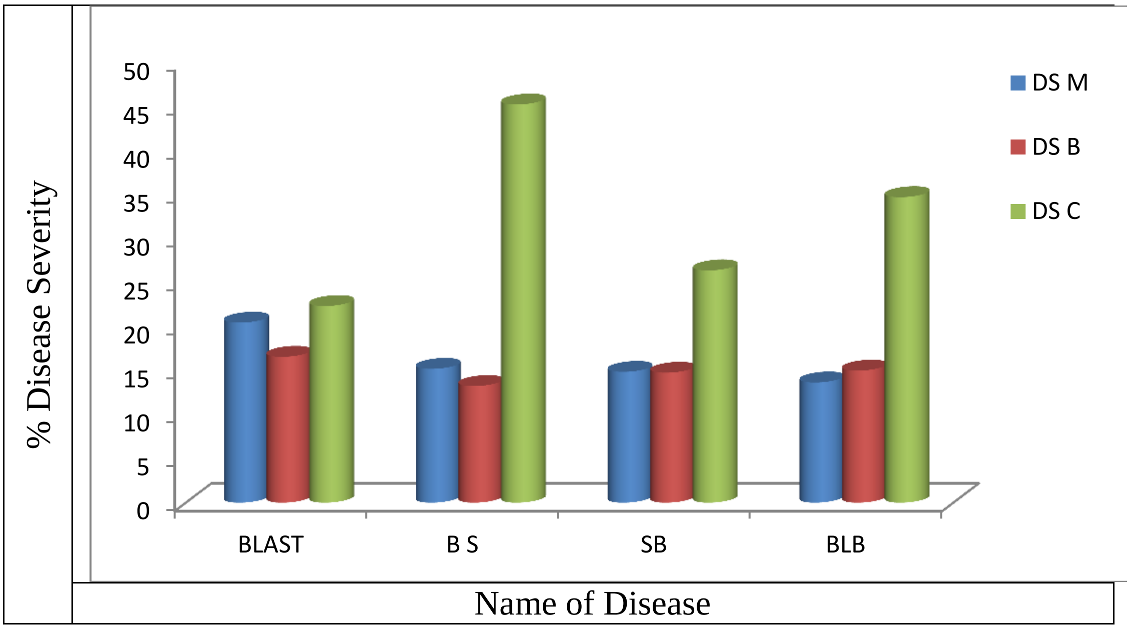


Figure 9. % Disease severity of major rice diseases in BRRI dhan 92

4.1.4. Effect of selected planting methods on the percent disease incidence and severity of major rice diseases in Purple rice

Disease incidence (%) of blast, brown spot, sheath blight and bacterial leaf blight in Purple rice, the highest % disease incidence (27.50, 30.00, 45.00 and 33.50 respectively) was recorded in conventional planting method and the lowest % disease incidence (20.00, 16.67, 18.99 and 26.67 respectively) was found in basic SRI method. In modern SRI method, the moderate % disease incidence (26.60, 23.33, 29.00 and 33.00 respectively) was recorded which was statistically non-significant with basic SRI method and significant with conventional method. Disease severity (%) of blast, brown spot, sheath blight and bacterial leaf blight in Purple rice, the highest % disease severity (30.52, 48.86, 29.67 and 38.24 respectively) was recorded in conventional planting method and the lowest % disease severity (16.61, 25.77, 18.44 and 24..40 respectively) was found in basic SRI method. The moderate % disease severity

(22.3, 22.61, 25.74 and 29.77 respectively) was recorded in modern SRI method which was again statistically non-significant with basic SRI method and significant with conventional method.

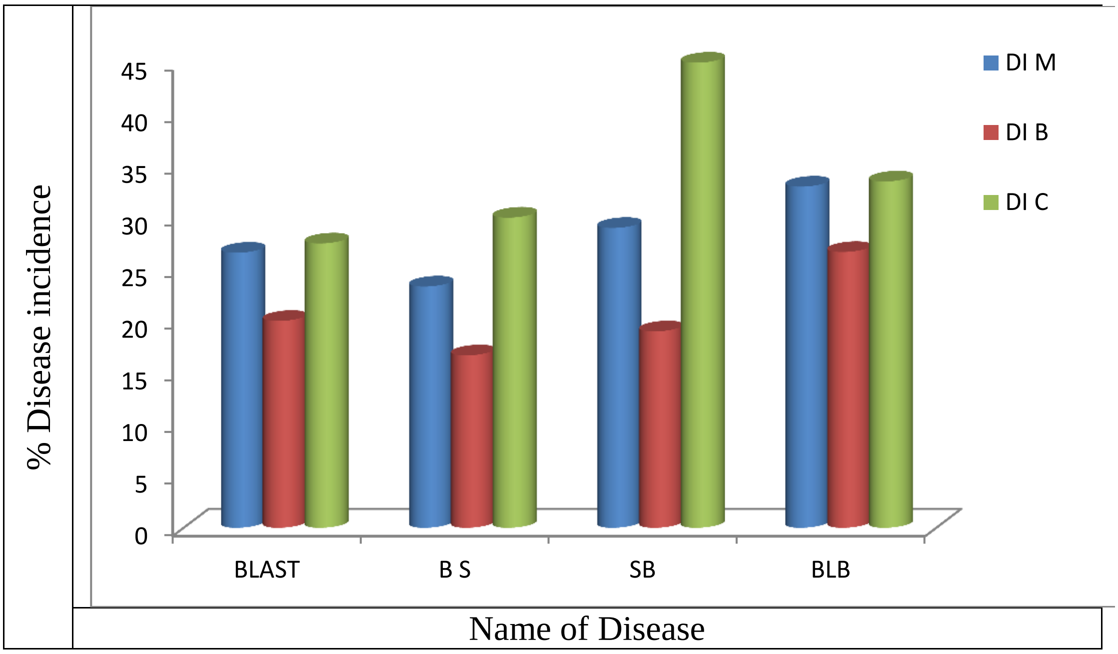


Figure 10. % Disease incidence of major rice diseases in Purple Rice

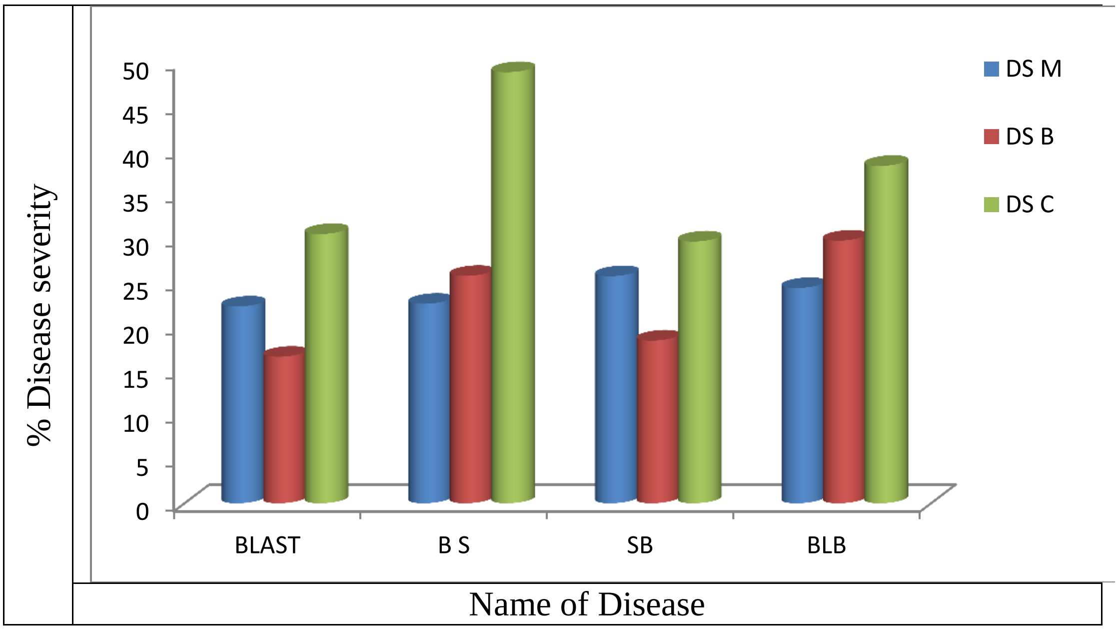


Figure 11. % Disease Severity of major rice diseases in Purple Rice

4.1.5. Effect of selected planting methods on growth and yield parameters

From the study, it was revealed that selected planting method interferes in growth and yield contributing parameters. In case of BRRI dhan 28, the highest plant height (100 cm) was measured in basic SRI method followed by modern SRI method (98 cm) and the lowest plant height (92 cm) was calculated in conventional method. In case of BRRI dhan 89, the highest plant height (106 cm) was recorded in modern SRI method and the lowest plant height (97) was found in conventional method which was statistically similar with basic SRI method (97 cm). In case of BRRI dhan 92, the highest plant height was found in conventional method (102 cm) and lowest plant height was recorded in modern SRI method (100 cm) which was statistically similar with basic SRI method (100 cm). In case of Purple rice, the highest plant height was discovered in modern SRI method (96 cm) and lowest plant height was recorded in conventional method (93 cm) which was statistically similar with basic SRI method (93 cm).

4.1.5.1. Number of tiller per hill

Number of tiller per hill is an important growth calculating parameter which was influenced by the selected planting methods. In case of BRRI dhan 28, highest number of tiller was recorded in basic SRI method (18) followed by modern SRI method (15) and lowest number of tiller per hill was recorded in conventional method (11). In case of BRRI dhan 89, the highest number of tiller was also recorded in basic SRI method (17) followed by modern SRI method (15) and lowest number of tiller per hill was recorded in conventional method (13). Basic SRI method dominated over other methods calculating number of tiller per hill in case of BRRI dhan 92 as well. We found 18 tiller per panicle in basic SRI method which was highest followed by modern SRI method (16) and lowest was in conventional method (14). In case of Purple rice, we got highest number of tiller per hill was recorded in basic SRI method (18) followed by modern SRI method (17) and lowest number of tiller was recorded in conventional method (14).

4.1.5.2. Number of panicle per hill

Number of panicle (active tiller) per hill is also an important character to measure yield which was directly influenced by selected planting methods. In case of BRRI dhan 28, highest number of panicle per hill was observed in basic SRI method (18) followed by modern SRI method (15) and lowest number of panicle per hill was seen in conventional method (11). In case of BRRI dhan 89, the highest number of panicle per hill was also recorded in basic SRI method (17) followed by modern SRI method (15) and lowest number of panicle per hill was recorded in conventional method (13). In case of BRRI dhan 92, we found 18 panicle per hill in basic SRI method which was highest followed by modern SRI method (16) and lowest panicle per hill was recorded in conventional method (14). In case of Purple rice, we got highest number of panicle per hill in basic SRI method (18) followed by modern SRI method (17) and lowest number of panicle per hill was recorded in conventional method (14).

4.1.5.3. Panicle length (cm)

Panicle length is one of the most important parameter which contribute yield greatly. This parameter was also affected by selected planting methods in this study. In case of BRRI dhan 28, highest panicle length was measured in basic SRI method (25 cm) and lowest panicle length was recorded in conventional method (23 cm) which was similar with modern SRI method (23 cm). In case of BRRI dhan 89, highest panicle length was recorded in basic SRI method (27 cm) followed by modern SRI method (25 cm) and minimum panicle length was recorded in conventional method (22 cm). We found maximum panicle length (26 cm) in basic SRI method in case of BRRI dhan 92 followed by modern SRI method (25 cm) and minimum panicle length was found in conventional method (22 cm). In case of Purple rice, best panicle length was recorded in basic SRI method (23cm) which was similar with modern SRI method (23cm) and lowest panicle length was seen in conventional method (22cm).

4.1.5.4. No. of Grain

Selected planting methods interfered in number of grain per panicle character. In case of BRRI dhan 28 the highest number of grain per panicle was found in basic SRI method (163) followed by modern SRI method (149) and lowest number of grain per panicle was seen in conventional method (118). In case of BRRI dhan 89, the highest number of grain per panicle was recorded in basic SRI method (167) followed by modern SRI method (160) and lowest number of grain was recorded in conventional method (153). In case of BRRI dhan 92, the highest number of grain per panicle was seen in basic SRI method (163) followed by modern SRI method (141) and lowest number of grain per panicle was recorded in conventional method (118). In case of Purple rice, the highest number of grain per panicle was observed in basic SRI method (183) followed by modern SRI method (152) and lowest number of grain per panicle was seen in conventional method (120).

4.1.5.5. Weight of 1000 seeds (gm)

Planting methods also interfere in the weight of 1000 seeds which is an important yield calculating parameter. In case of BRRI dhan 28, the highest weight of 1000seeds was recorded in basic SRI method (21.63gm) followed by modern SRI method (21.62 gm) and lowest weight of 1000seeds was seen in conventional method (21.60 gm). In case of BRRI dhan 89, the highest weight of 1000 seeds was calculated in basic SRI method (22.46 gm) followed by modern SRI method (22.36 gm) and lowest weight of 1000 seeds was calculated in conventional method (22 gm). In case of BRRI dhan 92, the highest weight of 1000 seeds was recorded in modern SRI method (22.70 gm) followed by basic SRI method (22.68 gm) and lowest weight of 1000 seeds was recorded in conventional method (22.28 gm). In case of purple rice, the highest weight of 1000 seeds was discovered in basic SRI method (20.29 gm) followed by modern SRI method (20.18 gm) and lowest weight of 1000 seeds was found in conventional method (19.88 gm).

4.1.5.6. Yield per Plot (kg)

Selected planting method interfered yield per plot (3X 2 sq m) greatly. In case of BRRI dhan 28, the highest weight per plot was calculated in basic SRI method (4.58 kg) followed by modern SRI method (3.84 kg) and lowest weight was found in conventional method (3.31 kg). Highest weight per plot also found in basic SRI method (4.90 kg) in BRRI dhan 89 followed by modern SRI method (4.47kg) and lowest weight was recorded in conventional method (4.04 kg).In case of BRRI dhan 92, the highest weight per plot was calculated in basic SRI method (4.94 kg) followed by modern SRI method (4.13 kg) and lowest weight was found in conventional method (4.05 kg). In case of Purple rice, the highest weight per plot was found in basic SRI method (3.53 kg) followed by modern SRI method (3.40 kg) and lowest weight was seen in conventional method (2.80 kg).

Except weight of 1000 seeds, basic SRI method dominates over other methods and in conventional method those data was lowest. Weight of 1000 seeds was almost same in all planting methods.

We found maximum plant height (103.2 cm) in modern SRI method for BRRI Rice 89. All other growth and yield parameter was maximum in basic SRI method and minimum in conventional method.

We also found maximum plant height (102.1 cm) in conventional method for BRRI Rice 92 but it did not make any contribution in yield. Rest parameters were higher in basic SRI method.

Maximum plant height (96.4 cm) was observed in modern SRI method in purple rice followed by basic SRI and conventional method (93.8 cm and 93.5 cm respectively). But basic SRI method dominated in other yield contributing character over modern SRI and conventional method. There was a significant difference between basic SRI and conventional method in grain per panicle parameter. In basic SRI, 183 grain was produced in a panicle on an average whereas only 123 grain was produced in each panicle in conventional method.

Table 3: Yield and Yield contributing parameters of Selected Varieties

Variety	Method	Plant height (cm)	Tiller No.	Panicle No.	Panicle length (cm)	Grain/ Panicle	1000 seeds weight (cm)	Yield/ Plot (kg)
BRRI dhan 28	Modern SRI	98.2	15	15	22.8	148.5	21.62	3.84
	Basic SRI	100.2	18.1	18.1	24.8	162.6	21.63	4.58
	Conventional	92.8	11.4	11.4	22.7	118.3	21.60	3.31
BRRI dhan 89	Modern SRI	103.2	15.2	15.2	24.6	160.2	22.36	4.47
	Basic SRI	97.6	17.6	17.6	26.9	166.8	22.46	4.90
	Conventional	97.3	11.4	11.4	22.4	152.7	22	4.05
BRRI dhan 92	Modern SRI	100.6	16.2	16.2	24.8	141.4	22.7	4.13
	Basic SRI	100.7	18.3	18.3	25.9	163.5	22.68	4.94
	Conventional	102.1	14.3	14.3	24	118.3	22.28	4.05
Purple Rice	Modern SRI	96.4	17.3	17.3	22.2	152.3	20.18	3.40
	Basic SRI	93.8	18.2	18.2	23.2	182.6	20.29	3.53
	Conventional	93.5	14.1	14.1	21.6	120.5	19.88	2.80
	CV (%)	3.87	8.66	8.66	5.66	16.01	9.04	4.0

4.2: Isolation of Pathogens

4.2.1: Isolation and Cultural characterization of fungal pathogens

All fungal pathogens were isolated in Potato Sucrose Agar (PSA) media and purified. In the study, the pathogen was re-isolated and grown in PSA media to increase sporulation. At initial stage, the rice blast pathogen, *Magnaporthe oryzae* was produced white mycelial growth and later on it turned into brown to black colour (PLATE 4A).

For Sporulation study, the mycelial growth was recorded at 7, 14 and 21 days after inoculation. Sporulation was found after 25-35 days of culture maintenance. Conidiophores were single, simple, non-branched and septed.

Conidia were pyriform (pear-shaped with pointed tip), narrowed toward tip, rounded at the base, 2 septate, hyaline in color with a distinct basal hilum.

At initial stage, the brown spot pathogen, *Bipolaris oryzae* was produced dark brown mycelial growth and later on it turned into blackish. For sporulation study, the mycelial growth was recorded at 7, 10 and 15 days after inoculation. Sporulation was found after 10-15 days of culture maintenance. Conidiophores; Brown, short, erect, simple or single, bear 1-6 conidia arranged at short distance in the upper half. Conidia; elliptical or ellipsoid, dark brown to black, smooth, mostly straight or slightly curved, thick walled, broadest in the middle, ends rounded, 3-12 transversely septed (plate 4B).

For confirmation of the causative agent pathogen was isolated. For isolation of causal organism of sheath blight, *Rhizictonia solani*, mature sclerotia were collected from infected plant and transfer on PDA media. After the mycelial growth, the cultural characteristics were studied and found white cottony thread like mycelia that formed on PDA media, and mycelia was become aggregated to form the sclerotia after 10-15 days. Sclerotia were cottony in color in the young stage but dark brown to black while mature.

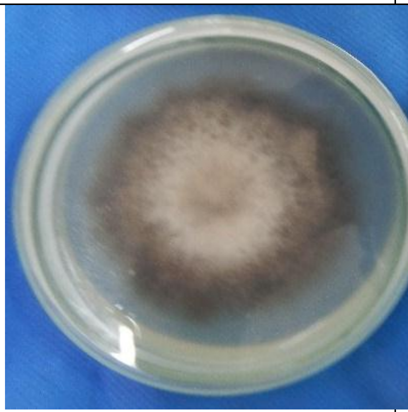
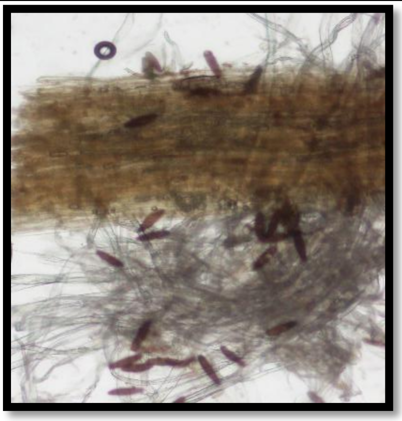
Disease symptom	Pure culture	Morphological structures
 *Magnaporthe oryzae*		
 *Bipolaris oryzae*		
 *Rhizictonia solani*		

Plate 4. Morphological and cultural characterization of identified fungal pathogens (*Magnaporthe oryzae, Bipolaris oryzae and Rhizictonia solani*)

4.2.2 Isolation of *Xanthomonas oryzae pv. oryzae*

One ml of the stock solution was transferred with the help of sterile pipette into the new test tube containing 9 ml sterile water and shaken thoroughly resulting 10^{-1} dilution. Drops of diluted solution were streaked onto the NA media plates and incubated at 28 ± 2 °C for 2 days. After incubation period, single colonies were grown over the NA plate. Then, Identification of the pathogen causing bacterial leaf blight (BLB) disease of rice was determined by gram's staining test. From the staining test, it was given gram positive. So, it was confirmed that BLB caused by bacterium, *Xanthomonas oryzae.*

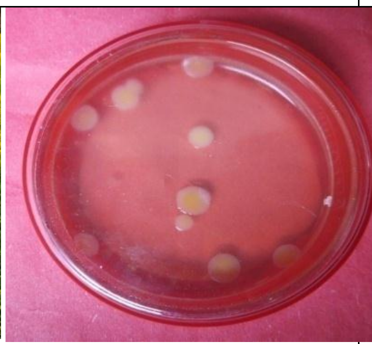
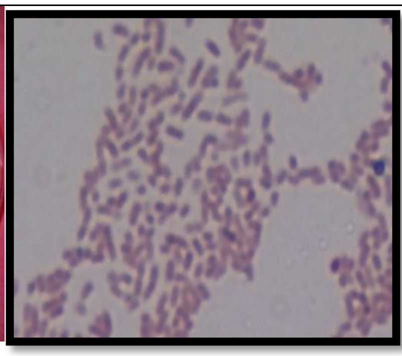
Disease symptom	**Pure culture**	**Morphological structures**
 ***Xanthomonas oryzae* pv. *oryzae***		

Plate 5. Morphological and cultural characterization of identified and bacterium (*Xanthomonas oryzae*)

DISCUSSION

Bangladesh has an agrarian (agrobased) economy in which rice is the dominant crop. Rice is the staple food, reflected in the high per capita rice consumption in this country. The nutritional demand of the majority of people is met with rice (Shelley et.al. 2016). Rice (*Oryza sativa* L.) is one of the most important cereals of the world and is consumed by 50% of the world population (Luo *et al.,* 1998). It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country. It is consumed as a staple food in most of the Asian countries including Bangladesh (Yaduraju, 2013). The main constrains of rice production in Bangladesh is some major diseases. From the last decade some major diseases like blast, brown spot, false smut, sheath blight and bacterial leaf blight are common. Among these major diseases blast and bacterial leaf blight was showed the severe outbreak in boro season. These caused great yield losses and great threat for our existing food security and national economy (Jabeen *et al.,* 2012).

For the importance of rice production and consumption along with wide distribution and destructiveness across the world, blast (caused by *Magnaporthe oryzae*) has been extensively studied. The extent of damage caused depends on environmental factors, but worldwide it is one of the most devastating cereal diseases, resulting in losses of 10–30% of the global yield of rice. (Buddy, 2016). Rice blast is a serious fungal disease that is threatening global food security (Shammy, 2018). Brown spot caused by the fungus, *(Bipolaris oryzae*) is one of the most prevalent rice diseases in the world where rice is grown (Groth and Hollier, 2016). This disease was responsible for Bengal famine in 1942-43. Sheath blight is a soilborne disease caused by the fungus (*Rhizoctonia solani)* (Sai Sree Uppala and Xin-Gen Zhou**,** Texas A & M Agri Life Research Center, Beaumont, TX, 2019). Sheath blight occurs in areas with high temperature (28−32°C), high levels of nitrogen fertilizer, and relative humidity of crop canopy from 85−100% (IRRI Rice knowledge Bank). This disease causes significant grain yield and quality losses. Yield losses of up to 50% have been reported under most conducive environments. Bacterial leaf blight (BLB) is an important bacterial disease of rice caused by bacterium, *Xanthomonas oryzae* pv. *oryzae*. It can occur in both tropical and temperate environments, particularly in irrigated and rain fed lowland areas. In general, the disease favors temperatures at 25−34°C, with relative humidity above 70% (Nasir, et. al., 2018). It is reported that due to this disease, yield loss up to 20-50%. In severe condition, yield loss up to 80%. On seedlings, infected leaves turn grayish green and roll up. As the disease progresses, the leaves turn yellow to straw-colored and wilt, leading whole seedlings to dry up and die. On older plants, lesions usually develop as water-soaked to yellow-orange stripes on leaf blades or leaf tips or on mechanically injured parts of leaves. Lesions have a wavy margin and progress toward the leaf base. On young lesions, bacterial ooze resembling a milky dew drop can be observed early in the morning. The bacterial ooze later on dries up and becomes small yellowish beads underneath

the leaf. So it is needed to use environmentally safe approaches to overcome the loss of grain yield in rice due to this disease. (Yeamin, S. et. al. 2016.)

Bangladesh is an agricultural country and rice is staple food here. Maximum people eat rice each and every day. About 80 percent people are directly engaged with the production of rice. Moreover rice grows here three times per year. Now days, rice production has to face lots of agronomic and environmental challenges related to the intensification of crop production. Reduction in rice yields , soil depletion, ground water use, scarcity of surface water, water and air pollution increasing as well as climate change are some of the biggest issues. Due to climate change effect, new diseases are reported and some minor diseases are become major, these factors are hampered rice production in various ways. Farmers of different region of the country are unable to protect their rice from diseases due to lack of suitable technologies against the changing agricultural environment. Farmers use pesticide to control diseases but pest resistance and resurgence occurred. Moreover, pesticides are costly and create environmental problems as well as health hazard. System of Rice Intensification (SRI) method requires less water. Initially soil moisture maintains here near saturation level and irrigation water is allowed in when surface soil develops hairline cracks. Irrigation intervals depend on soil texture. Soils having low water holding capacity requires frequent irrigation. Use of lots of organic matter improves the water holding capacity of soil. Due to not flooded, healthy roots develop in all directions. Due to the wide spacing, root growth is extensively. As the field is intermittently irrigated and dried, the micro organisms grow well which make nutrients available to the plants. This method also helps in better growth and spread of roots.

Technological change in agriculture drives much of the structural transformation that defines the process of economic development in low-income agrarian nations (Gollin et al. 2002; Emerick et al. 2016; McArthur and McCord 2017; Mellor 2017). We use new technologies to boost up productivity and well-being for individual farmers and the farming population. We also use new technology to reduce production cost to increase cost benefit ratio.

These transitions in agriculture are based upon a growing appreciation of agro-ecological principles that re-embed agricultural crops within the ecosystems in which they have emerged, inter dependent with the myriad of flora and fauna that have co-evolved with plants over hundreds of millions of years (Uphoff, 2002; Uphoff et. al., 2006). Agricultural practice would be more compatible by practicing SRI which have the effect of making agricultural practice more compatible with conservation of natural resources and biodiversity as well as helping agriculturalists to understand how their practices are intimately and intrinsically part of what we refer to broadly as 'nature.'

In SRI, there is no standing water and as a result of this weed infestation is very common here. In SRI, alternate wetting and drying (AWD) influences excessive weed growth. Timely unchecked weed cause immense loss in yield. There are lots of benefits of using weeder to turn into the soil. Timely incorporation of weeds by using weeder between rows also helps to supply nutrients to the crop as green manures. Weeding is done at least two times in the rice field in conventional method. So, production cost may not be hampered.

SRI is a set of modified practices for managing rice plants and the soil, water and nutrients. We can get more production by less external inputs in SRI. Moreover, SRI is environment-friendly. SRI method can be adapted to any type of rice variety (local variety, HYV, hybrid variety). SRI is an innovation that is depends on knowledge, but not depending on external inputs and materials. SRI is a concept consisting of the following practices (menu); Transplant young seedlings, Transplant single seedling at a hill with utmost care for seed roots, Transplant at wider spacing, Less use of chemicals (fertilizer, pesticide, insecticide, herbicide), Less water use by applying wet-dry cycle of soil moisture. The SRI concept is now a days applying to other crops (wheat, sugarcane, millet).

Before considering any technology broadly for government sector, we have to consider three things clearly- 1. it is financially possible, 2. socially acceptable and 3. environmental friendly.

SRI can fulfill all these demand. It does not need much cost than conventional method though it is seems one more labor is required here. But as we can get more and more output, one more labor cost is not a big matter to discuss. SRI is not method that may create any conflict in the society. Basically it's a method of management of major rice disease by alternate method along with production enhancement. So, this method should be accepted by the rice producers. Finally we can say, SRI is a environmental friendly technology. As minimum disease incidence and severity occurred here compare to conventional method, less pesticide is required here to spray. That's why SRI is a environmental friendly technology.

From this study, it was observed that the lowest disease incidence DI and severity of major diseases viz. blast, brown spot, sheath blight and bacterial leaf blight was recorded in basic SRI method as compare to conventional and modern SRI method in selected 4 varieties used in this study. Farmers have to pay a lot of money just to manage these diseases, as these diseases are very common and some time more devastating in different part of the country. It was observed that these diseases are appeared in all season in different region of Bangladesh. Usually farmers are managed these diseases by chemical application but it is related with high cost and environment hazard ultimately to the human health hazard as well as damaging the ecology. DI and severity interpreted not only the production but also the quality of grain yield. The expected output of the present study was to minimize the DI and severity of the major rice diseases through adoption of SRI method. From the present study it was also found that yield and yield attributes were got higher compare to conventional method. SRI methods only enabled farmers and irrigation managers to reduce the water requirements of irrigated rice by 25-50 %, this is one of the important point for government, international agencies and environmental organizations to promote the adoption of SRI. Water is becoming more and more limited to meet agricultural production needs. Optimum amount of water ensure maximum tillering and more water hamper root growth system as well as tiller growth. It is an important characteristic of SRI method. In this study, water was irrigated in wet and dry alternative cycle of soil moisture and got maximum number of tiller than conventional method in all cultivated rice varieties. From the study it was revealed that in case of BRRI dhan 28, in total 18 tiller per hill was recorded in basic SRI method and only 11 tiller was found in conventional method. Same results were found in BRRI dhan 89, BRRI dhan 92 and Purple rice. Moreover, the scarcity of irrigation water sometime make problem to the farmer, as surface water is not available in all parts of the country, farmers has to use more ground water by using different pumps to pull water and as a result heavy metals comes out and pollutes rice cultivated land. Pollution of surface water is also one of the important reasons for using ground water. SRI method also raises production and lower costs, thereby making rice production more profitable and attractive. Moreover, less seeding is needed in SRI method because only single seedling is needed per hill that save seeds and seedbed preparation cost as well (SRI Book Part 1).

Therefore, from the study it could be concluded that basic SRI is the best planting method for rice cultivation to reduce disease incidence (DI) and disease severity (DS) of rice , enhance production and to reduce use of water.

SUMMERY AND CONCLUSION

The present study was carried out under field condition at central farm of Sher-e-Bangla Agricultural University, Dhaka as well as molecular biology and virology laboratory under the department of plant pathology during 2020-21 to ascertain the adoption to climate change and effect of system of rice intensification (SRI) in boro rice production. In total four varieties were used in this study under three different treatments (planting method). The field experiment was carried out with randomized complete block design (RCBD) with three replications. All the tested varieties were remaining in natural condition without treating with chemicals.

The experiment was aim to adopt the climate change effect and to find an alternate approach for the management of major rice diseases in Bangladesh. Rice seedlings were grown in seed bed for conventional planting method and basic SRI method. Seedlings were also grown in plastic tray for modern SRI planting method. Thirty days old seedlings were transplanted in conventional method and basic SRI method with spacing 15 cm X 20 cm and 25 cm X 25 cm, respectively. Fifteen days old seedlings grown in plastic tray were transplanted in selected plots having 25cm X 25 cm spacing. For molecular study, disease infected leaves were collected and cultured in molecular laboratory for identifying pathogen. Gram staining protocol was followed to identify bacteria.

Among all methods (planting methods), all four disease (blast, brown spot, sheath blight and bacterial leaf blight) incidence and severity were lowest in basic SRI method for BRRI dhan 28 which was followed by modern SRI and conventional method. In BRRI dhan 89, highest disease incidence and severity were recorded in conventional method and lowest disease incidence and severity were found in basic SRI method which was followed by modern SRI method. In case of BRRI dhan 92, minimum disease incidence and severity for four diseases were obtained in basic SRI method which was followed by modern SRI method and maximum disease incidence and severity were got in conventional method except bacterial leaf blight. In case of purple rice, highest disease incidence and severity were found in conventional method and lowest disease incidence and severity were recorded in basic SRI method followed by modern SRI method.

Yield and yield contributing parameters also studied in this experiment and it was found that planting method also influenced yield and different yield contributing parameters. Data of basic SRI always dominated over other planting method (modern SRI and conventional) in case of BRRI dhan 28. In case of BRRI dhan 89, plant height was highest in modern SRI method but other parameters were highest in basic SRI method compare with other two planting methods. In case BRRI dhan 92, plant height was highest in conventional method but rest data were best in basic SRI method compare with two other methods. In case of purple rice, plant height was best in modern SRI method but other yield and yield contributing characteristics were best in basic SRI method.

From this study, it can be concluded that basic SRI is the best planting method for the management of major rice diseases in Bangladesh along with adoption to climate change. Although it was the first study here in Bangladesh in plain land, SRI method was used as a alternative for management the major rice diseases, which correlated with research that took place in Madagascar.

REFERENCE

Agricultural Statistics , (2019). Department of Agricultural Extension.

Akhter, A. (2019). MS Thesis. Growth and Sporulation of Magnaporthe oryzae causing Blast of Rice in Selective culture Media and its in vitro Management, Sher-e-Bangla Agricultural University. Dhaka.

Akhtar, M. A., Abbasi, F. M., Ahmad, H., Shahzad, M., Shah, M. A. and Shah, A. H. (2011). Evaluation of rice germplasm against Xanthomonas oryzae causing bacterial leaf blight. *Pakistan Journal of Botan*y: 43(6): 3021-3023.

Alam, M. M., Buresh, R. J., Ladha, J. K., Khan, A. H. (2004). Site specific Nutrient Management for Rice. BRRI, Gazipur, Bangladesh.

Ali, A., Teli, M. A., Bhat, G. N., Parry, G. A and Wani, S. A. (2009). Characterization status of rice blast (Magnaporthe grisea), cultivar reaction and races of its causal fungus in temperate Agro-ecosystem of Kashmir, India. *SAARC Journal of Agriculture*. 7(2): 25-37.

Ali, M. A., Rahman, M. M., Latif, M. A., Hossain, M., Sharma, N. R., Akter, S., Mia, T. A., and Nahar, M. A. (2003). Survey of rice sheath disease caused by different *Rhizoctonia* sp. in Bangladesh. Paper presented in the stakeholder workshop on Rice sheath blight disease complex, 3 December 2003. BRRI, Gazipur.

Ansari, T. H., Ahmed, M., Akter, S., Mian, M., S., Latif, M. A., and Tomita, M., (2019). Estimation of Rice Yield Loss Using a Simple Linear Regression Model for Bacterial Blight Disease. *Bangladesh Rice Journal*. 23 (1): 73-79, 2019, doi.org/10.3329/brj.v23i1.460831

Arthur, W.B., (2009). The Nature of Technology, New York: Free Press.

Azzam, O. and Chancellor, T. C. B. (1999). The biology, epidemiology and management of tungro disease in Asia. Plant Dis. Research highlights, Directorate of Rice Research, Hyderabad, India. pp. 56-64.

Baranwal, M. K., Kotasthane, A., Magculia, N., Mukherjee, P. K., Savary, S., Sharma, A. K., Singh, H. B., Singh, U. S., Sparks, A. H., Variar, M. and

Zaidi, N. (2013). A review on crop losses, epidemiology and disease management of rice brown spot to identify research priorities and knowledge gaps. *European Journal of Plant Pathology*. 136: 443-457.

Basso, A., Onasanya, A., Issaka S., Sido, A. Y. and Haougui, A. (2011). Bacterial leaf blight of rice in Niger: Pathological diversity of isolates collected on irrigated lands. J. Appl. Biosci. 38: 2551-2563.

BBS, (2013-2014). Statistical Pocketbook of Bangladesh. Agriculture Wing, Government of the People's Republic of Bangladesh. pp. 2.

Bipasha Roy, Basabdatta Das, Manoj Prasad and Tapas Kumar Ghose (2014). Genetic Diversity of Bacterial Leaf Blight Disease in a Set of Rice Landraces of West Bengal. *International Journal of Genetic Engineering and Biotechnology*. ISSN 0974 3073 Volume 5, Number 2 (2014), pp. 85-92.

Bonman, J. M., Estrada, B. A. and Banding, J. M. (1989). Leaf and neck blast resistance in tropical lowland rice cultivars. *Plant Disease*. 73:388-390.

BRRI, (2004). Adhunic Dhaner Chas (Bengali Bulletin), Bangladesh Rice Research Institute, Gazipur. pp. 26.

Cabauatan, P. Q., Cabunagan, R. C. and Koganezawa, H. (1995). Biological variants of rice tungro viruses in the Philippines. *Phytopathology*. 85 (1): 77-81.

Cabunagan, R. C., Castilla, N., Coloquio, E. L., Tiongco, E.R., Fernandez, J. Du. M. J., Zaragosa, B., Hozak, R. R., Savary, S. and Azzam, O. (2001). Synchrony of planting and proportions of susceptible varieties affect rice tungro disease epidemics in the Philippines. *Crop Prot*.. 20: 499-510.

Christopher, B. B., Islam, A., Malek , A., Pakrashi, D. & Ruthbah, U., (2020).Experimental Evidence on Adoption and Impact of the System of Rice Intensification, SRI Impact on Rice Quality & Yield.

Dai, S. and Beachy, R. N. (2009). Genetic engineering of rice to resist rice tungro disease. In Vitro Cell Dev. *Biol. Plant*, 45: 517-524.

Dallagnol, L. J., Rodrigues, F. A. and Da Matta, F.M. (2011). Brown spot of rice as affected by phyton irradiance and temperature. *J. Phytopathol*. 159: 630- 634.

Dasgupta, I., Hull, R., Eastop, S., Poggi-pollini, C., Blakebrough, M., Boulton, M. I. and Davies, J.W. (1992). Rice tungro bacilliform virus DNA independently infects rice after Agrobacterium-mediated transfer. *J Gen Virol* 72:1215–1221.

Depatment of Agricultural Extension DAE, (2010). Government of the People's Republic of Bangladesh. Dhaka.

Don Groth and Clayton Hollier, Brown Spot of Rice, Louisiana Plant Pathology. Eizenga, G. C., Lee, F. N., and Rutger, J. N. 2002. Screening *Oryza* species plants for rice sheath blight resistance. Plant Dis. 86:808-812.Emerick, K., De Janvry, A., Sadoulet, E. and Dar, M. (2016). Technological Innovations, Downside Risk and the Modernization of Agriculture. *American Economic Review*, 106 (6):1537-1561.

Eizenga, G. C., Lee, F. N., and Rutger, J. N. 2002. Screening *Oryza* species plants for rice sheath blight resistance. *Plant Dis*. 86:808-812.

Ezuka, A. and Kaku, H. (2000). A Historical Review of Bacterial Blight of rice. National Institute of Agrobiological Resources Bulletin, Japan. P. 207.

Expert System of Paddy. TANU Agro Portal. Guideline on SRI Practice for Tropical Countries, (2012). Japan Association of the System of Rice Intensification.

Fahad, S., Adnan, M., Noor, M., Arif, M., Mukhtar Alam, M., Khan, I. A., Ullah, H., Wahid, F., Mian, I. A., Jamal, Y., Abdul Basir, A., Hassan, S., Saud, S., Amanullah, Riaz, M., Chao Wu, C., Khan, M. A. and Wang, D.(2019). Major Constrains for Global Rice Production. Advances in Rice Research for Abiotic Stress Tolerance (pp.1-22) DOI: 10.1016/B978-0-12-814332-2.00001-0

Groth, D. E., and Bond, J. A. 2007. Effects of cultivars and fungicides on Rice Sheath Blight, yield, and quality. *Plant Dis*. 91:1647-1650.

Gujja, B. and Thiyagarajan, T.M. (2009) *New Hope for Indian Food Security? The System of Rice Intensification*, Gate keeper 143, International Institute for Environment and Development, London.

Guideline on SRI Practice for Tropical Countries, (2012). Japan Association of the System of Rice Intensification

Herdt, R.W. (1991). Research priorities for biotechnology. In: Khush GS, Toennissen GH (eds) Rice biotechnology. CAB International, Wallingford, UK. pp. 19–54. Hibino, H. (1996). Biology and epidemiology of rice viruses. Annual Review of Phytopathology, 34: 249-274.

Hibino, H. and Cabauatan, P.Q. (1987). Infectivity neutralization of rice tungro associated viruses acquired by vector leafhoppers. *Phytopatholog*y, 77:473–476.

Igawa, T., Tokal, T., Kudo, T., Yamagushi, I. and Kimura, M. (2005). A wheat xylanase inhibitor gene, Xip-I, but not Taxi-I, is significantly induced by biotic and abiotic signals that trigger plant defense. *Bioscience, Biotechnology and Biochemistry. 69: 1058 – 1063.*

IRRI, (1980). Standard Evaluation System for Rice. International Rice Testing Program. Losbanos, Philippines. pp. 7- 20.

IRRI Rice Knowledge Bank.

Jha, A. C., Rai, B. and Jha, M. M. (2004). Response of direct seeded and transplanted rice varieties on the development of brown spot disease. *Annals Biol*. 20: 195-197.

Jia, Y., Correa-Victoria, F., McClung, A., Zhu, L., Liu, G., Wamishe, Y., Xie, J., Marchetti, M. A., Pinson, S. R. M., Rutger, J. N., and Correll, J. C., (2007). Rapid determination of rice cultivar responses to the sheath blight pathogen *Rhizoctonia solani* using a micro-chamber screening method. *Plant Dis*. 91:485-48

Jones, M. C., Gough, K., Dasgupta, I., Rao, B. L., Cliffe, J., Qu, R., Shen, P., Kaniewska, M., Blakebrough, M., Davies, J. W., Beachy, R.N. and Hull,

R. (1991). Rice tungro disease is caused by an RNA and a DNA virus. *J Gen Virol*. 72: 757–761.

Kadai, (2010). Diversity and pathogenicity of the rice brown spot pathogen, Bipolaris oryzae (Breda de Haan) shoem. in Bangladesh assessed by genetic fingerprint analysis. *Bangladesh. J. Bot*. 38 : 195-200.

Kamal, M. M. and Mia, M. A. T. (2009). Diversity and pathogenicity of the rice brown spot pathogen, Bipolaris oryzae (Bredade Haan) shoem. in Bangladesh assessed by genetic fingerprint analysis. *Bangladesh J. Bot* . 38: 195- 200.

Kato, H. (2001). Rice blast disease. Pesticide Outlook February. pp: 23-25.

Khalili, E., Sadravi, M., Naeimi, S. and Khosravi, V. (2012). Biological control of rice brown spot with native isolates of three Trichoderma species. *Braz. J. Microbiol*. 43 : 297-305.

Khatun, M. T., Nessa, B., Salam, M. U. and Kabir, M. S. (2021). Strategy for Rice Disease Management in Bangladesh. *Bangladesh Rice J*. 25 (1):23-36.

Kulkarni, S., Ramakrishnan, K. and Hegde, R.K. (1986). Demonstration on supervisory control of brown leaf spot of rice caused by Drechslera oryzae (Breda de Haan) Subram. and Jain ex. M.B. Ellis. Pl. Pathology News l. 4 : 22.

Kyle Emerick, Alain de Janvry, Elisabeth Sadoulet, & Manzoor H. Dar. (2016). Technological Innovations, Downside Risk, and the Modernization of Agriculture. American Economic Review. Vol. 106. No 6. June 2016. pp. 1537-61.

Lakshmanan, A.S., Geethalakshmi, V., Latha, P. and Nagothu, U.S. (2012) Role of photosynthethic Diazotrophs in reducing methane flux from rice soil ecosystem, Technical brief.

Lakshmi, V. G., Tesfai, M., Lakshmanan A., Borrell, A., Nagothu,U., S., . Arasu M. S, Senthilraja, K., Manikandan, N. & Sumathi, S.,(2016). Climate-smart rice cultivation system to mitigate climate change impacts in India. System of Rice Intensification.

Li, Di-q, Q-y Tang, Y-b Zhang, J-q Qin, H Li, L-j Chen, S-h Yang, Y-b Zou and S-b Peng. 2012. Effect of nitrogen regimes on grain yield, nitrogen utilization, radiation use efficiency, and sheath blight disease intensity in super hybrid rice. *Journal of Integrative Agriculture*. 11: 134-143.

Luo, J., Fort, D.M., Carlson, T.J., Noramesi, B.K., nii-Amon-Kotei, D., King, S.R., Tsai, J., Quan, J., Hobensack, C., Lapresca, P., Waldeck, N., Mendez, C.D., Jolad, S.D., Bierer, D.E., Reaven, G.M.(1998). Cryptolepis sanguinolenta: an ethnobotanical approach to drug discovery and the isolation of a potentially useful new antihyperglycaemic agent. Diabetic Med. 15, 100.

Marmey, P., Brian, B., Emmanuel, J., De Kochko, A., Ching, A.O., Piere, Y., Gary, S., Roger, N. B. and Claude, M.F. (1999). RTBV open reading frame 3 encodes a single 37-Kda coat protein. *Virology* 253: 319-326.

Medina, V., Venkitesh, R. and Markham, P.G. (1994). Immunoelectron microscopy of viral complex causing rice tungro disease (RTD). pp. 343-354.

Mew, T.W. and Gonazales, P. (2002). A Handbook of Rice Seed borne Fungi, International Rice Research Institute, Los Banos, Philippines. pp. 20.

Mew, T.W.(1987). Current status and future prospects of research on bacterial blight of rice. Ann. Rev.Phytopathol., 25: 359-382.

Mew, T.W., Alvarez, A.M., Leach, J.E. and Swings, J. (1993). Focus on bacterial blight of rice. Plant Dis. 77:5-12.

Miah, S.A., Shahjahan, A.K.M., Hossain, M.A. and Sharma, N.R. (1983). Survey of rice disease in Bangladesh. Trop. Pest management 31(3): 208-213.

Minnatullah M D and Sattar A 2002. Brown spot developmenting Boro rice as influenced by weather condition. *Journal of Applied Biology* 12: 71–77.

Mohammed I. A., Al-Neemi Mohammed S.B. Al-Hlawee Ilham N. Ezaddin Hesham J.Mosa Abbas F. Abdulkadir Alan I. Khalil. (2012). The Effect of Two Feeding Regimens (Programs) Upon Broiler Growth

Performance, Carcass Traits and Economic Indicators. Kirkuk University. College of Agriculture. Kirkuk. Iraq.

Muralidharan, K., Krishnaveni, D., Rajarajeshwari, N. V. L.and Prasad A. S. R. (2003). Tungro epidemic and yield losses in paddy fields in India. *Curr Sci*. 85:1143–1147.

Nadarajah, k., Nurfarahana Syuhada Omar, N. S., Marhamah, M. R. and Tze, O., S., (2014). Molecular Characterization and Screening for Sheath Blight Resistance Using Malaysian Isolates of *Rhizoctonia solan.* Hindawi, Volume 2014, Article ID 434257, 18 pages.

Nagarajan, S. (1993). Plant diseases in India and their Control. Ciba Found Symp. 177, 208-223.

Nutsugah, S. K., Twumasi, J. K., Chipili, J., Sere, D. and Sreenivasaprasad, H. (2008). Diversity of the blast pathogen populations in Ghana and strategies for resistance management. *Plant Pathology Journal.* 7(1): 109113.

Ou, S.H. (1985). Rice Diseases. 2nd edition. Commonwealth Mycological Institute, Kew, Surrey, England. pp. 61-96.

Pannu, P. P. S., Chahal, S. S., Kaur, M. and Sidhu, S. S. (2005). Influence of weather variable on the development of brown leaf spot caused by Helminthosporium oryzae in rice. *Indian Phytopathology*. 58 : 489 – 492.

Rajkishore, S.K., Doraisamy, P., Subramanian, K.S. and Maheswari, M. (2013). Methane emission patterns and their associated soil microflora with SRI and conventional systems of rice cultivation in Tamil Nadu, India, *Taiwan Water Conservancy*, 61(4):126–134.

Rashid, M. M., Bhuiyan, M. R., Dilzahan, H. A., M A Hamid, M. A., Hasan, N., Khan, M. A. I. and Latif, M. A. (2020). Biological Control of Rice Sheath Blight Disease (*Rhizoctonia solani*) Using Bio-pesticides and Bio-control Agents. *Bangladesh Rice Journal*. 24 (1) : 47-58,

Ritobrata Goswami, Rukhsana Jabeen, Ryoji Yagi, Duy Pham, Jinfang Zhu, Shreevrat Goenka, and Mark H. Kaplan.(2012). STAT6- dependent regulation of Th9 development. *The Journal of Immunology*. 2012 Feb 1; 188(3): 968–975.

Saniya Akter Rozy, (2014). Incidence and Severity of Brown Spot of Rice (BS), Bacterial Leaf Blight (BLB), and Tungro Disease in mostly cultivated Hybrid and Inbreed Rice varieties in Bangladesh. MS Thesis. Sher-e- Bangla Agricultural University.

Savary, S., Castilla, N. P., Elazegui, F. A. and Teng, P. S. (2005). Multiple effects of two drivers of agricultural change, labour shortage and water scarcity, on rice pest profiles in tropical Asia. *Field Crops Research*. 91: 263– 271.

Savary, S., Nelson, A., Sparks, A. H., Willocquet, L., Duveiller, E., Mahuku, G., et al. (2011). International agricultural research tackling the effects of global and climate changes on plant diseases in the developing world. *Plant Disease*. 48:1– 40.

Savary, S., Teng, P.S., Willocquet, L. and Nutter, F.W. (2006). Quantification and modeling of crop losses: a review of purposes. Annual Review of Phytopathology. 44: 89 –112.

Selvaraju, R., (2013), Fifth annual Investment Days, Rome, Italy. Sere, Y., Onasanya, A., Verdier, V., Akator, K., Ouedraogo, L.S., Segda, Z., Mbare, M.M., Sido, A.Y. and Basso, A. (2005). Rice bacterial leaf blight in West Africa: Preliminary studies on disease in farmers' fields and screening released varieties for resistance to the bacteria. *Asian J. Plant Sci*. 4: 577-579.

Shahjahan, A.K.M., Duve, T. and Bonman, J.M. (1987). Climate and rice diseases. In weather and rice. IRRI, Los Banos, Laquna, Philippines. pp.125-128.

Shammy Akter, (2020). M. S. thesis. Assesment of mostly Cultivated Boro Rice Varieties Against Rice Blast Caused by Magnaporthe oryzaeand Establishmentof the kock's Postulate through Pathogenesis. Shet-e-Bangla Agricultural University.

Shelley, I. J., Takahashi-Nosaka, M., Kano-Nakata, M., Haque, M. S., and Inukai, Y., (2016) Rice Cultivation in Bangladesh: Present Scenario, Problems, and Prospects. J Intl Cooper Agric Dev 2016; 14: 20–29

Sherf, A. F., Page, R. M., Tullis, E. C. and Morgan, T. L. (1947). Studies on factors affecting the infectivity of Helminthosporium oryzae. Phytopathology. 37: 281– 290.

Singh G and Prasad CS. 2007. Evaluation of fungicides against blast in Basmati rice. *Ann. Pl. Prot. Sci*. 15 (2): 514-515.

Singh, R. K., Singh, C. V. and Shukla, V. D. (2005). Phosphorus nutrition reduces brown spot incidence in rainfed upland rice. International Rice Research Notes. 30 (2): 31–32.

Singh, R.S., Singh, S.N. and Yadav, B.P. (2000). Management of brown spot disease of rice caused by Drechslera oryzae. *Madras Agric. J*. 87 : 372-375.

Singh, A., Rashmi Rohilla, R., Singh, U.S., Savary, S., Willocquet, L. and Duveiller , E. (2001). An improved inoculation technique for sheath blight of rice caused by *Rhizoctonia solani*. *Can. J. Plant Pathol*. 24: 65–68 (2002).Vol. 97, No. 10,

Siopongco, J.D.L.C., Wassmann, R. and Sander, B.O. (2013) *Alternate Wetting and Drying in Philippine Rice Production: Feasibility Study for a Clean Development Mechanism*, Technical Bulletin, No.17, International Rice Research Institute, Manila, Philippines

Skorbiansky, S. R. (2018). Rice in Asia’s Feed Market. December 2018. Report number: RCS-18L-01. Affiliation: United States Department of Agriculture

SRI Book Part 1.

Steven A. Brooks (2007). Sensitivity to a Phytotoxin from *Rhizoctonia solani* Correlates with Sheath Blight Susceptibility in Rice. *Phytopathology*. Vol 97, No. 10,

Suprapta and khamdan.(2012). Anti- fungal activities of selected tropical Plants from Bali Island. *Phytopharmacology*. 2(2): 265-270.

Sustainable Development Goal.

Swings, J., Mooter, M.V., Vauterin, L., Hoste, B., Gillis, M., Mew, T.W. and Kersters, K (1990). Reclassification of the causal agents of bacterial blight of rice (Xanthomonas campestris pv.oryzae) and bacterial leaf streak (Xanthomonas campestris pv. oryzicola) of rice as pathovars of Xanthomonas oryzae. *Int. J. Syst. Bacteriol*. 40: 309-311.

System of Rice Intensification (SRI) - Principles and Methods. *Directorate of Rice Development, Patna*

The Fungi. Lynne Buddy, (2016).

Uddin, A. B. M. A., (2018). Ph D. Thesis. Resurgence of Brown Plant Hopper, *Nilaparvata Lugens* (Stal) and its management. Bangladesh Agricultural University. Mymensingh. pp: 1-200.

Uphoff, N. (2002). Opportunities for raising yields by changing management practices: the System of Rice Intensification in Madagascar. Cornell University

Uphoff, N. (2006). The system of rice intensification (SRI) as a methodology for reducing water requirements in irrigated rice production. International Dialogue on Rice and Water: Exploring Options for Food Security and Sustainable Environments, IRRI, Los Banos, 7-8 March 2006.

Veena, M.S., Shetty, H.S., Mortensen, C.N. and Mathur, S.B. (2000). Bacterial leaf blight of rice. Technical Bulletin, Department of Studies in Botany, 54 University of Misore, India and Danish Govt. Institute of Seed Pathology for Developing Countries, Denmark, pp.16.

Vu-Van, B.A. and Sangchote, S. (2006). Seed borne and transmission of Bipolaris oryzae, the causal pathogen of brown spot of rice. *Kasetsart J.Natural Sci*. 40: 353-360.

Waheed, M. A., Ahmad, H., Sirajuddin, H. A., Khan, A.Q. and Khan, A. (2009). Evaluation of rice genotypes for resistance against bacterial leaf blight. *Pak. J. Bot*. 41(1): 329 – 335.

Yasmin, S., Hafeez, F. Y., Mirza, M. S., Rasul, M., Arshad, H. M. I., Zubair, M. and Iqbal, M., (2016). Biocontrol of Bacterial Leaf Blight of

Rice and Profiling of Secondary Metabolites Produced by Rhizospheric Pseudomonas aeruginosa BRp3. Front. Microbiol. (2017) 8: 1895.

Yaduraju, N. (2013).Implications of weeds and weed management on food security and safety in the Asia-Pacific region. Conference Paper. 24th Asian-Pacific Weed Science Society Conference October 22-25, 2013, Bandung Indonesia October 2013.

Zhou, Z.J., Lin, Q.Y. and Xie, L.J. (1992). Occurrence of rice tungro bacilliform virus in China. *Acta Phytopathologica Sinica*. 22(1):15-18.

APPENDIX 1

Map 1. Map of Dhaka City

APPENDIX 2

Map 2. Map of Experimental Site

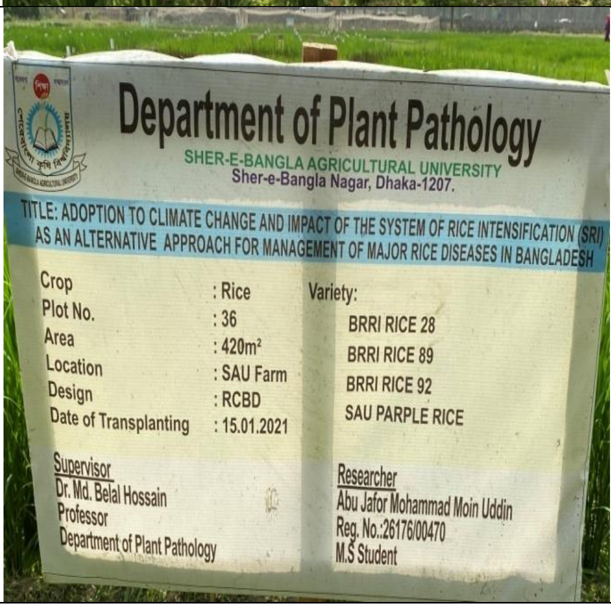
APPENDIX 3


SAU PARPLE RICE


MODERN SRI


BASIC SRI


CONVENTIONAL


Department of Plant Pathology
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
Sher-e-Bangla Nagar, Dhaka-1207.
TITLE: ADOPTION TO CLIMATE CHANGE AND IMPACT OF THE SYSTEM OF RICE INTENSIFICATION (SRI) AS AN ALTERNATIVE APPROACH FOR MANAGEMENT OF MAJOR RICE DISEASES IN BANGLADESH
Crop : Rice
Plot No. : 36
Area : 420m²
Location : SAU Farm
Design : RCBD
Date of Transplanting : 15.01.2021
Variety:
BRRI RICE 28
BRRI RICE 89
BRRI RICE 92
SAU PARPLE RICE
Supervisor
Dr. Md. Belal Hossain
Professor
Department of Plant Pathology
Researcher
Abu Jafor Mohammad Moin Uddin
Reg. No.:26176/00470
M.S Student